DISSERTATION FROM THE
NORWEGIAN SCHOOL OF
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Roar Amundsen

Hamstring injuries in women's football

Building the foundation for future hamstring injury prevention

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Table of Contents

Acknowledgements

During the spring 2019, I came to the Norwegian School of Sports Sciences (NIH) for an interview regarding a PhD position on prevention of hamstring and/or groin injuries. At the time I had a hamstring injury, but I do not think that was mentioned to Roald Bahr and Thor Einar Andersen, who were the persons interviewing me. I had some lectures with Thor Einar during my bachelor's degree, so I knew his background, but I had not met Roald. Being 30 minutes early for the interview, I decided I could browse through his research to be prepared. Fair to say, I did not get through all of it. Still, the interview went okay and what was originally announced as one PhD-position turned out to be two, me focusing on hamstring injuries and Solveig Thorarinsdottir focusing on groin injuries (luckily for me, I was ranked 2nd for the position). The four years since have been amazing, and I would like to thank everyone that has contributed to that:

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Roar Amundsen

Oslo, 7th July 2023

List of papers

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

I. Amundsen, R., Thorarinsdottir, S., Clarsen, B., Andersen, T.E., Møller, M., Bahr, R. *#ReadyToPlay: Health problems in women's football – a two-season prospective cohort study in the Norwegian premier league* [Manuscript submitted to British Journal of Sports Medicine].

II. Amundsen, R., Thorarinsdottir, S., Larmo, A., Pedersen, R., Andersen, T. E., Møller, M., Bahr, R. *#ReadyToPlay: Hamstring injuries in women's football – a two-season prospective cohort study in the Norwegian women's premier league* [Manuscript submitted to Science and Medicine in Football].

III. Amundsen, R., Møller, M., Bahr, R. *Performing NordBord-testing with additional weight affects the maximal eccentric force measured - do not compare apples to oranges* [Manuscript submitted to Scandinavian Journal of Medicine & Science in Sports].

IV. Amundsen, R., Heimland, J. S., Thorarinsdottir, S., Møller, M., Bahr, R. *Effects of High and Low Training Volume with the Nordic Hamstring Exercise on Hamstring Strength, Jump Height, and Sprint Performance in Female Football Players: A Randomised Trial.* Translational Sports Medicine, vol. 2022, Article ID 7133928, 9 pages, 2022. https://doi.org/10.1155/2022/7133928

Abbreviations

ACL	Anterior cruciate ligament
ANOVA	Analysis of variance
ANCOVA	Analysis of covariance
CI	Confidence interval
DOMS	Delayed-onset muscle soreness
FIFA	Fédération Internationale de Football Association
IOC	International Olympic Committee
MRI	Magnetic resonance imaging
OSIICS	Orchard Sports Injury and Illness Classification System
OSTRC-H	Oslo Sports Trauma Research Center Questionnaire on Health problems
OSTRC-H2	Oslo Sports Trauma Research Center Questionnaire on Health problems (updated version)
SD	Standard deviation
SMDCS	Sport Medicine Diagnostic Coding System
UEFA	Union of European Football Associations

Summary

Introduction: Training and match demands in women's football have soared during the last decades and may have altered the risk for injury and illness players face. To develop effective preventive measures tailored to the needs of modern female football players, we need reliable, up-to-date surveillance data. Therefore, we aimed to describe the prevalence, incidence, and burden of all health problems in the Norwegian women's premier league (*Paper I*). Because we hypothesised that the changes in women's football had caused a high risk for muscle injuries, particularly hamstring injuries, we also conducted an in-depth study on hamstring injuries in the Norwegian women's premier league (*Paper II*). Low eccentric strength is considered a risk factor for hamstring injury, therefore accurate measurement of maximal eccentric hamstring strength is important. The NordBord is a commonly used for this purpose and measures maximal eccentric hamstring force through the Nordic hamstring exercise. To ensure that the test is supramaximal, as intended, several studies have made participants hold extra weights during the test if they are able to control the last 20° of the Nordic hamstring exercise's range of motion. This approach has not been based on substantial evidence and may have introduced bias and overestimated the true change in strength. Therefore, we examined how performing NordBord-testing with added weight affected the force measured (*Paper III*). Although eccentric hamstring strengthening programmes can effectively reduce the risk of hamstring injuries, they are not adopted by football teams, possibly due to the high training volume and long duration of the programmes. Therefore, we compared the effect of a high- and low-volume Nordic hamstring programme on maximal eccentric hamstring strength in female football players (*Paper IV*).

Methods: We conducted a two-season prospective cohort study in the Norwegian premier league (2020-2021). In *Paper I*, 294 players (22±4 yrs, 93% of all players invited) reported all health problems by responding to the updated version of the Oslo Sports Trauma Research Center Questionnaire on Health problems (OSTRC-H2) once a week. The reported health problems were diagnosed by team physiotherapists using the Sports Medicine Diagnostic Coding System (SMDCS). In *Paper II*, the hamstring injuries recorded in the prospective cohort study were examined by standardised clinical examinations performed by the team physiotherapists and with magnetic resonance imaging (MRI). In *Paper III*, we tested 84 of the female premier league players (22±4 yrs) and 56 male 1st division players (24±4 yrs) in the NordBord with 0 kg, 5 kg and 10 kg added weight and compared the results from the three testing conditions. In *Paper IV*, we conducted a randomised trial where 45 players (21±4 yrs) from two 1st division women's teams (2nd tier) performed a high- or low-volume Nordic Hamstring training programme during the pre-season period, and compared the training programmes' effect on maximal eccentric hamstring strength, jump height and sprint performance.

Main results: The average weekly prevalence of substantial health problems was high (22%, 95% CI: 21-23%), mainly caused by injuries. The prevalence, incidence and burden of illness was low. Gradual-onset injuries were more common than previously reported (35% of all health problems), but sudden-onset injuries were still the most severe (68% of total days lost). Muscle injuries were the most frequent, while injuries to ligament/joint capsule were most severe. Hamstring injuries were the most common injury diagnosis and caused the 3rd highest injury burden (7.9 days lost/1000 h), behind anterior cruciate ligament (ACL) injuries (39.3 days lost/1000 h) and concussion (8.3 days lost/1000 h). In *Paper II*, 53 hamstring injuries were examined clinically and 31 of these with MRI. Most were non-contact and occurred during sprinting. Gradual-onset (53%) and sudden-onset injuries (47%) were evenly distributed. Of injuries displaying MRI changes, 60% were in the m. biceps femoris, most involving the muscle-tendon junction, and 40% in the m. semimembranosus, most in the proximal tendon. In *Paper III*, maximal eccentric hamstring force was higher when tested with 5 kg (females: +2%, p<0.001, males: +4%, p<0.001) and 10 kg (females: +5%, p<0.001, males: +6%, p<0.001) compared to 0 kg. This was the case for both players who could control the final 20° of the test (5 kg: + 4%, p<0.001, 10 kg: + 7%, p<0.001) and those who could not (5 kg: +3%, p<0.001, 10 kg, +4%, p<0.001). In *Paper IV*, both groups increased maximal eccentric force (high-volume: 29 N (10%), 95% CI: 19-38 N, p<0.001, low-volume: 37 N (13%), 95% CI: 18-55 N, p=0.001), but there were no between-group differences (p=0.38). Maximal eccentric torque, jump height and sprint performance did not change in either group.

Conclusion: The average weekly prevalence of health problems, especially injuries, in the Norwegian women's premier league was high. Hamstring injuries were the most frequent and third most burdensome injury. Compared to previous findings from men's football, a higher proportion of hamstring injuries in women's football had a gradual onset and involved the m. semimembranosus, particularly its proximal tendon. Both players who could and could not control the final 20° of the NordBord test demonstrated higher maximal force when adding weight to testing. Therefore, this should not be used to decide if players should perform NordBord testing with or without weight in the future. Both the high- and low-volume Nordic hamstring programme increased the maximal eccentric hamstring force in female football players, but there was no difference between the programmes.

Sammendrag (Summary in Norwegian)

Introduksjon: Arbeidskravene i kvinnefotball har økt betydelig de siste tiårene, og dette kan ha endret risikoen for skade og sykdom. Pålitelig og oppdatert data er nødvendig for å kunne utvikle effektive forebyggende tiltak tilpasset kvinnelige fotballspillere. Derfor ønsket vi å beskrive prevalensen, insidensen og byrden av alle helseproblemer i den norske Toppserien for kvinner (*Artikkel I*). Vi antok at risikoen for muskelskader, spesielt hamstringsskader, var høy. Derfor gjennomførte vi også en dybdestudie av hamstringsskader som en del av det samme prosjektet (*Artikkel II*). Lav eksentrisk hamstringsstyrke er en risikofaktor for hamstringsskader, og eksentriske styrketrening kan forebygge hamstringsskader. Det er derfor viktig å kunne måle maksimal eksentrisk hamstringsstyrke nøyaktig. NordBord, som måler kraften som utvikles under gjennomføring av øvelsen Nordic hamstrings, er mye brukt til dette formålet. Flere studier har fått deltagere til å gjennomføre NordBord-testing med ekstra vekt hvis de kunne kontrollere de siste 20° av testen. Vi mistenkte at denne måten å gjennomføre testingen kunne bidra til å overestimere effekten av treningsintervensjoner. Derfor undersøkte vi hvordan resultatene fra NordBord-testing ble påvirket av at testingen ble gjennomført med vekt (*Artikkel III*). Selv om eksentriske styrketrening av hamstringsmusklene kan forebygge hamstringsskader, brukes ikke disse skadeforebyggende programmene av fotballag. Én mulig årsak er det høye treningsvolumet og den lange varigheten av programmene. Derfor sammenlignet vi effekten av et Nordic hamstring-program med høyt og lavt treningsvolum på maksimal eksentrisk hamstringsstyrke hos kvinnelige fotballspillere.

Metode: Vi gjennomførte en prospektiv kohortstudie over to sesonger (2020-2021) i Toppserien. I *Artikkel I* rapporterte 294 spillere (22±4 år, 93% av alle inviterte spillere) alle helseproblemer ved å svare på OSTRC-H2 én gang i uken. Helseproblemene ble diagnostisert av lagets fysioterapeuter som brukte SMDCS. I *Artikkel II* ble hamstringsskadene som ble registrert i den prospektive kohortstudien, undersøkt gjennom standardiserte kliniske undersøkelser utført av lagets fysioterapeuter og med MR. I *Artikkel III* gjennomførte 140 spillere (84 kvinner, 56 menn) NordBord-testing med 0 kg, 5 kg og 10 kg ekstra vekt, og vi undersøkte hvordan bruk av vekt påvirket kraften som ble målt. *Artikkel IV* var en randomisert studie hvor 45 spillere (21±4 år) fra to 1. divisjonslag (nest høyeste nivå) gjennomførte et Nordic Hamstrings treningsprogram med enten høyt eller lavt treningsvolum i sesongoppkjøringen, og vi sammenlignet effekten av treningsprogrammene på maksimal eksentrisk hamstringsstyrke, spenst og hurtighet.

Resultater: Gjennomsnittlig ukentlig prevalens av betydelige helseproblemer var høy (22%, 95% KI: 21-23%), og skyldtes hovedsakelig skader. Prevalensen, insidensen og byrden av sykdom var lav. Belastningsskader var vanligere enn tidligere rapportert (35% av alle helseproblemer), men akutte skader var fortsatt de alvorligste (68% av totalt fravær). Muskelskader var den vanligste skadetypen, mens skader på leddbånd/leddkapsel var mest alvorlige. Hamstringsskader var den hyppigste skadediagnosen og forårsaket den tredje høyeste skadebyrden. Kun korsbåndskader og hjernerystelser forårsaket høyere skadebyrde. I *Artikkel II* ble 53 hamstringsskader undersøkt klinisk, 31 av disse også med MR. De fleste skadene oppstod under sprint. Belastningsskader (53%) og akutte skader (47%) var jevnt fordelt. Av skadene som viste MR-forandringer involverte 60% m. biceps femoris og disse lå hovedsakelig muskel-sene-overgangen. Skader i m. semimembranosus utgjorde 40%, og disse involverte som oftest den proksimale senen. I *Artikkel III* var kraften som ble målt høyere når NordBord-testen ble gjennomført med 5 kg (kvinner: +2%, $p<0.001$, menn: +4%, $p<0.001$) og 10 kg (kvinner: +5%, $p<0.001$, menn: +6%, $p<0.001$) enn uten vekt. Dette gjaldt både spillere som klarte å kontrollere de siste 20° av testen (5 kg: +4%, $p<0.001$, 10 kg: +7%, $p<0.001$) og de som ikke klarte dette (5 kg: +3%, $p<0.001$, 10 kg: +4%, $p<0.001$). I *Artikkel IV* økte begge gruppene maksimal eksentrisk kraft (høyt volum: 29 N (10%), 95% konfidensintervall: 19-38 N, $p<0.001$, lavt volum: 37 N (13%), 95% konfidensintervall: 18-55 N, $p=0.001$), men det var ingen forskjeller mellom gruppene ($p=0.38$). Maksimalt eksentrisk dreiemoment, spenst og hurtighet endret seg ikke i noen av gruppene.

Konklusjon: Den gjennomsnittlige ukentlige forekomsten av helseproblemer i Toppserien, spesielt skader, var høy. Hamstringsskader var den hyppigste skaden og blant dem som førte til mest fravær. Sammenlignet med tidligere funn fra herrefotball var en større andel av hamstringsskadene i kvinnefotball belastningsrelaterte og de involverte oftere m. semimembranosus og spesielt den proksimale senen. Dette kan ha betydning for skadeforebygging rettet mot kvinnelige fotballspillere. Resultatene til spillerne som ble testet i NordBord var høyere når de ble testet med ekstra vekt enn uten, uavhengig av om de kunne kontrollere de siste 20° av testen eller ikke. Derfor bør dette ikke brukes som et kriterium for å avgjøre om spillere skal testes med eller uten vekt. Nordic hamstring-programmet som har vist skadeforebyggende effekt og består av et relativt høyt treningsvolum økte ikke hamstringsstyrke i større grad enn et program med lavt treningsvolum. Mindre omfattende treningsprogrammer har antagelig større sjans for å bli brukt i praksis. Resultatene våre indikerer at å gjennomføre et lavt treningsvolum med Nordic hamstring effektiv kan øke hamstringsstyrke, men kan ikke si noe om den skadeforebyggende effekten også er like stor.

Introduction

Football is one of the world's most popular sports and women's football has seen significant growth in popularity and participation over the last few decades. From year 2000 to 2006, the number of registered female football players world-wide increased by 54%.[1] In Europe, the financial resources allocated to women's football, attendance at matches and number of professional players have increased substantially. [2] Female football players on the top-level are exposed to greater training volumes, higher competition demands and more matches than ever before. [3, 4] This may have implications for the injury and illness risk the players face. Increased training and competition load have been associated with higher incidence of injury and illness[5], a greater amount of high-intensity running has been associated with increased risk of lower extremity soft tissue injuries, [6] and muscle injury rates in professional football increase with fixture congestion. [7] Injuries can negatively affect team performance[8, 9] and player development. [10] Player performance is often reduced when returning from injury, [11-13] and increased player availability improves chances of success. [14] Preventing injuries and illness is therefore essential, not only to protect the short- and long-term health of the players, but also for maximising performance.

Framework for sports injury prevention research

Sports injury prevention research has been described by van Mechelen et al. [15] as a four-step process, known as the "sequence of prevention" (Figure 1). The first step is to identify and describe the extent of injuries through injury surveillance and epidemiological studies. These are fundamental to identify prioritised areas for injury prevention and to guide the rest of the sports injury prevention research. [16] Secondly, risk factors and injury mechanisms must be identified. [15] While injuries may appear to result from a single inciting event, players can be predisposed to injury through risk factors, such as previous injury, low strength or poor flexibility. [17] The third step is to develop and introduce preventative measures likely to reduce the future injury risk or severity based on the risk factors and injury mechanisms identified in the second step. [15] In the fourth and final step, the effect of these measures must be evaluated by repeating the first step, [15] preferably through a large randomised controlled trial.

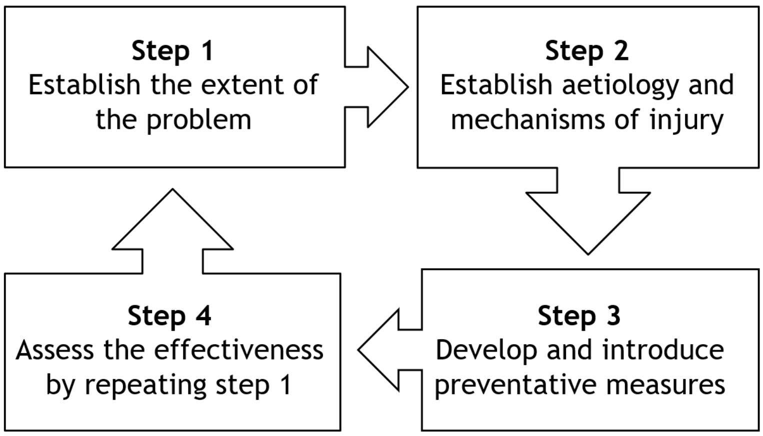

Figure 1. The four-step "sequence of prevention", adapted from van Mechelen et al. [15]

A limitation to van Mechelen's sequence of prevention[15] is that it does not describe the process after a preventative measure has been found effective. For sports injury prevention measures to be successful, they need to be accepted, adopted and complied with by the athletes and sports bodies they are intended for. [18] The effectiveness of an intervention is evaluated under "ideal conditions", but the resources used during these studies are usually not available to the teams, coaches and players after the study has finished. [18] Therefore, Finch[18] developed a new framework for sports injury prevention research, the "Translating Research into Injury Prevention Practice" framework. This framework incorporates the four-step sequence described by van Mechelen et al. [15] but introduces two additional steps: describing the intervention context to inform implementation strategies and evaluating the effectiveness of preventative measures in the implementation context. These two frameworks have been used as a basis for this thesis.

Sports injury prevention research should be undertaken on homogeneous groups. [15] Female participants have been significantly under-represented in sports medicine research[19] and this also applies to football. While some research findings from men's football probably are applicable to women's football, it is important to recognise that the risk of injury and effectiveness of injury prevention programmes can differ between male and female football players. [20, 21] Only applying knowledge derived from men's football is therefore unlikely to provide an accurate and comprehensive understanding of injuries in the women's game. [22] A recent scoping review on women's football injuries highlighted the limited quantity of research, with focus given mainly to a few specific research topics and body locations (e.g. knee and head injuries). [22] They also stated that the literature quickly outdates because of the rapid development of women's football and suggested that future research should aim to understand injury mechanisms, risk factors, inform design and execution of preventive strategies and guide the return to play process of injuries in women's football.[22] In a recent editorial on the evolution of women's football and the challenges for the years ahead, it was specified that more research is needed to better understand the incidence and prevalence, as well as the burden and the actual causes of injuries in female football players.[23]

#ReadyToPlay: Protecting the health of Norwegian elite football players

To address some of the important research gaps in women's football, we initiated the #ReadyToPlay project in the Norwegian premier league of women's football. The project was approved for ten years and includes collaboration with several stakeholders: the Norwegian Football Association, the Norwegian Football Association's Sports Medicine Clinic in Oslo (Idrettens Helsesenter) and the interest organisation for the teams in the two top divisions of women's football in Norway (Toppfotball Kvinner). This thesis, and the four papers it is based on, is the first of many that will originate from the project.

In *Paper I*, we covered the first step in the "sequence of prevention". While previous sports injury research and the frameworks just described has primarily focused on sudden onset injuries, there has been an increasing emphasis on capturing gradual onset injuries and illnesses in recent years.[16, 24, 25] We therefore aimed to describe the extent of all health problems in the Norwegian women's premier league by conducting a two-season prospective cohort study (2020-2021).

In men's football, hamstring injuries have been the most common and burdensome injury for years,[26-30] most often occurring during sprinting[29-31] and more frequent in periods of fixture congestion.[7] With the current developments in women's football, we expected that hamstring injuries may have become a major problem in the women's game too. In *Paper II*, we therefore examined the hamstring injuries recorded through the prospective cohort study in more detail.

Due to issues related to the Covid-19 pandemic, we were not able to conduct a study examining risk factors for hamstring injuries as originally planned. However, from men's football we know that maximal eccentric hamstring strength is considered an important risk factor for hamstring injuries,[32, 33] and that eccentric hamstring strengthening programmes, mostly using the Nordic hamstring exercise, can reduce the risk of hamstring injuries.[34-37] Measuring maximal eccentric hamstring strength accurately is therefore essential in both the second and third step of hamstring injury prevention research. A test device measuring maximal eccentric hamstring strength through the Nordic hamstring exercise[38] is now a commonly used for this purpose.

Without substantial evidence, several studies have performed this testing with added weight,[39-43] potentially affecting the results in unintended ways. In *Paper III*, we therefore examined how adding weight to NordBord testing affected the maximal eccentric hamstring force measured.

Although Nordic hamstring programmes over 10-13 weeks can reduce hamstring injury risk in men's football,[34-36] their adoption among men's elite teams remains poor.[44, 45] One potential issue is the long duration and high training volumes.[46] Consequently, it has been suggested that programmes of shorter duration and lower training volumes is more suited for implementation in elite teams.[47] Modifying a programmes content may affect its effectiveness, but some studies have indicated that low-volume Nordic hamstring programmes can also substantially increase maximal eccentric hamstring strength.[40, 47] In *Paper IV*, we therefore conducted a randomised trial to determine if using the evidence-based high-volume programme of the Nordic hamstring exercise was more effective in increasing maximal eccentric hamstring strength compared to a low-volume programme that we considered more likely to be adopted by football teams. The method used for measuring maximal eccentric hamstring strength in *Paper IV* was guided by the results from *Paper III*.

Theoretical framework and background

Health problem surveillance methodology

The first step in "the sequence of prevention" is to study the extent of injuries and illnesses through injury and illness surveillance and epidemiological studies. [15, 18] These studies are fundamental building blocks for developing preventative programmes and establishing the risk and pattern of injuries and illnesses are important topics to address. [16] The methodology and definitions used in these studies are crucial for the results.[48] Therefore, both general[16] and football-specific[48, 49] consensus statements on injury and illness research have been published to encourage consistency and enable data comparison across studies. Using a prospective cohort design is recommended, to allow a standardised registration of injuries before they happen, accurate recording of exposure and minimise issues related to recall bias which is a major problem with retrospective studies. [48] Surveillance studies in football should follow more than one team of players for a minimum period of one season (including pre-season). [48] However, a "one-size fits all" approach to sports injury surveillance studies do not exist, [16] and choices of methodology and definitions used depends on the sport, the context and the research objective. The most important factors to consider in injury and illness surveillance studies are presented in the next sections.

Defining and classifying of health problems

What is defined a recordable event is arguably the most important factor affecting the results of injury and illness surveillance studies. [24] Three definitions of health problems are commonly used: 1) "any complaint" irrespective of the need for medical attention or time-loss from training or competition, 2) "Medical attention" which only records health problems that result in medical attention, 3) "time-loss" which only records health problems resulting in the player being unable to participate in future training or match play[16, 24, 48] (Figure 2). The time-loss definition is considered reliable, as it is easy to identify when a player misses match or training. [24] However, this narrow definition will overlook many health problems, as players often continue to train and compete despite having a health problem. [24] In addition, for team sport players the threshold for being absent from training or matches can depend on the time of the season and the importance of the player. [24] The broader "medical attention" or "any complaint" definitions will identify more health problems, and therefore represent a more complete picture. However, reliability may be lower when using these definitions.[24] The choice of health problem definition therefore has to match the study setting, purpose and design of the study.[24]

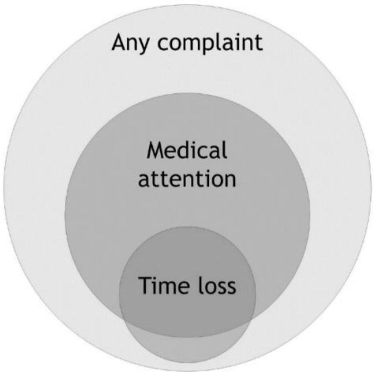

Figure 2. Distribution of health problems by consequences (not to scale).[16] Reused with permission.

Injuries should be classified by mode of onset, location and type.[48] Traditionally, injuries have been described as those with a sudden onset and those with a gradual onset.[16] Other definitions, such as traumatic, acute and overuse injuries have also been used.[48] It is important to note that some injuries can have elements of both gradual and sudden onset and these nuances will be missed by using only two categories.[16] For sudden onset injuries, mechanism of injury can also be reported. When reporting injury characteristics, it is recommended to report body area, tissue type, pathology and diagnosis, and use categories based on the Sport Medicine Diagnostic Coding System (SMDCS) or the Orchard Sports Injury and Illness Classification System (OSIICS).[16, 49, 50] For illnesses, organ systems/regions and aetiology should be reported using the same classification systems.[16, 49, 50]

Recording health problems

How health problems are recorded and who are responsible for recording them are also important.[51] Data collection methods should also be adapted to the context, research question and study objectives.[16] In most football injury surveillance studies, medical staff have recorded injuries on injury report forms.[48] An obvious strength in using medical professionals is the ability to obtain detailed information about the injuries (e.g. injury diagnosis). However, if medical support is low or inconsistent between teams, it may lead to systematic underreporting. Depending on the health problem definition used, it is also possible that medical staff in different teams will have different thresholds for what is considered a health problem. Furthermore, they are unlikely to be aware of health problems not requiring medical attention. If using broad injury definitions, it will place large demands on the medical staff and there could be issues to obtain complete and accurate data.[24] For example, when medical staff voluntarily recorded injuries for their team, fewer mild injuries were reported than when research-invested clinicians were involved.[51, 52] A possible solution to obtain a more complete picture of injuries is to get the players to record the injuries themselves by administering surveys via SMS or mobile applications.[24] Using player self-reports and an "all physical complaints" injury definition identified ten times more overuse injuries than when coaches or medical staff reported time loss injuries.[25] The threshold for what is considered an injury is also likely to differ between players, but the potential for systematic bias between teams is lower than with medical staff.[24] With player reporting, however, accurate diagnoses of injuries may not be obtainable and high response rates are required. As player self-reporting and medical staff reports each have its own strength, combining the two methods can be a possible solution to exploit the best of both.

Reporting health problems

In sports injury and illness surveillance studies it is recommended to express risk in terms of incidence or prevalence.[16]

Incidence refers to the number of new health problems sustained in a cohort over a defined period.[16] The benefit of reporting incidence is that different studies can be compared more directly because it incorporates time at risk.[53] To enable comparison between studies it is important that the exposure is measured on the same scale.[53] For injuries, it is preferable to report the number of new injuries per hour of exposure to risk (rather than per training or per match) to be able to compare different groups and sports.[16] Incidence is often reported as number of new injuries per 1000 player hours to provide numbers that are easy to interpret and allow injury risk to be compared between studies. When communicating risk to stakeholders, risk can be also expressed in "simpler" ways such as injuries per squad per season. Incidence-based measures are most appropriate to describe the extent of sudden-onset injuries.[16]

Prevalence refers to the number of existing cases divided by the total population at risk (e.g. the proportion of players in a football team that is injured).[16] Prevalence can be measured at a given point in time (point prevalence) or over a window of time (period prevalence). If prevalence measures are repeated over time, for example once weekly over a season, it is possible to report the average prevalence during the season and to compare different stages of the season. The extent of gradual onset injuries is best described by prevalence-based measures.[16]

For illnesses, the incidence should be estimated based on the period of exposure (e.g. one season) rather than sport specific exposure, as it is difficult to measure the exposure to pathogens [16]. Reporting prevalence-based measures is also a good method to report illness risk. [16]

Risk of injury and illness is a function of both the probability of an injury or illness occurring and its severity. Therefore, a more accurate representation of the risks also requires the measurement of severity. [54] The most commonly used measure to describe the severity of health problems in sports is the number of days lost to sport participation. [16] Using the number of days lost as a measure of severity may, however, underestimate (e.g. a player return to sport before the injury is fully resolved or plays despite having pain and/or reduced performance) or overestimate the injury severity (e.g. a player takes extra time off after injury as a precaution or because of a season break). Because time-loss data distribution is likely to be right-skewed, the total number of days lost with median and quartiles should be reported. [16, 49] Time loss can also be categorised (e.g. 0 days, 1–3 days, 4–7 days, 8–28 days, 29–90 days, 91–180 days and >180 days), [16, 48, 49] but if this approach is used the incidence and severity must be reported in isolation. Combining the incidence and severity into the concept of burden may be a better option. [55] If reporting the incidence and time loss, burden can be expressed as the number of days lost per 1000 player hours of exposure. Reporting burden rather than incidence and severity separately can give a more thorough risk assessment. [55] Another option of reporting severity can be that players self-report the consequences. One example of this approach is the Oslo Sports Trauma Research Center Questionnaires on Health problems (OSTRC-H) that was developed to capture all types of injuries and illnesses. It calculates a severity score based on players' answers to questions about how their injury or illness have affected their participation and performance, modified their training or competition and caused symptoms. [56, 57] It should be noted that, although addressing some of the limitations of measuring severity in time-loss, the OSTRC-H severity score has not been fully validated. [56]

Health problems in women's premier league football

To summarise the existing literature on injury and illness risk and pattern in women's premier league football, a systematic search in PubMed was conducted. This search was originally conducted as part of a PhD-course at the Norwegian School of Sports Sciences (In depth academic and methodological study) in November 2021 but was updated in the finishing work with the thesis. Search details and inclusion criteria are described in Table 1.

Table 1. Details and inclusion criteria for the systematic search of studies on injury risk and pattern.

Domains	Sport	Level	Sex	"Intervention"	Outcome	Reporting
Keywords	Football Soccer	Elite Professional Senior Premier Top National International Championship*	Women Female*	Surveillance Cohort Epidemiology Audit Risk factor Risk factors	Injur* Problem* Complaint* Illness* Health	Incidence Prevalence Risk Pattern
Inclusion criteria	• English language and full text available • Original peer-reviewed article • Prospective data collection • Female football players#			• Senior top division club football## • Following >1 team for ≥1 season • Overall injury and/or illness outcome • Article published after 2000		
Initial search results (PubMed, June 2023): 1025 Studies included after screening titles/abstracts/full texts/reference lists: 9						

Domains were combined with AND, keywords were combined with OR. #Studies including men or other sports were included if the article reported data for the female football players only. ##Studies including both elite and sub-elite/amateur players or both senior and junior players not included.

Study characteristics

Through the systematic search, 9 articles meeting the inclusion criteria were identified,[20, 58-65] one of which was published after we initiated the #ReadyToPlay project.[62] All the studies focused on injuries, while none described illnesses. Two studies covered two seasons,[61, 62] while the rest had a one-season duration. Three studies covered the pre-season period in addition to the competitive season.[60, 61, 63] Most studies were conducted in Europe, used a time-loss definition of injury and medical staff to record injuries. One study used player self-reports to record injury,[64] and one used an insurance database.[61]

All included studies reported injury risk as injuries per 1000 h exposure (incidence), and eight also reported incidence proportion (proportion of players who were injured). None of the studies reported the prevalence of injuries. In the following paragraphs, a general overview of the results is presented. Key characteristics and incidence measures of the included studies can be found in Table 2, while an overview of injury severity, burden, mode of onset, location and type is presented in Table 3.

Table 2. Key characteristics, incidence proportions and rates in the studies identified through the systematic search.

1st author (publ. year) Duration (years)	Level, country	No. of players	Injury definition, recorder	Exposure	No. of injuries	Incidence proportion	Incidence (injuries per 1000 h)		
							Overall	Match	Training
Horan (2021) [62] 2 seasons (2018-2019)	Top division, Ireland	271	Time-loss injuries, Medical staff	Individual	266	-	7.9	19.2	2.5
Blokland (2017) [58] 1 season (2014/2015)	Top division, Netherlands	114	Time-loss injuries, Medical staff	Individual	179	72%	8.4	30.3	5.2
Nilstad (2014) [64] 1 season (2009)	Top division, Norway	173	Time-loss injuries, Player self-reports	Individual	171	62%	3.8	12.9	2.6
Gaulrapp (2010) [60] 1 season (-)	Top division, Germany	254	Time-loss injuries, Medical staff	Team based	246	57%	3.3	18.5	1.4
Hägglund (2009) [20] 1 season (2005)	Top division, Sweden	228	Time-loss injuries, Medical staff	Individual	299	66%	5.5	16.1	3.8
Tegnander (2008) [65] 1 season (2001)	Top division, Norway	181	Time-loss injuries, Medical staff	Individual	189	52%	6.2	24.3	3.7
Jacobson (2007) [63] 1 season (2000)	Top division, Sweden	269	Time-loss injuries, Coach	Individual	237	48%	4.6	13.9	2.7
Faude (2005) [59] 1 season (2003/2004)	Top division, Germany	165	Time-loss injuries, Medical staff	Individual	241	70%	8.4	23.3	2.8
Giza (2005) [61] 2 seasons (2001-2002)	Top division, USA	202	Medical attention, Insurance database	Team based	173	55%	1.9	12.6	1.2

Table 3. Summary of key findings on injury risk pattern in the studies identified through the systematic search.

1st author (year)	Mode of onset	Most common injury locations	Most common injury types	Injury severity	Injury burden
Horan (2021) [62]	Sudden: 76% Gradual: 24%	Ankle: 24.4% Knee: 21.8% Thigh: 19.2%	Muscle injuries: 35% Ligament sprains: 30.1% Contusions: 9%	0 days: 1.1%, 1-3 days: 17.7% 4-7 days: 20.3%, 8-28 days: 39.5% >28 days: 21.4%	Ligament: 104 days/1000 h Muscle: 33 days/1000 h Knee: 107 days/1000 h Ankle: 41 days/1000 h Thigh: 25 days/1000 h
Blokland (2017) [58]	-	Thigh: 25.1% Knee: 23.5% Ankle: 12.3%	Sprain/ligament: 24.0%	0 days: 15.6%, 1-3 days: 34.6% 4-7 days: 17.9%, 8-28 days: 17.9%, >28 days: 14.0%	-
Nilstad (2014) [64]	-	Knee: 31% Ankle: 23% Thigh: 21%	Ligament sprain: 37% Muscle injury: 34% Tendon: 18%	1-3 days: 14%, 4-7 days: 19% 8-28 days: 37%, >28 days: 30%	-
Gaulrapp (2010) [60]	Overuse: 24%	Knee: 31% Ankle: 22.1% Thigh: 12.9%	Sprains: 35.4% Contusions: 15.8% Muscle strains: 10.8%	1-7 days: 34%, 8-30 days: 37% >30 days: 29%	-
Hägglund (2009) [20]	-	Thigh: 23% Knee: 22% Ankle: 16%	Muscle injury/strain: 28% Sprain/ligament injury: 22% Overuse complaints: 18%	1–3 days: 25%, 4–7 days: 28% 8–28 days: 34%, >28 days: 12%	Knee: 52% of all time-loss Thigh: 11% of all time-loss Ankle: 8% of all time-loss
Tegnander (2008) [65]	Acute: 90% Overuse: 10%	Ankle: 24% Thigh: 17% Knee: 16%	Muscle and tendon: 36% Joint and ligament: 31% Overuse: 11%	1-7 days: 51%, 8-21 days: 28% >21 days: 17%, Drop-outs: 4%	-
Jacobson (2007) [63]	Traumatic: 69% Overuse: 31%	Knee: 25% Thigh: 19% Ankle: 13	Overuse: 31% Strain: 29% Sprain: 24%	1-3 days: 17%, 4-7 days: 22% 1 week-1 month: 39%, >1 month: 22%	-
Faude (2005) [59]	Overuse: 16% Traumatic: 84%	Knee: 19% Thigh: 18% Ankle: 18%	Sprains: 33% (80/241) Contusions: 24% (57/241) Strains: 17% (42/241)	1-6 days: 51%, 7-30 days: 36% >30 days: 13%	-
Giza (2005) [61]	Acute: 82% Chronic: 16%	Knee: 31.8% Head: 10.4% Ankle: 9.3%	Strains (30.7%) Sprains (19.1%) Contusions (16.2%)	-	-

Incidence and incidence proportion

Over the course of one season, 48-72% of the football players sustained at least on injury. The overall incidence of injuries ranged from 1.9-8.4 injuries per 1000 h of exposure. The lowest incidence was found in the study using an insurance database to record injuries. [61] Incidence of injuries were 4-13 times higher in matches than in training, with results ranging from 12.6-30.3 injuries per 1000 h of match exposure and 1.2-5.2 injuries per 1000 h of training exposure. Horan et al. [62] also estimated that a squad of 22 players can expect 15 time-loss injuries during a season.

Injury severity

Eight of the nine studies reported injury severity in four to five categories based on time loss. Most studies found the majority of injuries (18-40%) to be of moderate severity, defined by a time-loss from 7-8 days to 28-30 days. [20, 59, 60, 62-64] Minor injuries (1-7 days) were most common (51%) in one study, [58] and slight injuries (1-3 days) in another. [65] Severe injuries with time loss over 21-30 days comprised 12-30% of all injuries.

Injury burden

Only two studies reported injury burden, one as days lost per 1000 h exposure, [62] one as percentage of total time loss. [20] Horan et al. [62] reported ligament and muscle injuries to be the most burdensome injury types, and the knee, ankle and thigh as the locations with the highest injury burden. Hägglund et al. [20] also reported knee, thigh and ankle injuries as the most burdensome locations, causing 54%, 16% and 12% of all days lost, respectively.

Mode of onset

Different definitions were used in the studies reporting mode of onset: sudden and gradual onset, [62] acute and chronic, [61] acute and overuse[65] and traumatic and overuse[59, 60, 63] were all used. In all studies reporting injury onset, sudden onset/acute/traumatic injuries were most common, comprising 69-90% of all injuries.

Injury location

Lower extremity injuries comprised 60-92% of all time-loss injuries. [21, 59-62, 65] All studies using a time-loss definition of injury found the three most commonly injured locations to be the knee

(16-31% of all injuries), the thigh (13-30%) and the ankle (12-24%). Giza et al.,[61] using an insurance database to record injuries, reported head injuries as the second most common location, compromising 10% of all injuries.

Injury types

The definitions of different injury types were inconsistent between studies, but muscle injuries or strains, ligament injuries or sprains, and contusions stand out among the most common injury types across all studies.

Injury diagnosis

Only three studies reported injury diagnosis. Lateral ankle sprains (13.9%) and hamstring injuries (12.4%) were the most common diagnoses in the Irish league.[62] In the Swedish premier league, hamstring injuries (15%), ankle inversion sprains (12%) and groin pain (6%) were most common,[20] while in the German premier league the most frequent injuries were ankle sprains (15%), thigh strains (10%) and knee sprains (10%).[59]

Research gaps in the existing literature

Most of the surveillance studies identified through the systematic search were based on data collected 10-20 years ago. With the rapid development in women's football occurring over the last decade, it is likely that injury risk has changed during that time. Nearly all studies have used the narrowest definition of injury, the time-loss definition, and all have reported severity in terms of time loss. This may not represent the complete picture and is likely to underestimate the number and severity of gradual-onset injuries. The categories used to describe injury location were fairly consistent among studies, while a myriad of terms and definitions were used to describe onset of injury, injury type, severity and burden, many not consistent with recently published consensus statements on injury and illness surveillance.[16, 49] Few studies reported injury burden and specified diagnoses, which is important to give a thorough risk assessment and to enable the development of well-targeted preventative measures. Studies describing the extent and severity of illnesses were lacking and no studies reported the prevalence of injuries, which is most appropriate to describe gradual-onset injuries.

In *Paper I*, we therefore conducted a two-season prospective cohort study of all health problems in the Norwegian women's premier league. To address the limitations of previous research, we included both injuries and illnesses, used an "all complaints" definition, recorded problems through the combined use of player self-reporting and diagnoses set by team physiotherapists, and included both prevalence, incidence, severity and burden as outcomes.

Models of sports injury occurrence

After describing the extent and severity of injuries, the second step in sports injury prevention research is to establish why and how injuries occur (aetiology and injury mechanism). [15] Sports injuries are complex and multifactorial, and several models for injury causation have been developed. The models by Meeuwisse et al. [66] and Bahr and Krosshaug[17] describes how an athlete can be predisposed to injury due to internal risk factors such as age, sex, anatomy, strength, neuromuscular control or skill level. When playing a sport, the athlete is exposed to external risk factors, such as opponent behaviour or weather conditions. The sum of internal and external risk factors and the interaction between them, results in an athlete that is susceptible for an injury to occur. The final link in the chain, and a necessity for injury occurrence, is the inciting event (Figure 3).

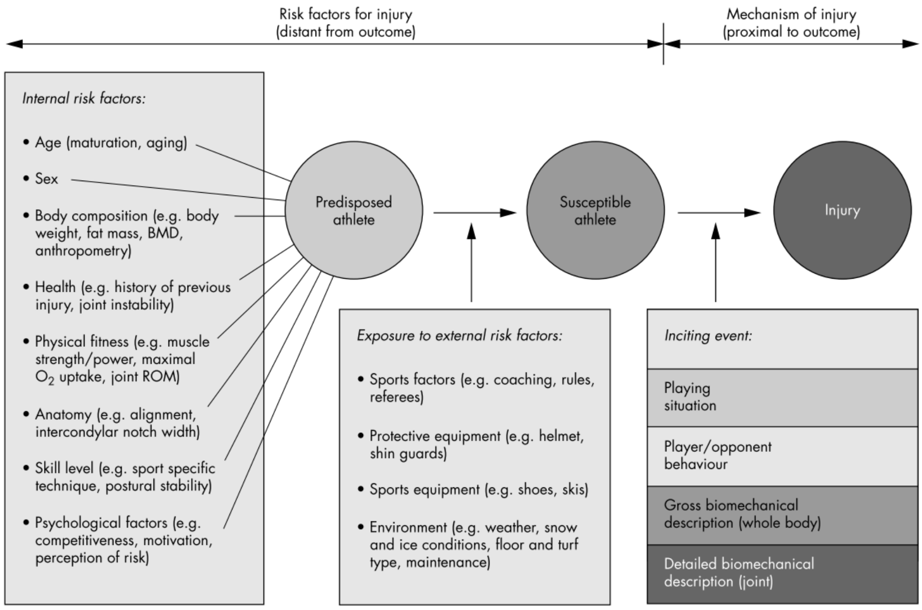

Figure 3. Bahr and Krosshaug's model for injury causation. [17] Reused with permission.

Both models[17,66] describe sports injuries as a linear process where the injury is the endpoint, but this is often not the case. To account for these issues, the models have been further elaborated to more dynamic models of sports injury [67, 68] (Figure 4). If sustaining an injury, the athlete often goes through a period of rehabilitation, before returning to sport.[67,68] The injury and rehabilitation process can affect the internal risk factors, and a consistent finding in most sports and injury types is that previous injury is the strongest risk factor for new injury. [69] However, most often when players are exposed to external risk factor and events similar to those causing injuries, they do not become injured. Still, this exposure can also affect their internal risk factors: a player can be exposed to body contact, but instead of getting injured the player gets stronger and better to resist body contact from others, and therefore less likely to get injured. Adaptations of exposure can also negatively affect the internal risk factors. Repeated exposure to sprinting can result in microdamage of the hamstring muscle tissue. If this happens regularly over time, without sufficient recovery for the muscle tissue to heal, the tissue can be weakened and therefore more susceptible to injury.

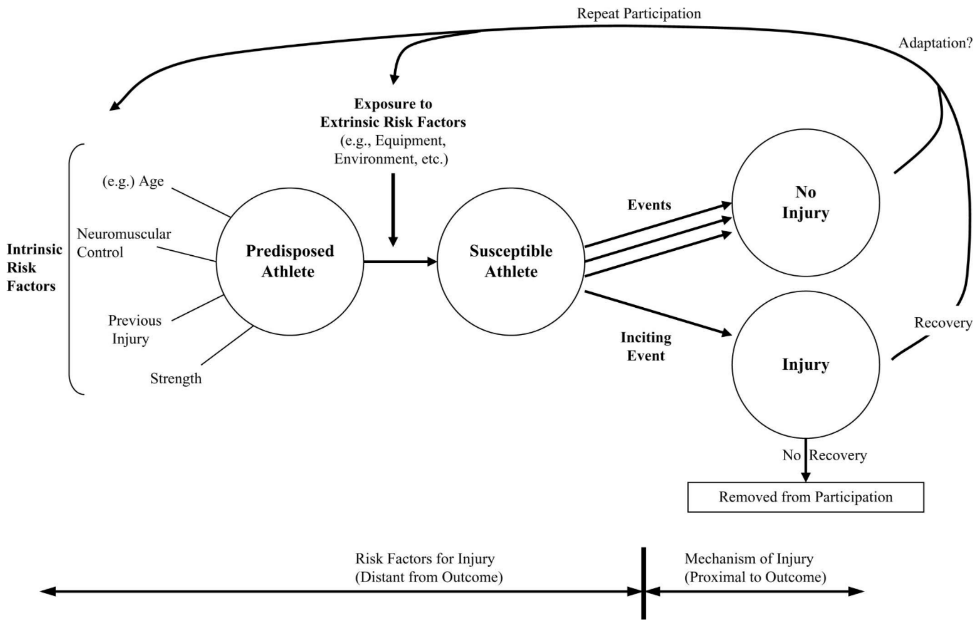

Figure 4. Meeuwisse et al.'s model of aetiology in sport injury. [67] *Reused with permission.*

While risk factors can be classified as internal and external, they can also be classified as modifiable or non-modifiable. [70] Finding non-modifiable risk factors, such as age, previous injury and sex, may be important to identify groups at increased risk of injury. However, modifiable risk factors, such as balance, strength or flexibility, must be identified to enable the development of preventative measures. [70] When studying risk factors for sports injuries, a prospective cohort study is, in most cases, the preferable design. [70] Typically, this involves measuring potential risk factors, and then follow a group of athletes for a period of time and record the injuries that occur and the athletes' exposure. This can provide direct and accurate estimates of the risk of injury. An alternative design to study risk factors is through intervention studies. This provides the strongest evidence to evaluate cause-effect relationships but are limited to modifiable risk factors and can usually only evaluate one risk factor at the time. [70]

The risk factors and injury mechanisms are likely to be specific for specific injury types. When a specific injury type has been identified as frequent or severe in surveillance studies, how and why these specific injuries occur must be examined. [15] Our systematic search showed few epidemiological studies in women's premier league football have recorded specific diagnoses. Furthermore, previous research in women's football has been limited to mainly knee and head injuries, while data on other injury types is lacking. [22] Studying other common injuries in women's football in detail and understanding their injury mechanisms and risk factors is therefore necessary. [22, 23]

Hamstring injuries

Hamstring injuries have been the most common and burdensome injury in men's football for years, constituting 12-24% of all injuries[26, 30, 71] and having high recurrence rates (12-16%).[27, 30] Among Champions League teams, the incidence and burden of hamstring injuries have increased during the last 20 seasons,[28, 71] and the increasing intensity[72] and number of matches has likely contributed to this development. [71] The same changes are now seen in modern women's football, where both the physical demands[4] and number of matches have increased substantially in recent years. Consequently, we expected that hamstring injuries had become frequent in women's football too. As early as 2009, it was proposed that the observed increase in speed and intensity of women's football had increased the risk of hamstring injuries. [20] The most recent injury surveillance study from women's premier league football (published after we initiated the #ReadyToPlay project), reported that hamstring injuries were the second most common injury, constituting 12% of all injuries in the Irish league. [62] However, research on severity, mechanisms and timing of hamstring injuries in women's football is lacking. [73] In *Paper II*, we therefore conducted an in-depth study of the hamstring injuries that occurred during the two-season prospective cohort study.

The following section will cover the hamstring muscles anatomy and function and describe how and why hamstring injuries occur in football. Due to the limited research on hamstring injuries in women's football, most data presented in the next sections will be based on studies on men.

Hamstring anatomy and function

The hamstring muscle group is located on the posterior thigh and consists of three muscles. Laterally lies the m. biceps femoris with two heads, the long and the short head, and medially is the m. semimembranosus and m. semitendinosus[74] (Figure 5). Except the m. biceps femoris short head, all hamstring muscles originate from the ischial tuberosity. The m. biceps femoris long head and the m. semitendinosus share a common tendon, whereas the m. semimembranosus origin is above and lateral. [75] The short head of m. biceps femoris originates from the lateral lip of the linea aspera in the middle third of the femur. [74] The long and short heads of m. biceps femoris merge to form a single tendon that inserts to the lateral side of the head of the fibula[75]. The m. semimembranosus inserts the medial tibial condyle, and the m. semitendinosus to the medial tibia via the pes anserinus (along with the tendons of m. gracilis and m.sartorius). [74]

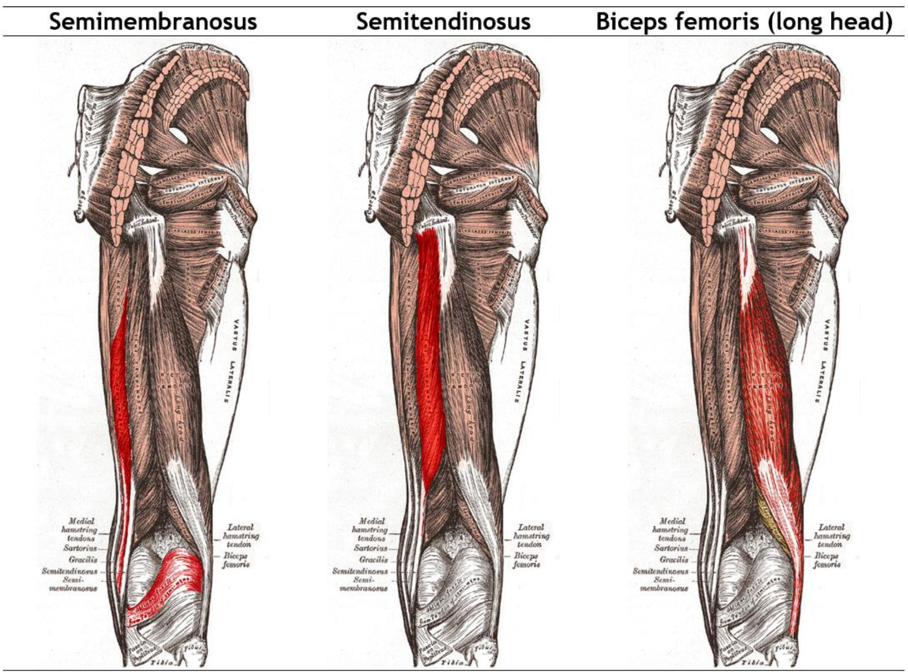

Figure 5. Anatomy of the hamstring muscles. Used with permission. [76]

The hamstring muscles have a central role in the gait cycle of walking and running and is important to the performance of most sport-related activities, particularly when fast running is required. [32]. With exception of the biceps femoris short head, the hamstring muscles are biarticular muscles, crossing both the hip and knee joint. They function as hip extensors and knee flexors, [74] meaning they work concentrically to extend the hip and flex the knee, or eccentrically to control hip flexion and knee extension. In addition, they contribute with internal or external rotation of the tibia and to stabilise the pelvis in the sagittal plane. [74]

Hamstring injuries in football

Most hamstring injuries in men's football are muscle strains. [30] Although the hamstrings can be affected by other injuries, such as tendinopathies and back-related injuries that refer pain to the posterior thigh, [33] hamstring muscle strains have received most attention in the literature and was therefore our main focus when this project started.

Two main types of acute hamstring strain injuries have been described based on a study on hamstring injuries in sprinters and dancers: the sprint-type and the stretch-type. [77, 78] Sprint-type hamstring injuries mainly occurred when sprinting at maximal or near maximal speed, and typically involved the proximal muscle tendon junction of the long head of biceps femoris. [77] These injuries caused a marked reduction in hamstring strength and flexibility but required shorter time before returning to full activity compared to stretch-type hamstring injuries. [77] Stretch-type hamstring injuries occurred during excessive lengthening when performing slow stretching type exercises. They were commonly located close to the ischial tuberosity and typically involved the tendon tissue of semimembranosus. Initial pain and functional impairment for these injuries were often mild, but the rehabilitation period was significantly longer than the sprint type. [77]

Football places high demands on sprinting but also involves many actions that cause stretching of the hamstring muscles, such as kicking, tackling or receiving the ball. However, extensive research data from men's top-level football collected for the past 20 years, have shown that the majority of hamstring injuries occurred during sprinting or high-speed running and most involved the biceps femoris long head. [29, 30, 71] Injuries to the biceps femoris, semimembranosus and semitendinosus caused similar time-loss, but recurrence rates were higher for biceps femoris injuries. [79] Furthermore, severity grading based on MRI was associated with lay-off times after hamstring injuries. [29, 79] About two thirds of hamstring injuries in football had a sudden onset, and nearly all were non-contact injuries. [29, 30, 71] More hamstring injuries has been observed to occur towards the end of each half[30, 71] and in periods of fixture congestion. [7] Hamstring injury incidence and burden were significantly higher during matches than in training. [27, 28, 30] The increased importance, intensity, sprint distances and speeds in matches compared to training are likely causes for the differences. [80] However, it has been observed that training-related hamstring injury rate among men's Champions League teams increased substantially from 2001 to 2014 while match-related hamstring injuries remained stable. [28] The authors suggested that training rates may have increased because training sessions have started to include more high-intensity actions to mirror the demands of the game. This likely caused more hamstring injuries in training but made players better prepared for game situations, [28] and could be the reason that match-related hamstring injuries remained stable despite a substantial increase in sprint distances covered by players during matches in the same period. [72]

While hamstring injuries in men's football have been studied extensively, data from women's football is limited. A recent systematic review and meta-analysis of hamstring injuries in female athletes of all ages and participation levels who play field sport identified 12 studies, six of which from football. [73] They found moderate certainty evidence that the incidence of hamstring injury in female field sport athletes was 0.6 injuries/1000 hours, but insufficient reporting of injury severity, mechanism, and timing of hamstring injuries. [73] Only two studies reporting mechanisms of hamstring injuries were identified. Similarly to what is reported in men's football, most hamstring injuries were non-contact and occurred during sprinting or running. [81, 82]

Sprint-type hamstring injury mechanism

Understanding injury mechanisms is a crucial aspect of sports injury prevention research. [17, 66-68] Sprint-type hamstring injuries, that seem to be most common in football, are primarily believed to occur during the terminal swing phase (Figure 6)[83, 84] when the hamstrings are required to produce high amounts of force while the muscles are lengthening to decelerate the extending knee and flexing hip. [33] Simulation studies have demonstrated that the hamstring muscles reached their maximum lengths during the late swing phase during running and sprinting. The biceps femoris long head, which is most commonly injured in sprint-type hamstring injuries, was stretched to a larger extent than the semimembranosus and semitendinosus. [85, 86] Peak hamstring force and negative work (i.e. eccentric work) were also highest during the late swing phase and increased significantly with speed. [86] It is generally agreed that strain injuries occur when the tissue's mechanical limits are exceeded. [86] Both excessive strain and eccentric force have been proposed as potential causes for muscle strain injuries, with a possible interrelationship between them. [33] As the late swing-phase is where both the maximal stretch and maximal force in the running gait cycle is required, it is reasonable to assume that this is the phase the tissues limits are exceeded. This hypothesis is further supported by two case studies where hamstring injuries occurred during biomechanical analysis of running, both identifying the late swing phase as the time of injury. [87, 88]

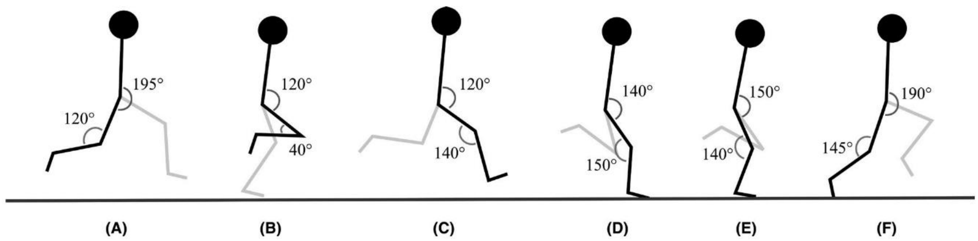

Figure 6. The sprinting gait cycle. (A) Early swing (B) Mid-swing (C) Late swing (D) Early stance/ foot strike (E) Mid-stance (F) Late stance/toe-off. Used with permission. [84]

Risk factors for hamstring injuries

Several systematic reviews and meta-analyses have examined the risk factors associated with hamstring injuries, with a primary focus on studies conducted in association football and other football codes such as rugby, Australian rules football, and Gaelic football. [32, 33, 89] The data predominantly involve male participants, as research on risk factors for hamstring injuries specifically in women's football is virtually non-existent. Here, some of the most commonly assessed risk factors for hamstring injuries will be presented.

Non-modifiable risk factors

A consistent finding across most injury types and sports is that a history of previous injury is by far the strongest risk factor for injury. [69] This is also the case for hamstring injuries, where a meta-analysis showed that players with a prior hamstring injury are 2.7 times more likely to sustain a hamstring injury compared to players without a history of injury[32] and one study even reported a 11.6 higher risk in previously injured players. [90] Several factors may contribute to the increased risk, including the formation of scar tissue, reduced flexibility or eccentric strength or alterations in the angle of peak torque. [33] Previous anterior cruciate ligament (ACL) and calf strain injury were also associated with higher risk for hamstring injury. [32] Notably, if an ACL reconstruction utilizes a hamstring tendon graft, this could potentially explain the higher risk of hamstring injuries. Although these results were based on data from men, the finding of previous ACL injury as a risk factor for future hamstring injury could be particularly relevant to women's football where the rate of ACL injuries is approximately three times higher than in men's football. [91, 92] Older age is also one of the strongest risk factors for hamstring injury, independently of previous injury. [32] Ethnicity has been suggested as a risk factor, with black players found to have a higher risk compared to white. [30, 32] It has been suggested, without substantial evidence, that this could possibly be linked to factors such as anterior pelvic tilt or muscle fibre type composition. One study has found association between muscle fibre type and hamstring injury risk, where players considered having fast muscle typology had higher risk for hamstring injuries compared to players with slow muscle typology. [93] While non-modifiable risk factors can help identify high-risk groups, finding modifiable risk factors is necessary to develop effective preventive measures. [70]

Modifiable risk factors

Strength and flexibility are the most extensively studied modifiable risk factors for hamstring injuries, [32] understandably as it has been assumed that hamstring injuries occur because the tissue's capacity to withstand force or strain is exceeded. Hamstring strength has often been described relative to quadriceps strength, as the hamstrings:quadriceps ratio, because the quadriceps ability to generate speed determines the forces the hamstring muscles must be able to resist. [70] Bilateral strength differences have also been considered, as a weaker hamstring on one side may increase the vulnerability to injuries. [33] Various methods have been employed to assess these measures, but data from prospective cohort studies examining the association between hamstring strength and hamstring injury risk are equivocal. [94-97] Although prospective cohort studies are often preferred when examining risk factors for injuries, the strongest evidence for the causal effect of a modifiable risk factor is obtained through intervention studies, [70] and several intervention studies have demonstrated that eccentric hamstring strengthening programmes can reduce the risk of hamstring injuries. [34-37] It should be noted that while the preventative effect was originally proposed to be a result of increased eccentric strength, [36, 98] it has also been suggested that it may work through other mechanisms, such as increased muscle fascicle length[99] which has shown some associations with hamstring injury risk. [100] It has been suggested that shorter fascicles, with fewer in-series sarcomeres, may be more susceptible to overstretching and damage during powerful eccentric contractions, such as those encountered during the terminal swing phase of high-speed running. [100]

While strength seems an important risk factor for hamstring injuries, flexibility has provided limited value as a stand-alone risk factor, [32] and an intervention study found no effect of flexibility training on hamstring injury risk. [36] Increased running exposure[101, 102] and sprint kinematics, including increased side-bending during front swing and anterior pelvic tilt during backswing, have also been associated with hamstring injury risk. [103] Player position have also been related with hamstring injury risk, [32] with players in positions that require more sprinting and high-speed running being at greater risk. Because of the observation that more hamstring injuries occur towards the end of each half[30, 71] and during periods of match congestion, [7] fatigue has also been suggested as a risk factor for hamstring injuries. Fatigued muscles can absorb less energy before failure compared to unfatigued muscles, [104] and fatigue may potentially also alter running technique. [33]

Hamstring injury risk factors in women's football

Injury risk can differ between male and female football players, and it has been suggested that there may be sex-based differences in hamstring injury risk factors. [105] Unfortunately, little research on risk factors for hamstring injuries in women's football exist. Recently, a survey of the chief medical officers of European women's professional football clubs was published, and they considered "lack of communication between medical staff and coaching staff", "load on players", "lack of regular exposure to high-speed football during training", and "playing matches 2–3 times a week" as the most important risk factors for hamstring injuries. [106] Furthermore, two intervention studies may give some indications on hamstring injury risk factors. A prospective crossover cohort study showed that a soccer-specific balance training programme could reduce the number of hamstring injuries. [82] The authors hypothesised that proprioceptive training could be beneficial in prevention of hamstring injuries. The training was mainly based on jumping and landing exercises, so the eccentric work of the hamstrings during landing could be another possible reason for the preventative effect. A randomised controlled trial of three Spanish women's teams have indicated that eccentric training can reduce hamstring injuries, [107] although the results were non-significant due to a low sample size.

Because of issues related to the Covid-19 pandemic, we were unfortunately not able to conduct a planned study on risk factors for hamstring injuries. However, we considered maximal eccentric hamstring strength to be important to evaluate both as a risk factor and a potential preventative measure against hamstring injuries in women's football. For both these purposes, accurately measuring maximal eccentric hamstring strength is essential.

Measuring maximal eccentric hamstring strength

Isokinetic dynamometry has been described as the gold standard for measuring maximal eccentric hamstring strength, [38, 108] but the high cost, the lack of portability and the time required for testing limits widespread use. [38, 109] Handheld dynamometry is an alternative but is dependent on the skill and strength of the operator to provide reliable and valid data. [38, 109] Because of these limitations, several alternative tools with lower cost and easier use have been developed. [110] The Nordic hamstring exercise has been commonly used in research aiming to increase maximal eccentric hamstring strength and prevent hamstring injuries. [34-36] Consequently, a test device measuring maximal eccentric hamstring force via the Nordic hamstring exercise has been developed, [38] commercialised (NordBord, Vald Performance, Albion, Australia) and is now commonly used in both research[110] and by elite teams in various sports. This test was also part of the regular pre-season testing of the Norwegian premier league players (Figure 7). During the test, the player's ankles are secured by braces attached to load cells. These measure the maximal eccentric hamstring force when the athlete leans forward, using their hamstring muscles to resist the forward falling motion for as long as possible (i.e. performs the Nordic hamstring exercise). The test has displayed high test-retest reliability, [38] but the correlation to isokinetic dynamometry testing of maximal hamstring strength is low. [108, 111] It has therefore been suggested that the two tests measure different traits. [108, 112]

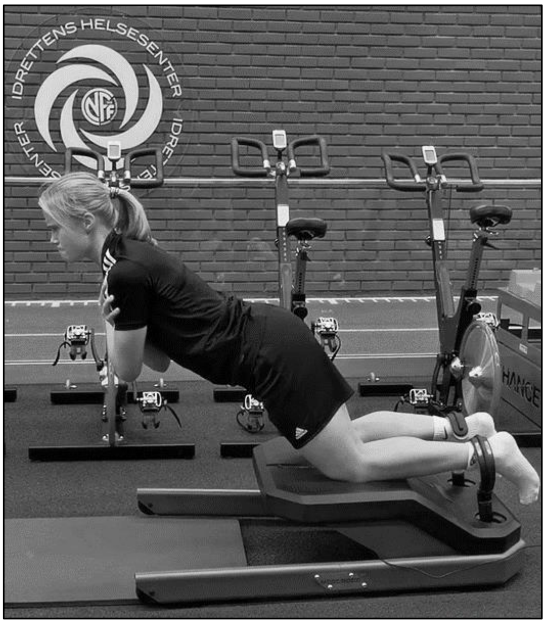

Figure 7. Picture of NordBord testing. The ankle braces are attached to load cells measuring the force when the player perform the Nordic hamstring exercise.

The Nordic hamstring exercise is intended to be supramaximal, and a prerequisite for the NordBord test is that the subject reaches a "critical point" where the external load from gravity acting on the upper body exceeds their maximal eccentric hamstring strength. [38] However, some athletes are able to control the forward falling motion throughout the full range of motion of the exercise. These will never reach the "critical point" and the test may therefore not be able to measure their maximal eccentric hamstring strength as intended. Some studies have addressed this problem. To ensure that supramaximal intensity is achieved, study participants who were able to control the forward falling movement during the final 10-20° before full extension have performed training while holding weight plates, increasing the weight over the intervention period.[39-43, 99, 113] Several of these studies have used the same criterion when testing maximal eccentric hamstring force with NordBord.[39-43] The criterion, however, seems to have been adopted based on reasoning but without substantial evidence. As maximal eccentric hamstring force measured by NordBord is largely dependent on body mass,[114] performing the test with added weight could possibly affect the force measured irrespective of changes in eccentric hamstring strength. This would be critical, especially if using different weights for pre- and post-tests when evaluating the effect of a training intervention or when comparing groups that have performed the testing with different weights.

In *Paper III*, we therefore aimed to investigate how adding extra weight when performing the NordBord test affected the maximal eccentric hamstring force recorded in male and female football players, and if there were any differences between players who were able to control the forward falling movement during the final part of the range of motion and those who could not.

Preventing hamstring injuries

Based on the assumption that hamstring injuries occur as a result of lack of eccentric hamstring strength, eccentric hamstring strengthening is a likely effective preventative measure. The Nordic hamstring exercise has been widely used in research on the prevention of hamstring injuries because it requires no equipment and can be performed anywhere, making it easy to incorporate into football training sessions.[98] Mjølsnes et al.[98] were the first to show that using the Nordic hamstring exercise could significantly increase maximal eccentric hamstring strength in male football players, and to a greater extent than traditional strength training. They used a 10-week programme, gradually progressing the training volume, ending up with three sessions per week during the last five weeks. This programme, or a slightly longer version of it, have later demonstrated to reduce hamstring injury risk in male football players by approximately 65%,[34-36] with an even greater preventive effect observed for recurrent hamstring injuries.[34] It should be noted that high compliance is crucial.[115] Limited research has investigated use of the Nordic hamstring in women's football, but one study suggested that eccentric training, with the Nordic hamstring exercise as one of three exercises, could reduce the risk of hamstring injuries.[107] However, this study had a limited sample size, and the results were not statistically significant.

It does, however, take more than an existing exercise programme to prevent injury.[18, 116] As described by Finch,[18] an intervention's effectiveness is evaluated under "ideal conditions", but the preventative measures need to be accepted, adopted and complied with by the athletes and sports bodies they are targeted at to prevent injuries. Despite the proven effectiveness of the Nordic hamstring programme, its adoption among football teams was low. [44, 45, 117, 118] In the men's Champions League, less than one in five teams were considered fully or partly compliant to the 10-week programme. [44] Several factors could contribute to this low adoption rate, and it is important to address these issues to ensure better compliance. [115]

Two main challenges in achieving player adherence to injury prevention are concerns about muscle soreness and the perception of "heavy legs".[119] Unaccustomed eccentric exercise can cause delayed-onset muscle soreness (DOMS), which typically peaks 48 hours post exercise and is a common reason for compromised sportive performance. [120] However, one session with low-volume eccentric training seems to protect against muscle soreness the next sessions because of the "repeated-bout effect". [121] Although low levels of muscle soreness was reported in the original study of the 10-week Nordic hamstring programme, [98] later studies have reported that most players performing the programme reported DOMS during the first weeks, [34] and that the programme caused more DOMS and non-DOMS pain compared with lower training volumes with the Nordic hamstring exercise. [122]

Another potential barrier to implementing the programme could be its poor fit within the elite football context. Improving physical qualities such as strength is often a focus during the pre-season period, which for most football teams is shorter than 10 weeks. If the 10-week Nordic hamstring programme is initiated at the start of the pre-season, the final stages will, for many teams, coincide with the start of the competitive season. The coaching staff decide the training content and are vital for the implementation of injury prevention. [123] When important matches start, often several per week, coaches are likely hesitant to performing three sessions per week with an exercise potentially causing muscle soreness. The long duration and high training volume were also highlighted as an issue by Fuller, [46] arguing that the programme in its current form, despite its effectiveness, does not provide an adequate return on player's time investment. Coaches are also concerned that time spent on an injury prevention impacts the time available to implement performance-based training sessions. [46] Highlighting the sport-specific performance enhancements of an injury prevention programme may therefore increase the motivation and compliance from both coaches and players. [124, 125] In this regard, the Nordic hamstring exercise has shown promise in improving both sprint and jump performance. [126-129]

Despite the low adoption of the full Nordic hamstring programme among men's elite teams, teams that used the Nordic hamstring exercise for the entire squad experienced lower hamstring injury burden than teams that did not.[130] This indicates that a modified version may also be effective if implemented by all players.[130] Indeed, football teams often tailor injury prevention programmes considerably to suit their specific implementation context.[131 132] A programme of shorter duration and lower training volume could potentially facilitate implementation in the busy training and match schedules of elite teams but may attenuate the effects as there is a dose-response relationship between strength gain and training volume.[133] Interestingly, recreationally active men performing a high training volume of the Nordic hamstring exercise did not improve their eccentric strength more than those performing a low training volume (440 vs. 128 total reps over 6 weeks), and the muscular adaptations for both groups occurred early during the intervention.[40] However, the training volumes needed to improve strength can be affected by training status,[134] concurrent training[135] and sex,[136] so the results from recreationally active men may not be transferable to female football players. Furthermore, the study used NordBord testing with weight to evaluate the training intervention,[40] which has potential issues already addressed above.

Given the preventative effect observed in male football players, eccentric hamstring strengthening is a measure likely to reduce hamstring injury risk in women's football as well. We considered a low-volume programme[40] to be more likely to be adopted by football teams compared to the protocol introduced by Mjølsnes et al.[98] In *Paper IV*, we therefore aimed to compare the effect of high and low training volumes with the Nordic hamstring exercise on maximal eccentric hamstring strength in female football players. Additionally, we evaluated muscle soreness, jump and sprint performance due to their potential implications for real-world implementation, and assessed the time course of strength changes.

Aims of the thesis

The overall aim of this thesis was to address some of the research gaps that exists in injury prevention research in women's football, with a main focus on hamstring injuries. We conducted four studies for this purpose, where we aimed to:

1. Describe the prevalence, incidence, and burden of all health problems in the Norwegian premier league during the 2020 and 2021 seasons (*Paper I*).
2. Describe the characteristics, clinical findings and MRI findings of hamstring injuries in the Norwegian premier league during the 2020 and 2021 seasons (*Paper II*).
3. Investigate how adding extra weight when performing the NordBord test affected the maximal eccentric hamstring force recorded in male and female football players, and if there were any differences between players who were able to control the forward falling movement during the final part of the range of motion and those who could not (*Paper III*).
4. Determine if using the evidence-based high-volume programme of the Nordic hamstring exercise was more effective on improving the hamstring strength, jump height and speed in female football players compared to a low-volume programme (*Paper IV*).

Methods

Context and study design

Because of the evident lack of sports medicine research in women's football, we initiated the #ReadyToPlay project, which the papers of this thesis are based on. All studies were planned during the autumn of 2019, conducted during the football seasons 2020-2022, and included players from Norwegian elite football, mainly women. The Norwegian season normally starts in early April and finishes in the end of November with a summer break in July. However, both in 2020 and 2021 the seasons were postponed due to the Covid-19 pandemic. Therefore, several of our projects were affected by the pandemic or restrictions relating to it and the duration of the seasons differed from normal. The 2020 season lasted from July to December without a summer break, while the 2021 season lasted from May to November with a shorter summer break than normal.

Paper I and *Paper II* were both part of a prospective cohort study in the Norwegian women's premier league during the 2020 and 2021 seasons. *Paper I* was an injury and illness surveillance study of all health problems, while *Paper II* was an in-depth study of the hamstring injuries that occurred. The Norwegian Football Associations Sports Medicine Clinic (Idrettens helsesenter) had some years prior to the start of this PhD project started to routinely perform pre- and post-season testing of all women's premier league teams to increase focus on physical training and have baseline data to support decision making in the return to play process after severe injuries. This pre-season testing was used to inform players about the project and invite them to participate, and to recruit team physiotherapists to contribute to the projects. We also attended a training camp for all premier league teams in February 2020 to recruit players and physiotherapist that could not attend the pre-season testing.

Paper III was a methodological study where we investigated how performing NordBord testing with added weight affected the force measured. This study included the female premier league players that were tested at Idrettens helsesenter between the 2020 and 2021 seasons. In this period, travel restrictions were implemented to reduce viral transmission, resulting in some teams being unable to attend. The research question was also relevant for men, therefore we also invited players from three men's 1st division teams (2nd tier, professional), chosen because of proximity to the Norwegian School of Sports Sciences and already established contact with members of their coaching staff.

Paper IV was a randomised trial aiming to compare the effect of high and low training volumes of the Nordic hamstring exercise in female football players on maximal eccentric hamstring strength, jump and sprint performance. Because we aimed to study high-level women's football players, but not interfere with the ongoing surveillance study in the premier league, we invited teams playing in the women's 1st division (2nd tier). The coaching staff of three 1st division teams based in the Oslo area were contacted and their teams were invited to participate, and two teams accepted.

Participants and ethics

Participants

All players in the Norwegian women's premier league (UEFA club coefficients ranking[137]: 12th) were invited to participate in the surveillance study that formed the basis for *Paper I* and *II*. In *Paper I*, we included 294 players (22±4 yrs, 93% of all invited players) during the 2020 and 2021 season. All players were part of the first team squad, had a signed contract and was ≥16 years old. In *Paper II*, we examined 53 hamstring injuries sustained by 42 players (25±5 yrs) from the same cohort. Twenty-two physiotherapists contributed to the data collected in these two papers.

In *Paper III*, we included 84 of the female premier league players (171±6 cm, 65±6 kg, 22±4 yrs) and 56 male 1st division players (183±6 cm, 78±9 kg, 24±4 yrs). All participants were ≥16 years old, part of the team's first team squad and free of injury when tested.

For *Paper IV*, 45 female players (21±4 yrs, 169±6 cm, 63±8 kg) from two 1st division teams were recruited for the randomised trial studying the effect of high and low training volumes of the Nordic hamstring exercise. All players included were members of the first team squads, ≥16 years old, and free of injury during pre-testing.

Ethics

Ethical approval for *Paper I* and *II* was obtained from the Norwegian Centre for Research Data (#662612) and the Norwegian School of Sports Sciences Ethics Board (#129-051219). *Paper III* was also approved in the same application, but the addition of male football players was approved through protocol amendments to both the Norwegian Centre for Research Data (#662612) and the Norwegian School of Sports Sciences Ethics Board (#179-180321). *Paper IV* was also approved by the Norwegian Centre for Research Data (#485861) and the Norwegian School of Sports Sciences Ethics Board (#164-291020). The women's premier league players gave their written informed consent to participate in the #ReadyToPlay project covering the data collection for *Paper I*, *II* and *III*, while a separate informed consent was given to the male players included in *Paper III*. The players included in *Paper IV* also gave their written informed consent. All decision letters from the Norwegian School of Sports Sciences Ethics Board and the Norwegian Centre for Research Data, and the informed consent forms used can be found in Appendix I-III.

Health problem surveillance (Paper I)

Definitions

In *Paper I*, we followed the definitions recommended in the IOC[16] and FIFA[49] consensus statements on methods for recording and reporting of epidemiological data on injury and illness in sport (Table 4).

Table 4. Definitions used in Paper I.

Health problem	Any condition that reduced a player's normal state of complete health, irrespective of its consequences on football participation or performance or whether she sought medical attention
Injury	Tissue damage or other derangements of normal physical function
Sudden-onset injury	Injuries caused by a single, clearly identifiable energy transfer
Gradual-onset injury	Injuries caused by multiple accumulative bouts of energy transfer without a single, clearly identifiable event responsible for the injury
Illness	Complaint or disorder experienced by a player, not related to an injury
Football training	Football-specific training defined as all sessions involving the techniques and/or tactics of football
Football match	Organised scheduled play against an opposing team (including official matches, friendlies and junior/reserve team matches, but not internal training matches)

Player self-reports

During the 2020 and 2021 season, players in the premier league responded to the updated version of the Oslo Sports Trauma Research Center questionnaire on health problems (OSTRC-H2) [56] weekly through a mobile app (AthleteMonitoring, Fitstats Inc., New Brunswick, Canada). In addition, players reported their football training and match exposure. The full questionnaire is illustrated in Figure 8. Players were sent automatic SMS reminders to complete the questionnaire every Sunday and were sent daily reminders if not responding. Players responded to the weekly questionnaire for 63 weeks: the full competitive season of 2020 (23 weeks from July to December 2020), and most of the pre-season and the full competitive season of 2021 (40 weeks from February to November 2021). Players had a 9-week recording break between seasons, mainly during the off-season period, but also including first weeks of the pre-season.

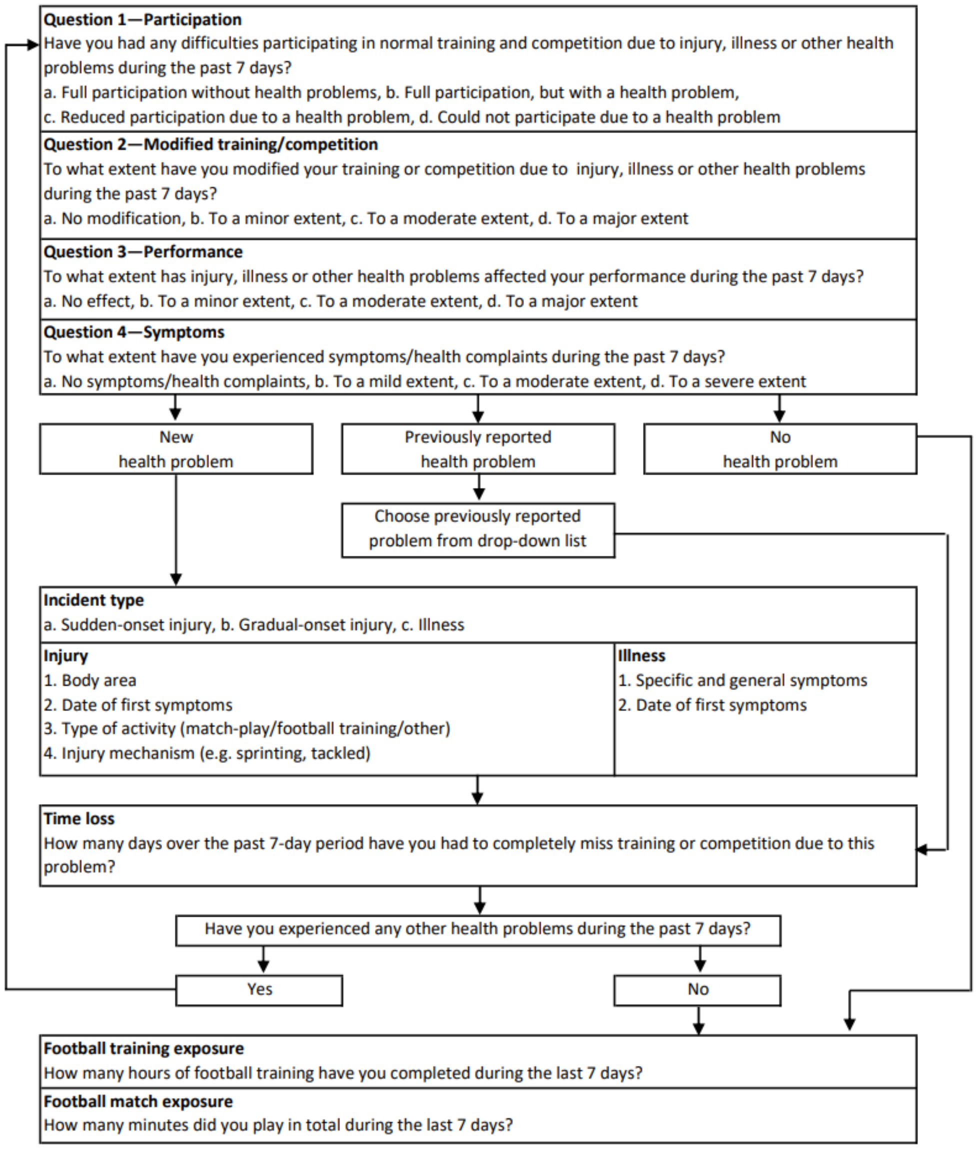

Figure 8. Overview of the questionnaire players responded to each week. Players were asked to report the most severe health problem first if they had several.

Based on the answers to the first four questions in the OSTRC-H2 (Figure 8), a severity score of 0-100 was calculated for each health problem. [25, 56] The first question acted as gatekeeper, so if players answered "Full participation without a health problem" or "Could not participate due to a health problem", they were assigned a total severity score of 0 and 100, respectively, and did not respond to questions 2-4. A health problem was classified as *substantial* if it led to at least moderate reductions in training volume or football performance[25] and as a time-loss problem if causing absence from football training or match play.

Team physiotherapists

Each team had one to three physiotherapists with access to their players' health reports and a medical staff profile in the AthleteMonitoring application. When a player reported a problem by responding to the OSTRC-H2, the team physiotherapist examined the player and diagnosed the reported health problems in the AthleteMonitoring application using the SMDCS.[50] If appropriate, they had the opportunity to reassign the onset and location of the injury reported by the players. If players were followed up by physiotherapists outside the team, we contacted the physiotherapist to record the diagnosis, which then was registered into the application.

Standardised examination and hamstring injury form (Paper II)

If a player monitored in the prospective cohort study (*Paper I*) sustained a hamstring injury, she was included in *Paper II*. To ensure no hamstring injuries were missed, we monitored all self-reported health problems each week and contacted the team physiotherapist whenever a problem to the posterior thigh had been reported. Hamstring injuries that were not self-reported (e.g. in players with low response rate to the weekly questionnaire) but identified by the team physiotherapist were also included. When a hamstring injury was identified, the team physiotherapist performed a standardised clinical examination of the player and completed a hamstring injury form. The examination and injury form were developed based on the literature[138-140] and presented to the team physiotherapists prior to the start of the project.

The hamstring injury form provided information about when the injury happened, injury onset (sudden/gradual/gradual with sudden deterioration), activity when the injury occurred (football training/match/other), which leg was injured (dominant/non-dominant), if the player had any previous hamstring injuries, and the inciting event was described in free text and by choosing from one or more of the following options: sprinting, running, changing direction, jumping, landing, falling, shooting/passing, dribbling, tackling, lunging, reaching with leg, passive stretch and other. The physiotherapist then examined the player, reporting whether there were any visible hematoma, tenderness on palpation of the lateral or medial part of the hamstrings, the distance from the ischial tuberosity to the point of maximal tenderness, the length and width of the tender area, and if the player experienced pain during the maximal hip flexion active knee extension test (MHFAKE), outer-range strength test and mid-range strength test. [138] Lastly, the physiotherapists reported their diagnosis as free text. The physiotherapists were instructed to perform the examination and submit the form to the research group as soon as possible after a player sustained a hamstring injury. The injury form (in Norwegian) can be found in Appendix I.

MRI examination and assessment (Paper II)

If the hamstring injury caused >3 days lost or affected the player for ≥2 weeks in a row, an MRI appointment was ordered via Idrettens helsesenter at a designated radiology clinic (Evidia or Unilabs) nearby the player's residence. All radiology clinics used MRI machines with a field strength of 1.5 T. MR sequences included T1, T2, Short Tau Inversion Recovery (STIR), and proton-density (PD) with fat saturation and were performed in coronal, axial and sagittal planes.

Two experienced consultant musculoskeletal radiologists, blinded to the clinical status, assessed and scored the injuries on a standardised MRI scoring form based on the literature. [29, 139, 141-144] Before commencing, they were familiarised with the scoring form by assessing, discussing and agreeing on hamstring injury MRIs from patients not involved in the project. After the 2021 season, they were given access to the images from all hamstring injuries that were investigated by MRI, scored all the hamstring injuries independently and, in cases of disagreement, reached consensus after re-assessing the scans together.

In the MRI scoring form, they first defined which muscle were involved and the location of the injury as follows: (1) proximal tendon, i.e. free tendon proximal to muscle fibre attachment, (2) proximal muscle-tendon junction, i.e. proximal intramuscular tendon and attached muscle fibres, (3) proximal muscle-belly, i.e. muscle proximal to the midpoint of the whole muscle-belly, (4) distal muscle-tendon junction, i.e. distal intramuscular tendon and attached muscle fibres, (5) distal muscle-belly, i.e. muscle distal to the midpoint of the whole muscle-belly, and (6) distal tendon, i.e. free tendon distal to muscle fibre attachment. [139, 143] They also evaluated whether the injury had myofascial involvement and if there were signs of structural damage to the free or intramuscular tendon, either by a focal defect separating proximal and distal parts of the tendon, or waviness (in place of the normal straight margins) suggesting loss of structural tension. [141] The distance from the most cranial pole of the injury to the most caudal part of the ischial tuberosity was measured,[139] and the site of injury was defined as the proximal, middle or distal third of the muscle. The proximal third was considered to be above the lower margin of the gluteus maximus and the distal third below the origin of the short head of biceps femoris.[142] The injury severity was graded with an MRI modification of Peetrons classification (grade 0: negative MRI, grade 1: oedema but no architectural distortion to muscle or tendon, grade 2: architectural disruption indicating partial tear of muscle or tendon, grade 3: total muscle or tendon rupture).[29, 144, 145] The MRI scoring form can be found in Appendix I.

Maximal eccentric hamstring force during Nordic hamstring test (Paper III and IV)

The NordBord was used to measure maximal eccentric hamstring force in both *Paper III* and *IV*. During the test, players knelt on the board and had their ankles secured by ankle hooks attached to uniaxial load cells. We instructed them to cross their arms in front of their chest, move slowly forward without bending their hip and resist the forward falling motion for as long as possible. Players performed three submaximal warm-up repetitions, followed by a short break, before performing the several test sets with maximal effort. All players first performed three repetitions without weight, then one repetition with 5 kg added weight and one repetition with 10 kg added weight. A few players in *Paper III* also performed the same routine but with two additional sets of one repetition, with 15 kg and 20 kg. All sets with maximal effort were separated by 1-min breaks. Verbal encouragement was given during the test to ensure maximal effort from the players. We recorded the maximal force (N) produced in the right and left leg for each of the sets, and always reported the maximal force as the average from the right and left leg.

In *Paper IV*, we used the NordBord to assess maximal eccentric hamstring force during pre- and post-testing, but also at two time-points during the training intervention. For pre- and post-testing, we used the methods described above with three sets up to 10 kg. For the two mid-tests, we only performed one set without weight due to time restrictions. The mid-test was conducted prior to football training, but Covid-19 restrictions implemented at the time of the project limited how early players were allowed to meet for training.

Maximal torque, jump and sprint testing (Paper IV)

During the pre-and post-testing in *Paper IV*, we also assessed maximal isometric and eccentric knee flexor torque, countermovement jump height and 40 m sprint times. Maximal isometric and eccentric knee flexor torque were tested unilaterally, right leg before left, in an isokinetic dynamometer (Humac Norm model 502140, Computer Sports Medicine Inc., Stoughton, MA, USA). Players did two 5 s maximal isometric voluntary contractions with the knee 90°, 60° and 30° from full extension, and three maximal repetitions of eccentric knee extension at 60°/s (90°-0°). We recorded the maximal torque (Nm) for each of the tests and report the results as the average of the right and left leg. Countermovement jump was tested on a force platform (HUR Labs, Kokkola, Finland). Players performed three maximal countermovement jumps with hands on their hips and self-preferred kneeling depth. Only the highest jump height (cm) was reported. Sprint was tested on an indoor running track. Players performed two 40 m sprints, separated by a 2-min break. Time was measured every 10 m by wall-mounted photocells (Athletics Training System, IC Control Media & Sport, Bromma, Sweden) placed 1 m above the ground, and we retained sprint times every 10 m (s) from the best trial for analysis. The reader is referred to *Paper IV* for more detailed description of the testing procedures.

Nordic hamstring training programmes (Paper IV)

In *Paper IV*, 45 players from the two included teams were randomised within teams to a high- or low-volume group. Training prescriptions were based on previous studies[34, 40, 98] but adjusted to an 8-week intervention period to match the pre-season (Table 5).

Table 5. Training protocol for the high- and low-volume training groups.

Week	High-volume group		Low-volume group	
	Sessions	Sets and repetitions	Sessions	Sets and repetitions
1	1	2 × 5	1	2 × 4
2	2	2 × 6	2	4 × 6
3	3	3 × 6-8	2	4 × 6
4	3	3 × 8-10	1	2 × 4
5	3	3 × 12-10-8	1	2 × 4
6	3	3 × 12-10-8	1	2 × 4
7	3	3 × 12-10-8	1	2 × 4
8	3	3 × 12-10-8	1	2 × 4
Total	21	538	10	144

Players performed the Nordic hamstring exercise in pairs after football training sessions (Figure 9). If players were able to control the fall throughout the range of motion, load was increased by adding speed to the starting phase of the motion. [98] Verbal encouragement was given during all repetitions to ensure maximal effort. Before every Nordic hamstrings session, players reported the maximal hamstring muscle soreness felt since the previous session on a numerical rating scale

(0=No pain, 1-3=Mild, 4-6=Moderate, 7-9=Severe, 10=Worst pain imaginable). A researcher attended all Nordic hamstring training sessions to ensure high compliance, proper execution of the exercise and prevent contamination between groups. We aimed to have at least 48 h between Nordic hamstring sessions, but to adjust for the team training plan and match schedule only 24 h separated some sessions in the high-volume group.

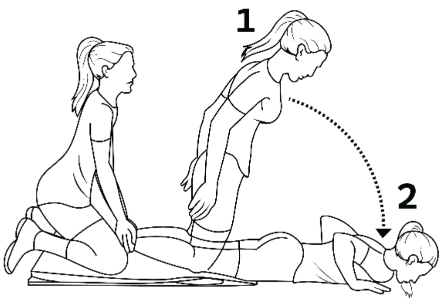

Figure 9. Illustration of the Nordic hamstring exercise performed with a partner securing the ankles.

Data management and statistical analyses

Paper I

At the end of the study, we and the team physiotherapists went over the data recorded and adjusted any obvious mistakes through human errors (e.g. reporting 540 hours of football exposure in one week or reporting four separate ACL injuries in four consecutive weeks). The severity of health problems that were not resolved at the end of the 2021 season were assigned the median time loss of resolved problems with a similar diagnosis. None of the ACL injuries that occurred during the study were fully resolved before it ended. Therefore, we estimated their time loss and severity score based on data from four players who had sustained ACL injuries just prior to inclusion and returned to play during the study period. For players reporting health problems causing 7 days lost in the last week of recording in 2020 and in the first week of recording in 2021, we imputed time loss (7 days per week) and severity score (100 per week) during the 9-week recording break between seasons. For incidents that involved multiple injuries, the severity of the primary injury was reported. [16] After the data collection, diagnosed injuries were reclassified to match the revised 2020 consensus version of the SMDCS[50] because the AthleteMonitoring-app used the old version. SMDCS codes that described similar injuries (e.g. muscle spasm, strain and tear in the same muscle or 1°, 2° and 3° sprains in the same ligament) were combined and reported as follows: quadriceps, hamstring, adductor, gastrocnemius and soleus muscle injuries, anterior cruciate ligament injuries, deltoid ligament sprains, lateral ankle ligament sprains, and tibiofibular ligament syndesmosis injuries.

Statistical analyses were conducted using R statistical software (version 3.6.1). The response rate was calculated as the number of responses to the questionnaire divided by the number of distributed questionnaires. We calculated the weekly prevalence of all health problems as the number of players reporting one or more problems each week, divided by the number of players responding to the questionnaire. Only health problems that occurred after players' inclusion were included in analyses of incidence, severity and burden. Incidence was reported as the number of health problems or injuries per 1000 h of football exposure, and the number of illnesses per player per 365 days. Severity was reported as the total number of days lost together with median days lost and quartiles and categorised as recommended. [49] Injury burden was reported as days lost per 1000 h of exposure and illustrated in risk matrices with incidence and mean severity. [146] We compared injury incidence[147] in match-play versus football training with the significance level set at $p<0.05$.

Paper II

In *Paper II*, the results from all injury and MRI forms were presented, and if there were any missing data this was reported. The time loss of the hamstring injuries was the total number of days of absence the players reported in their weekly reports. The statistical analyses were done in IBM SPSS Statistics 28.0. We analysed the difference in time loss duration between injuries with different severity and onset using one-way analysis of variance, and Tukey HSD was used as post hoc test. Shapiro-Wilk test and Levene's test were used to test the assumptions of normality and homogeneity of variances, respectively. The significance level was set at $p<0.05$.

Paper III

In *Paper III*, repeated measures analysis of variances (ANOVA) was used to analyse differences in maximal eccentric hamstring force between tests performed with different weight. This was done separately for female and male players, players with and without control during the final 20°, and for the male players that performed the extra test session with up to 20 kg added weight. Greenhouse-Geisser adjustment were performed if the assumption of sphericity was violated. Independent sample t-tests were used to compare the change in maximal eccentric force caused by adding weight to the test between players who were able to control the forward falling motion during the final 20° and players who could not. Results were presented as mean and 95%

confidence intervals. Statistical analyses were done in IBM SPSS Statistics 28.0, and the significance level was set at $p<0.05$.

Paper IV

Prior to the project, we estimated the required sample size needed. With a power of 80% and significance level at $p<0.05$, a sample size of 16 participants per group was required to detect the expected between-group difference. Analyses were decided to be per-protocol with compliance to the training intervention required to be ≥67%. We used two-tailed paired t-tests to assess within-group differences between pre- and post-tests, analysis of covariance (ANCOVA) for between-group differences in strength, jump and sprint performance (covariate: pre-test results, fixed factor : group), and unpaired t-tests for between-group differences in age, height and mass. Differences in NordBord test results with 0 kg, 5 kg and 10 kg added weight were analysed by repeated measures ANOVA. We imputed missing data (7% of values) from the NordBord tests in week 4 and 6 with the mean of the two closest tests, and analysed strength over the four test occasions by split-plot ANOVA (within-factor: group, between-factor: time). We calculated the Pearson correlation coefficient between the NordBord and the eccentric isokinetic dynamometer test. Compliance is expressed as the percentage of completed relative to assigned training sessions. Muscle soreness is the mean (±SD) of all responses to the muscle soreness questionnaire. Statistical analyses were done in IBM SPSS Statistics 28.0, and a p-value of <0.05 was considered significant.

Results

Health problems in women's football – a two-season prospective cohort study in the Norwegian premier league (Paper I)

In *Paper I*, the mean weekly response rate to the OSTRC-H2 was 79% (range: 57-100%), and team physiotherapist diagnosed 63% of the reported problems (71% of injuries, 38% of illnesses). In total, 819 health problems were reported. The average weekly prevalence is shown in Table 6.

Table 6. The average weekly prevalence of health problems.

	Mean (95% CI)
All health problems	**32% (31-33%)**
Injuries	30% (29-31%)
Sudden onset injuries	15% (15-16%)
Gradual onset injuries	15% (15-16%)
Illness	2% (2-3%)
Substantial health problems	**22% (21-23%)**
Injuries	20% (19-21%)
Sudden onset injuries	12% (11-12%)
Gradual onset injuries	8% (8-9%)
Illness	2% (2-2%)
Time-loss health problems	**23% (22-24%)**
Injuries	21% (20-22%)
Sudden onset injuries	12% (11-12%)
Gradual onset injuries	9% (9-10%)
Illness	2% (2-2%)

Of the 819 health problems reported, 110 had occurred prior to inclusion. Thus, 709 new health problems (44% sudden onset injuries, 35% gradual injuries and 21% illnesses) occurred during 66234 hours of football exposure (7351 match hours and 58884 training hours), resulting in an overall incidence of 10.7 health problems per 1000 h of football exposure (95% CI: 9.9-11.5). Twenty percent caused no time-loss, 38% caused 1-3 days, 17% caused 4-7 days, 17% caused 8-28 days, 5% caused 29-90 days, 2% caused 91-180 days and 1% caused >180 days. Sudden-onset injures were most severe both in terms of time-loss (68% of total) and severity score (62% of total), while the severity of illnesses was low (8% of total time loss, 10% of cumulative severity score).

The overall injury incidence was 8.4 injuries (95% CI: 7.7-9.2) per 1000 h (6.6 time-loss injuries per 1000 h, 95% CI: 6.0-7.3), and was higher during match play than in training (13.5 vs 3.6

injuries per 1000 h, p<0.0001). The most common injury locations were the thigh (26%), knee (15%) and ankle (14%) and the same body areas caused the largest proportion of total time loss (knee: 42%, ankle: 13% and thigh: 11%, total number of days lost to injury: 8749 days). Muscle injuries were most common (26% of all injuries), while injuries to ligament/joint capsule were most severe (caused 39% of days lost to injuries). Hamstring injury was the most frequently reported diagnose, while ACL injuries caused most days lost, being responsible for 30% of the total injury time loss. The three injury diagnoses causing the largest injury burden were ACL injury (39.3 days lost per 1000 h), concussion (8.3 days lost per 1000 h) and hamstring muscle injury (7.9 days lost per 1000 h). The reader is referred to *Paper I* for a table presenting the number, incidence, time loss and burden of all injuries. The incidence and severity of the body areas causing the largest injury burden is presented in Figure 10.

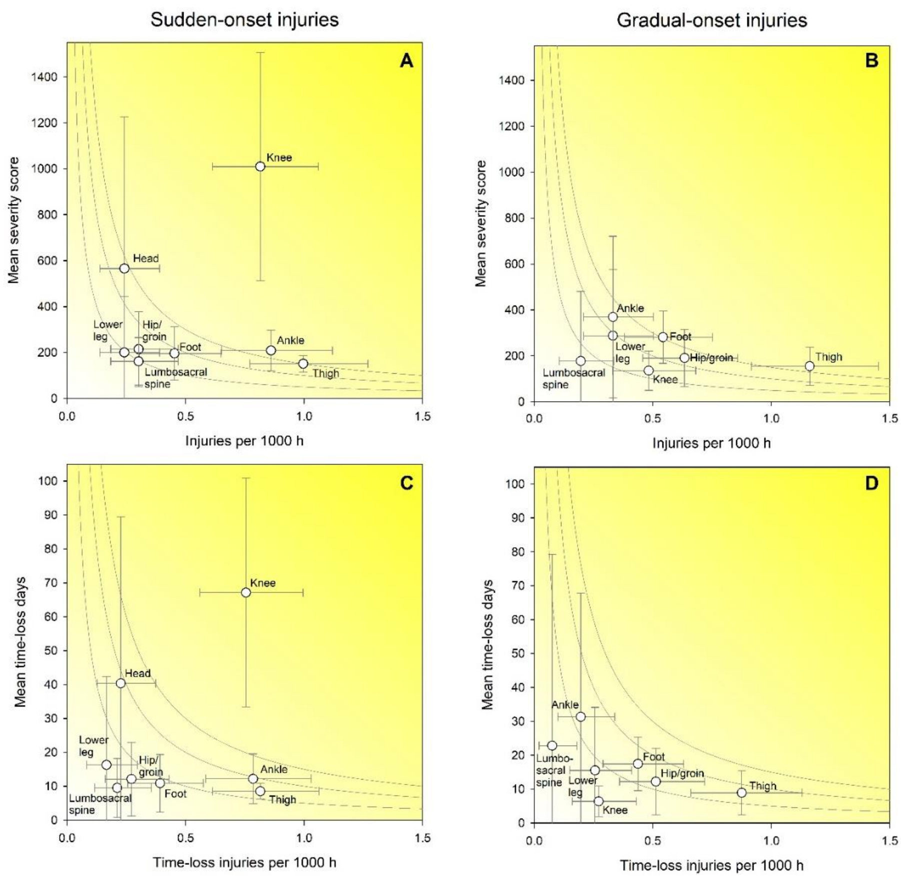

Figure 10. Risk matrices illustrating the incidence of all injuries with (a) sudden and (b) gradual onset and their mean cumulative severity score, and the incidence of time-loss injuries with (c) sudden and (d) gradual onset with mean days lost. Only the body regions with the highest injury burden are presented. Darker yellow represents greater injury burden and the curved lines indicate equal injury burden. Error bars displays 95% confidence intervals.

Hamstring injuries in women's football – a two-season prospective cohort study in the Norwegian premier league (Paper II)

In *Paper II*, standardised clinical examinations were completed of 53 hamstring injuries in 42 different players (age: 25±5 yrs., positions: goalkeepers 2%, central defenders 21%, fullbacks 19%, central midfielders 19%, wingers 26%, strikers 12%). The number of hamstring injuries does not match with *Paper I* because some were not reported by the player through the OSTRC-H2 but directly from the team physiotherapist.

Clinical examination

The median time from injury occurrence to clinical examination by a physiotherapist was 3 days (interquartile range: 1-10 days, range: 0-29 days). The characteristics of the 53 injuries are presented in Table 7. Six injuries (11%) were recurrences, occurring 117 days (median, interquartile range: 60-346 days) following the index injury. Sprinting and running were the most frequently reported mechanisms, and most hamstring injuries had a non-contact mechanism (94%).

Table 7. Characteristics of the hamstring injuries examined clinically (N=53) and with MRI (N=31).

	Injuries examined clinically	Injuries examined by MRI
Thigh		
Dominant	22 (42%)	13 (42%)
Non-dominant	31 (58%)	18 (58%)
Onset		
Sudden onset	25 (47%)	14 (45%)
Gradual onset*	28 (53%)	17 (55%)
Season period		
Pre-season	21 (40%)	12 (39%)
In season	32 (60%)	19 (61%)
Activity		
Football training	26 (49%)	15 (48%)
Football match play	24 (45%)	14 (45%)
Strength and conditioning	1 (2%)	1 (3%)
Not reported	2 (4%)	1 (3%)
Pain location by palpation		
Lateral	16 (30%)	9 (29%)
Medial	21 (40%)	14 (45%)
Medial and lateral	7 (13%)	4 (13%)
Ischial tuberosity	4 (8%)	2 (6%)
No pain during palpation	5 (9%)	2 (6%)

*Eight of the gradual onset injuries examined clinically, and six of those examined by MRI were reported as "gradual onset with sudden deterioration".

Time loss was reported for 39 of the 53 injuries (missing data from 14 injuries that were not self-reported). Hamstring injuries caused 8 days (median) of absence from full unrestricted football activity (interquartile range: 3-15 days, range: 0-188 days). There were no significant differences in time loss between injuries with sudden onset (13±9, 95% CI: 8-18 days, N=16), gradual onset (20±47, 95% CI: 0-46 days, N=15) and gradual onset with sudden deterioration (7±4, 95% CI: 4-10 days, N=8).

MRI analyses

MRIs were taken 26 days (median) after the reported injury date (interquartile range: 13-38 days, range: 3-122 days). Sixteen of the 31 injuries assessed by MRI were grade 0 (52%), 5 were grade 1 (16%) and 9 grade 2 (29%). There were no grade 3 injuries, and one injury (3%) was diagnosed as a proximal tendinopathy, and not given a severity grade. Nearly all injuries in the m. biceps femoris long head involved the proximal or distal muscle-tendon junction, while injuries in m. semimembranosus were mainly located to the proximal tendon (Figure 11). No injuries involved the m. biceps femoris short head or the m. semitendinosus.

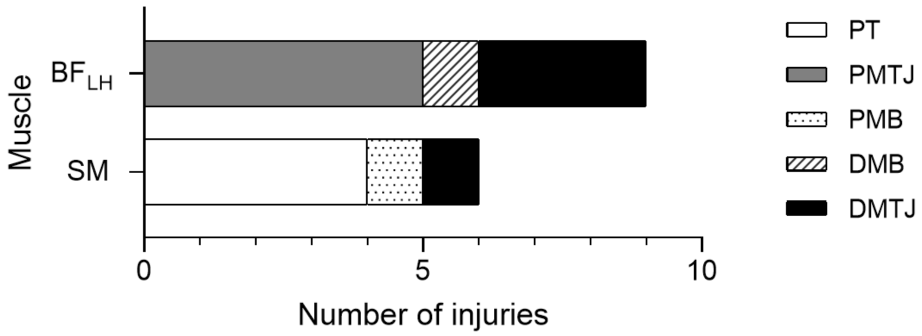

Figure 11. The location of the primary lesions found on MRI. BFLH: m. biceps femoris (long head), SM: m. semimembranosus, PT: proximal tendon, PMTJ: proximal muscle-tendon junction, PMB: proximal muscle belly, DMTJ: distal muscle-tendon junction.

Grade 2 injuries caused significantly longer absence (19±8 days, 95% CI: 13-25 days, N=9) compared to grade 0 injuries (7±7 days, 95% CI: 3-11 days, N=12, p=0.002) and injuries examined clinically but not with MRI (5±4 days, 95% CI: 3-7 days, N=13, p<0.001), but not compared to grade 1 injuries (11±12 days, 95% CI: 0 to 30 days, N=4, p=0.24).

Performing NordBord-testing with additional weight affects the maximal eccentric force measured - do not compare apples to oranges (Paper III)

In *Paper III*, 140 football players (84 females, 56 males) performed NordBord testing with 0 kg, 5 kg and 10 kg added weight. Their absolute and relative maximal eccentric hamstring force are presented in Table 8. Maximal eccentric force was higher when the test was performed with 5 kg and 10 kg added weight than without added weight for both female ($p<0.001$) and male players ($p>0.001$). This was also the case for both players that could control the final 20° ($p>0.001$, N=65) and not ($p<0.001$, N=75).

Table 8. Absolute and relative eccentric force (mean±SD) during the Nordbord test performed with 0, 5 and 10 kg added weight for female (N=84) and male players (N=56), as well as the mean percent change (with 95% CI) for the tests with 5 and 10 kg added weight.

	Female players			Male players		
	0 kg	5 kg	10 kg	0 kg	5 kg	10 kg
Absolute force (N)	335±45	343±53	352±54	431±52	449±54	458±61
Relative force (N/kg)	5.1±0.6	5.3±0.7	5.4±0.7	5.5±0.5	5.8±0.6	5.9±0.7
Change (%)		2% (1-3%)	5% (4-6%)		4% (3-5%)	6% (5-7%)

Thirty-three female (39%) and 32 male players (57%) were able to control the movement during the final 20° of the test without added weight. For female players, the increase in eccentric force when the test was performed with added weight was not significantly different between those who could and could not control the final 20° (Figure 12). Male players with control increased the eccentric force more than those without control when the test was performed with 10 kg (, $p=0.004$), but not with 5 kg (Figure 12).

Of the ten male players who also performed the test with 15 kg and 20 kg added weight, four completed the test with 15 kg before declining to add more weight, while six also tested with 20 kg before declining to add more weight. Figure 13 illustrates the change in force measured when these players performed the test with added weights compared to without added weight. For the six players completing all five test sets, the maximal eccentric force was significantly higher when tested with 15 kg added weight compared to 10 kg (15N, 95% CI: 1-30 N, $p=0.41$), while there was no difference between the tests with 15 and 20 kg (-1 N, 95% CI: -22-23 N, $p=0.95$).

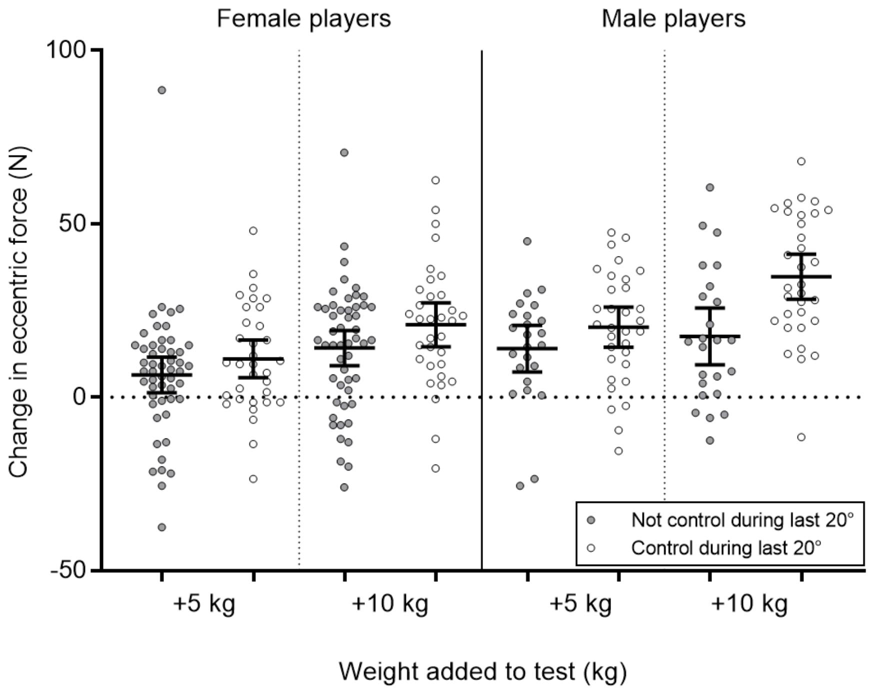

Figure 12. Difference in maximal eccentric force measured when the Nordbord-test was performed with 5 kg and 10 kg added weight compared to without added weight for female (N=84, left) and male players (N=56, right). Results are presented as mean with 95% confidence intervals. Circles represent individual results from layers who could control the final 20° of the test without weight (white) and players who could not (grey).

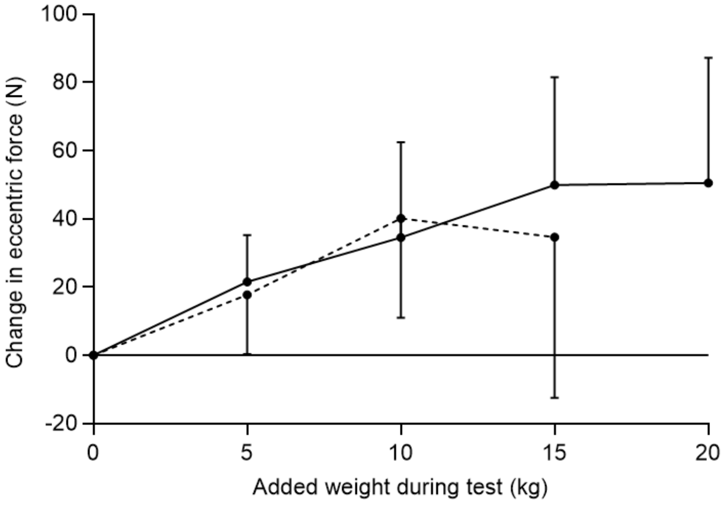

Figure 13. Change in maximal eccentric force measured when the test was performed with 5 kg, 10 kg, 15 kg and 20 kg added weight compared to without added weight (0 kg). Presented as mean±95% confidence intervals for players that performed the test up to 15 kg added weight (dashed lines, N=4) and 20 kg added weight (solid lines, N=6).

Effects of high and low training volume with the Nordic hamstring exercise on hamstring strength, jump height and sprint performance in female football players – a randomised trial (Paper IV)

In *Paper IV*, thirty-two players completed the training intervention per protocol and were included in the analyses. Players in the high-volume group completed 19±2 of 21 planned Nordic hamstrings sessions (89%) and the low-volume group 9±1 of 10 sessions (93%).

Both groups increased their maximal eccentric force in the NordBord tests—most when the test was performed with 10 kg added weight (high-volume: 294±57 to 323±58 N, p<0.001, low-volume: 293±64 to 330±51 N, p=0.001) (Figure 14). The increase in maximal eccentric force did not differ between groups in the NordBord tests (0 kg: p=0.11, 5 kg: p=0.25, 10 kg: p=0.38).

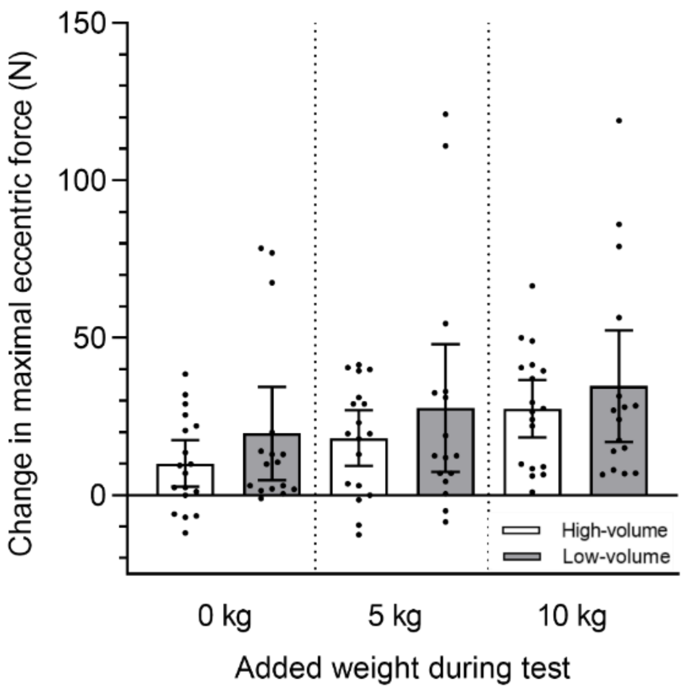

Figure 14. Change in maximal eccentric force for the high- (N=17) and low-volume groups (N=15) during NordBord testing with 0 kg, 5 kg and 10 kg added weight. Results are presented as mean with 95% confidence intervals and individual values for change (•).

When including the two intermediate NordBord tests without added weight in week 4 and week 6, there was a main effect for time on maximal eccentric strength ($p<0.001$), but no interaction between group and time ($p=0.52$). Pairwise comparisons showed an increase in maximal eccentric force from the pre-test to week 6 (mean change: 20 N, 95% CI: 8 to 31 N, $p<0.001$) and to the post-test (mean change: 16 N, 95% CI: 5 to 27 N, $p=0.002$), but not to week 4 (mean change: 8 N, 95% CI: -2 to 18 N, $p=0.22$).

No change within or between groups were seen in maximal isokinetic eccentric torque, countermovement jump height or sprint times. Hamstring muscle soreness was reported to be mild throughout the entire training intervention period for both groups (high-volume: 2.2±1.7, low-volume: 2.3±1.7), except after the pre-test.

Discussion

Health problems in the Norwegian premier league (Paper I)

Paper I in this thesis was the first study in women's premier league football to record all health problems, including illnesses, irrespective of time loss and medical attention. The results document that, at any given time, one in five players (22%) reported a substantial health problem. Low player availability can limit training content, reduce training quality and negatively affect player and team development and football performance,[8-10] therefore the high prevalence of health problems is a concern. The majority of the health problems were injuries, while the weekly average prevalence of substantial illness was low (2%). While team sport athletes have reported a lower prevalence of illness compared to athletes from other sports,[57, 148] both seasons followed in *Paper I* included periods with Covid-19 restrictions that likely prevented transmission of infections and contributed to the low prevalence of illness.

The incidence of time-loss injuries found in *Paper I* was similar to recent studies from women's premier league football,[21, 58, 62] but higher than most studies conducted between 2000-2010.[20, 60, 61, 63, 64] Although comparison between studies should be done with care due to methodological differences, this indicates that injury rates in women's football are going in the wrong direction. Increasing demands of the women's game, combined with low availability of medical care, strength and conditioning support and facilities[149] and the fact that many female players still have to combine their football career with their academic or working career, may contribute to the escalation in injury rate. Our data emphasize that medical support, injury prevention and load management measures should be given priority as the resources in women's football increase.

As nearly all previous research in women's premier league football had used a time-loss definition of injuries, severity measured in days lost and medical staff to record injuries, we speculated that the extent and severity of gradual-onset injuries had been underestimated. We observed that gradual-onset injuries were more frequent than previously reported, but sudden-onset injuries were still the most severe, regardless whether severity was measured by days lost or the OSTRC-H severity score. We also observed that reporting all injuries (regardless of time-loss) and time-loss injuries, with severity measured as OSTRC-H severity score and time-loss days, respectively, resulted in a similar injury pattern (Figure 10). We therefore suggest that recording time-loss injuries and expressing severity by the number of days lost, as done by most previous studies in football, gives a reliable picture of the overall injury pattern in women's football. However, our results cannot conclude if using players or medical staff to record the health problems would also result in a similar pattern. Implementing a surveillance system where players report all health problems weekly (or even daily) may yield significant clinical benefit by helping medical staff identify health problems and intervene early.

We hypothesized that muscle injuries, and especially hamstring injuries, were becoming frequent due to the rapidly increasing demands in women's football. Muscle was indeed the most commonly injured tissue, thigh the most commonly injured body area, and hamstring muscle injury the most frequent diagnosis. Hamstring muscle injuries also caused the 3rd largest injury burden, after ACL injuries and concussions. This highlights that hamstring injury prevention should be given priority in women's football.

Hamstring injuries in the Norwegian premier league (Paper II)

In *Paper II* we observed that hamstring injuries in women's football had both similarities and differences to what has been reported from men's football. Similarly to men's football,[28-30] nearly all injuries were non-contact and the most commonly reported mechanisms of injury were sprinting and running. The proportion of hamstring injuries with gradual onset (53%) was higher than reported in men's football (34-36%).[28, 29] Overuse complaints have previously been reported to be more frequent in female than male football players.[20] However, the difference may also be caused by our use of three categories for injury onset (sudden/gradual/gradual with sudden deterioration) rather than the traditional two (sudden/gradual),[16] or differences in the methods used to record injuries. Using player self-reporting of "all complaints" is more sensitive in identifying gradual-onset injuries compared to medical staff recording of time-loss injuries only[25] as has been done by the studies in men's football.[28, 29]

About half of the injuries examined by MRI did not show any structural changes. This could result from the large portion of gradual-onset injuries identified. In men's football, overuse injuries dominated grade 0 hamstring injuries,[29] and our data show that half of the grade 0 injuries had gradual onset compared to one tenth of the grade 2 injuries. As in men's football,[29, 79] there was an association between severity grade and days lost. Still, we would not recommend clubs to routinely examine all hamstring injuries with MRI as it does not add value in predicting time to return to sport over patient history and clinical examination,[150] and there are other areas were resources are more needed.

We observed that 40% of the injuries with MRI findings were located in the m. semimembranosus, compared to only 11-12% of hamstring injuries in men's football.[29, 31, 79] Most of the injuries in semimembranosus involved the proximal tendon. Furthermore, data from the clinical examinations of the injuries not examined with MRI indicate that an even higher proportion of all injuries involved the medial hamstring muscles. Addressing this should be a prevention priority in female players, and future research should explore why the m. semimembranosus seems more susceptible to injury than in their male counterparts.

Still, nine of 15 injuries with MRI findings were located in the m. biceps femoris long head, mainly in the muscle-tendon junction, which is considered highly susceptible to injuries. [151] In men's football, the majority of hamstring injuries involve the m. biceps femoris. [28-30] Therefore, we consider it likely that the preventative measures found to be effective in men's football are also relevant for female football players, and that eccentric strength therefore should be considered a risk factor and a target for injury prevention also in women's football.

Measuring maximal eccentric hamstring strength (Paper III)

A commonly used device to measure maximal eccentric hamstring strength is the NordBord, and several studies have used ability to control the final 20° of the NordBord test as a criterion to decide if participants should perform testing with added weight or not. [39-43] If only players that are able to control the final 20° of the test should be tested with weight, one is assuming that players not able to control the final 20° will not benefit from adding weight.

The main finding of *Paper III* was that performing the NordBord test with additional weight increased the maximal eccentric force measured compared to testing without additional weight. This was the case for both female and male players, for players who could control the final 20° of the test and players who could not. Our results therefore indicate that if participants are tested without weight during pre-testing and with weight during post-testing, this would cause a significant increase in the maximal force measured, regardless of any changes in strength. Additionally, for studies aiming to compare groups using different training volumes or exercises, [39-41] this testing approach can potentially bias the results. As an example, Behan et al. [41] compared four groups using different training volumes of the Nordic hamstring exercise, and reported that 80% of participants performing training and post-testing with added weight (range: 5-20 kg) were in the two higher-volume training groups of their study. Performing the test without added weight, however, may also be problematic. If players are able to stop the movement during the final part of the test, this does not necessarily require their maximal force. No matter how much stronger these players become during a training intervention, the force required to stop the movement during the final part of the test is likely to be the same. Testing these players without weight could therefore mask any changes in maximal strength.

An alternative approach to testing, used by Duhig et al. [113], is having all participants performing the NordBord test with bodyweight first, then adding weight in 5 kg increments until the force measured does not increase. This avoids the criterion of control during the last 20°, but ensures all participants reach their maximum. Our data (Figure 13) indicate that the force measured eventually reached a plateau when we kept increasing the weight used. How much weight is needed before the maximal force plateaus is likely highly individual and depending on the player's maximal eccentric hamstring strength but also other factors, such as body proportions, body mass, where the critical point occurs and the muscle force-length relationship. Another potential method is to have all players perform several test sets with gradually increasing weight, but only compare tests were the same weight has been used when performing the analyses. This prevents that differences in the weight used impacts the results but necessitates estimating the required weight for the post-testing before the commencement of the project. With either of these approaches, one should be aware that athletes may be reluctant to perform the NordBord test with much added weight. Few players agreed to be tested beyond 10 kg. Of the ten players who accepted, four declined adding weight beyond 15 kg and the remaining six did not want to go beyond 20 kg, despite not all of them reaching a plateau in the force measured. Fear of muscle soreness is one of the main challenges in obtaining adherence to injury prevention programmes from football players, [118, 119] and could also be a problem with NordBord testing with added weight.

Effects of high and low training volumes with the Nordic hamstring exercise (Paper IV)

In *Paper IV*, the main finding was that the evidence-based high-volume programme did not perform better than the low-volume programme in improving eccentric hamstring strength. This was in line with two previous studies comparing different volumes of the Nordic hamstring exercise. Both among recreationally active men (440 vs. 128 total reps over 6 weeks) [40] and male elite youth football players (1 vs. 4 sets per week for 6 weeks), [152] there were no differences in strength adaptations in the groups that were compared. A meta-analysis on Nordic hamstring exercise training volume has also concluded that performing lower training volumes of the Nordic hamstring exercise does not attenuate adaptations in eccentric strength. [47] This could be an important finding, as high training volumes is a potential barrier for implementation of the Nordic hamstring programme in football. While the low-volume programmes appear to be equally effective in increasing maximal eccentric hamstring force as the evidence-based high-volume programme, this do not provide evidence regarding effectiveness in preventing hamstring injuries. However, data from both the men's and women's Champions League suggest that using lower training volumes may also reduce the risk of hamstring injuries. The adoption of the complete 10-week Nordic hamstring programme was poor among both the men's and women's teams.[130, 153] Still, teams using the Nordic hamstring exercise for the full squad, despite most using a lower training volume than intended, had lower hamstring injury rates compared to teams that did not use the Nordic hamstring exercise for the full squad.[130, 153]

The 10-13% increase in maximal eccentric hamstring force seen in our study is similar to what was found in an 8-week Nordic hamstring intervention in female elite football players (13% increase),[154] but lower than what has been found though similar interventions in male athletes (~20%)[43, 152] and recreationally active men (~30%).[40, 99] Less concurrent training,[135] less experience with eccentric training, and a different approach to using weights during testing could be reasons for the discrepancy. Based on the data from *Paper III*, we decided to only compare pre- and post-test results where the same weight was used, to avoid the potential problems with overestimating the true change in strength.

Presland et al.[40] found muscular adaptations to happen early in the intervention with significant changes after only 14 days of training, and Ekstrand et al.[130] suggested identifying the minimal effective dose could be an important question to answer for coaches and medical staff. We observed that the maximal eccentric hamstring force did not increase significantly by week 4, but by week 6. At this time-point the training volume in the low-volume group was just one session per week with 2 sets of 4 repetitions. We would therefore not recommend stopping the programme at 6 weeks, but to maintain this training volume throughout the season.

While both the high and low volume group increased their maximal eccentric hamstring force measured in NordBord, neither group improved maximal eccentric torque measured in the isokinetic dynamometer. Although both tests are designed to measure eccentric hamstring strength, they may measure different traits and be specific to the training mode chosen.[108, 112] The NordBord test is very similar to the training exercise; this could be why we found improvements on the NordBord test but not on the dynamometer.

Concerns over muscle soreness and "heavy legs" is a major challenge in obtaining player adherence with injury prevention.[119] We, like other studies using a careful, gradual increase in training load,[98, 99] found the Nordic hamstring exercise to cause low levels of muscle soreness throughout the training intervention. Still, it should be noted that some players reported persistent soreness throughout the entire training period. While other studies have indicated the

Nordic hamstrings exercise can improve sprint times and jump height,[128, 129, 155] we did not detect any such changes.

Methodological considerations

Paper I

The main strengths of *Paper I* include the prospective design, the inclusion of nearly all players in the league, and the two-season duration. This should ensure good external validity for women's premier league football, although injury rates and patterns may differ between regions.[156, 157] The OSTRC-H2 is dependent on players providing honest information. As team physiotherapists had access to the player reports, it is possible that some players were reluctant to report problems if they were concerned it could reduce their chances of being selected for matches. Thresholds for reporting a health problem through the OSTRC-H2 may differ between sports, cultures and sex and could potentially be an issue if comparing studies using this method. The combined use of player self-reporting and team physiotherapists providing the diagnoses grants the benefits of both methods: self-reporting identifies more health problems than injury recording by medical staff,[25, 158] while team medical staff provides detailed information that cannot reliably be recorded by players. Medical staff diagnosed 71% of the injuries, and the undiagnosed injuries were of minor severity, causing 7% of the total injury time-loss. The diagnosis rate of illnesses (38%) was low, so our data do not provide much detail about these. While the OSTRC-H2 allows players to report problems such as mental illness and eating disorders, no such problems were reported. This was probably because players were hesitant to report these, not that they do not exist in this cohort. To provide valid data, a high response rate is required. The overall response rate in the current study was 79%, similar to what has been reported in studies with similar surveillance period[57] but lower than studies of shorter duration.[159, 160] The response rate to the questionnaire fell over the course of both seasons, most likely due to reporting fatigue, which should be considered in future research aiming to use the same methodology over long surveillance periods. A potential problem with reporting fatigue is that he threshold for reporting minor problems could increase. Players did not respond to the questionnaire for 9 weeks between seasons; therefore we do not have data on health problems sustained in this period and may have underestimated the severity of some problems that occurred toward the end of the 2020 season. While the response rate was relatively high, players not responding to the questionnaire during periods they were injured/ill may also have contributed to underestimating the severity of health problems. We wanted team medical staff to use the surveillance system as a practical tool, which may have allowed them to detect problems and intervene early and may have reduced the severity of some health problems. [57] During the prospective cohort study, two in-depth studies of hamstring injuries (*Paper II*) and groin injuries (*recently submitted*) were conducted simultaneously. It is possible that the extra focus on hamstring and groin injuries caused these injuries to be more likely to be diagnosed by the team physiotherapists. However, the diagnosis rate of thigh (81%) and groin injuries (60%) did not differ substantially compared to other body part (range: 43-100%).

Paper II

The combined use of player self-reporting and team physiotherapists to record hamstring injuries should ensure that most hamstring injuries that occured during the project were recorded. Another strength was that most injuries were examined clinically shortly after they occurred. The clinical characteristics of the injuries were reported on a standardised injury form by all physiotherapists, but we lack data on the inter-rater agreement of this reporting and the injury form was not validated. However, for injuries with MRI findings, the muscle observed to be injured (m. semimembranosus/m. biceps femoris long head) and the location of the injury decided by palpation during the clinical examination (medial/lateral) in most cases matched (13/15). For several injuries, the injury mechanisms were reported although the injury had a gradual onset. Injury mechanism is mainly to be described for sudden onset injuries. [49] It is therefore possible that for some of the gradual-onset injuries, the reported injury mechanism was an activity causing symptoms rather than the injury mechanism. Two consultant radiologists scored the MRIs separately which should reduce the risk of bias in interpreting the images. Good inter-rater reliability of the measures included in our MRI scoring form have been reported previously. [144] The time from injury occurrence to the MRI was longer than optimal and is a limitation. We consider it likely that the most severe hamstring injuries were examined with MRI, as the injuries not examined with MRI caused minor time loss. A limitation to our study is that we only have time loss data from the self-reported injuries (74% of all injuries), but for these, the players' weekly response rate from the injury occurred to it was recovered was excellent (93%). However, the few missing responses and four players that stopped responding before their injury was fully recovered have likely caused a small underestimation of days lost. While much of the discussion is based on comparing our results with data from men's Champions League football, [29, 79] it should be noted that differences in how we identified the hamstring injuries could also contribute to the differences found, not just the sex difference.

Paper III

In *Paper III*, we tested a high number of both female and male players. That the test was performed with gradually increasing weight rather than in a randomised order could, theoretically, have affected the force measured in the later sets both negatively and positively. Fatigue may have negatively affected the maximal force the players could produce in the latter sets. We consider this unlikely, as it has been shown that 1-minute break between sets was sufficient to maintain the force-production qualities between sets when the Nordic hamstring exercise was performed using the NordBord. [161] On the other hand, players could have experienced a learning effect throughout the test and therefore performed better in the later sets. We also consider this unlikely as all players used the Nordic hamstring exercise as part of their weekly training routine and therefore were familiar with the exercise. Most female players had also been tested in the NordBord as part of annual pre-season testing previous seasons. That players were experienced with the exercise is substantiated by the high maximal eccentric force they displayed; the female players (mean: 335 N) were stronger than what has been reported from elite female athletes from different football codes (mean: 250-275 N), [162] and the male players' results (mean: 431 N) were comparable to results from men's Premier League and Champion's League football (400-425 N). [163] Using visual inspection to determine which players are able to control the forward falling motion during the final 20° motion is likely tester dependent. The intra- and interrater reliability of this categorisation has not been tested and may be low. It is, nonetheless, the approach that has been adopted by several previous studies to decide which players should train and be tested with added weight. [39-43, 99, 113] The analysis of players performing the test with up to 20 kg added weight should be interpreted with care because of low statistical power. Also, the number of multiple comparisons may have increased the risk of making a type I error.

Paper IV

In *Paper IV*, we were unable to perform familiarisation sessions before pre-testing, which are recommended to avoid results being affected by a potential learning effect. However, we had previously tested 21 female premier league players in the NordBord one week apart without familiarisation and found good test-retest reliability (95% limits of agreement: -8 N (-32 N; 17 N), intraclass correlation coefficient: 0.93 (0.80-0.97), standard error of the mean: 11 N (3%)). Furthermore, maximal eccentric torque measured in the isokinetic dynamometer, jump height and sprint speed did not change from pre- to post-testing. Therefore, we consider it unlikely that a learning effect to any of the tests have affected the results, but the lack of familiarisation may have contributed to a higher variability than optimal. The study was conducted during the Covid-19 pandemic, and one of the teams was put in quarantine for a week because of a positive Covid-19 test (no one else was infected). During that week, these players performed the Nordic hamstring programme on their own and we followed up their training via phone calls. As players were randomised within teams this should not cause any systematic error but may have reduced the adherence and quality of training during that week. A potential problem in randomised trials is contamination between groups, but we consider this unlikely. A researcher was present during the Nordic hamstring training sessions and observed that all players followed the assigned training volume. We distributed a questionnaire after the intervention, where one of the questions was if the players had performed more Nordic hamstring training than what they were assigned. No-one had. Because we lack a control group, we cannot discard the possibility that a learning effect to the NordBord test or adaptations related to the football training rather than the Nordic hamstring training caused the improvements in strength. However, as previously discussed, we consider it unlikely that a learning effect has occurred. Furthermore, amateur players tested 8 weeks apart did not change their eccentric hamstring force when training football only, [154] therefore we also consider it unlikely that the adaptations is related to football training. Despite being a limitation to our study, we decided against having a control group because we considered it unethical to deprive players of the opportunity to perform an exercise likely to halve their risk for sustaining a hamstring injury, and it was not necessary to answer our research question: if the high-volume programme was more effective than the low-volume programme. Because some players were lost to follow up, the number of players completing the intervention in the low-volume group was slightly below our sample size calculations. This reduces our statistical power.

Conclusions

I. The prevalence and incidence of health problems in Norwegian premier league of women's football was high, with sudden-onset injuries representing the most severe problem. Hamstring injury was most frequent injury type, while ACL injuries were the most severe.

II. In the Norwegian premier league of women's football, hamstring injuries primarily occurred during sprinting, with approximately half the injuries having a gradual onset. Injuries with MRI changes were most commonly located in the muscle-tendon junction of the m. biceps femoris and the proximal tendon of m. the semimembranosus.

III. Both players who could and could not control the final 20° of the NordBord test demonstrated higher maximal force when adding weight to testing. Therefore, this should not be used to decide if players should perform testing with or without weight. Either all participants or none should be tested with weight, and the same approach should be used both for pre- and post-testing.

IV. The evidence-based high-volume Nordic hamstring programme did not lead to greater adaptations in strength, jump height or speed compared to a low-volume programme. Players in both groups had to train for at least 6 weeks to improve maximal eccentric force significantly.

Future perspectives

One in five players having a substantial health problem at any given time, the high rate of muscle injuries and massive injury burden caused by ACL injuries and concussions cannot be tolerated. This calls for action. The rapid and encouraging developments taking place in women's football must be accompanied with increased medical and strength and conditioning support to ensure player well-being. Currently, we are far from having enough research to support the decision-making for coaching and medical staff in women's football. Injury risk factors and mechanisms need to be identified and understood, as these are not necessarily the same as in men's football. Preventative measures tailored to the needs of the modern female footballer must be developed, tested and constantly re-evaluated to follow the accelerated development of women's football.

In *Paper I*, we identified hamstring injuries as the most frequent injury and one of the most burdensome. Because many of the hamstring injuries had gradual onset, we recommend close monitoring of players to detect potential problems early and intervene before the injury becomes severe. Careful load management of players is also likely an important factor. Future studies should investigate risk factors for hamstring injuries in female football players and explore why the m. semimembranosus seems more susceptible to injury than in their male counterparts. We would argue that future preventative measures should be developed and tested and should aim to target both injuries to the muscle-tendon junction of the m. biceps femoris and to the proximal tendon of m. semimembranosus. As most hamstring injuries occurred during sprinting, and sprint-type hamstring injuries are believed to occur because the eccentric forces required exceed the tissue's capacity, we consider it likely that maximal eccentric hamstring strength is also an important risk factor for women, and that eccentric strengthening programmes are a likely effective preventative measure.

If using the NordBord to evaluate maximal eccentric hamstring strength in hamstring injury prevention research or in clinical practice, one should be aware of its potential issues. If players are able to control the forward falling movement of the Nordic hamstring exercise throughout the full range of motion it may not be able to measure the maximal force in the intended way. Adding weight to the test should be done with care, as it may affect the results of the test. With the extensive use of the NordBord to measure maximal eccentric hamstring strength nowadays, clear recommendations based on data should be published. We have highlighted some issues and given some recommendations in *Paper III* – but have not necessarily come up with the perfect method.

In *Paper IV*, we observed that the evidence-based high-volume Nordic hamstring programme was not more effective in improving maximal eccentric hamstring strength compared to a low-volume programme. This is potentially good news regarding implementation in football teams, where high training volumes can be a barrier for implementation. [46] The low-volume programme[40] is likely to fit well within the football context. The two initial weeks with two sessions per week with 4 sets of 6 repetitions can be performed early in the pre-season when there are no important matches. Performing one session per week with 2 sets of 4 repetitions can then be used for the latter parts of the pre-season and during the competitive season, which should even be possible alongside playing important matches. Consistency in performing the exercise over a longer period is probably more important than the exact number of sets and repetitions. Our results cannot say anything about the injury preventative effect, but if future studies aim to evaluate the effectiveness of the Nordic hamstring exercise in hamstring injury prevention, we encourage them to use a low-volume training programme based the results of Paper IV and others[40, 47] and the likely higher potential for real-world implementation.

When research in women's football now is growing, it is important to recognise that differences in findings from men's football are not necessarily only related to sex differences, such as biology or anatomy. Environmental and sociocultural factors should also be considered. [164] Despite the encouraging developments in women's football, major differences still exist between male and female players. In Norway, the men's premier league is fully professional, while most of the women's premier league players must combine their playing career with studying or working, leaving less time for training and recovery and possibly a higher risk for injuries. Furthermore, Norwegian elite clubs spend three times more money on talent development for boys compared to girls. [165] Training age and exposure have been suggested as factors contributing to different injury rates seen in men and women. [164] Additionally, low availability of medical care, strength and conditioning support and facilities[149] has been identified as barriers for injury prevention in women's football in Ireland. Providing the same support for women as for men is therefore essential. On this note, the #ReadyToPlay project has contributed to increased funding for medical support in Norwegian premier league teams. From 2023, Idrettens helsesenter contributes to financing one physiotherapist per team in the premier division. The OSTRC, Idrettens helsesenter, the Norwegian Football Association and Toppfotball Kvinner will continue their cooperation and the #ReadyToPlay project in the years to come. This, and a continued focus on research in women's football around the globe, will hopefully contribute to improve current players performance and well-being, and also contribute to the future development of women's football.

References

1. FIFA. FIFA Big Count 2006: 270 million people active in football. 2007. https://digitalhub.fifa.com/m/55621f9fdc8ea7b4/original/mzid0qmguixkcmruvema-pdf.pdf. Accessed July 6, 2023.
2. UEFA. Women's football across the national associations 2017. https://www.uefa.com/MultimediaFiles/Download/OfficialDocument/uefaorg/Women'sfootball/02/51/60/57/2516057_DOWNLOAD.pdf Accessed March 16, 2022.
3. Datson N, Hulton A, Andersson H, Lewis T, Weston M, Drust B, et al. Applied physiology of female soccer: an update. Sports Med. 2014;44(9):1225-40.
4. Bradley P, Scott D. Physical analysis of the FIFA Women's World Cup France 2019. https://digitalhub.fifa.com/m/4f40a98140d305e2/original/zijqly4oednqa5gffgaz-pdf.pdf Accessed March 16, 2022.
5. Drew MK, Finch CF. The Relationship Between Training Load and Injury, Illness and Soreness: A Systematic and Literature Review. Sports Med. 2016;46(6):861-83.
6. Gabbett TJ, Ullah S. Relationship between running loads and soft-tissue injury in elite team sport athletes. J Strength Cond Res. 2012;26(4):953-60.
7. Bengtsson H, Ekstrand J, Hägglund M. Muscle injury rates in professional football increase with fixture congestion: an 11-year follow-up of the UEFA Champions League injury study. Br J Sports Med. 2013;47(12):743-7.
8. Eirale C, Tol JL, Farooq A, Smiley F, Chalabi H. Low injury rate strongly correlates with team success in Qatari professional football. Br J Sports Med. 2013;47(12):807-8.
9. Hägglund M, Waldén M, Magnusson H, Kristenson K, Bengtsson H, Ekstrand J. Injuries affect team performance negatively in professional football: an 11-year follow-up of the UEFA Champions League injury study. Br J Sports Med. 2013;47(12):738-42.
10. Larruskain J, Lekue JA, Martin-Garetxana I, Barrio I, McCall A, Gil SM. Injuries are negatively associated with player progression in an elite football academy. Science and Medicine in Football. 2021:1-10.
11. Verrall GM, Kalairajah Y, Slavotinek JP, Spriggins AJ. Assessment of player performance following return to sport after hamstring muscle strain injury. J Sci Med Sport. 2006;9(1-2):87-90.
12. Whiteley R, Gregson W, Bahr R, Tabben M, Chamari K, Lolli L, et al. High-speed running during match-play before and after return from hamstring injury in professional footballers. Scand J Med Sci Sports. 2022.

13. Whiteley R, Massey A, Gabbett T, Blanch P, Cameron M, Conlan G, et al. Match High-Speed Running Distances Are Often Suppressed After Return From Hamstring Strain Injury in Professional Footballers. Sports Health. 2020:1941738120964456.
14. Drew MK, Raysmith BP, Charlton PC. Injuries impair the chance of successful performance by sportspeople: a systematic review. Br J Sports Med. 2017;51(16):1209-14.
15. van Mechelen W, Hlobil H, Kemper HC. Incidence, severity, aetiology and prevention of sports injuries. A review of concepts. Sports Med. 1992;14(2):82-99.
16. Bahr R, Clarsen B, Derman W, Dvorak J, Emery C, Finch CF, et al. International Olympic Committee consensus statement: Methods for recording and reporting of epidemiological data on injury and illness in sports 2020 (including STROBE Extension for Sport Injury and Illness Surveillance—STROBE-SIIS). Br J Sports Med. 2020.
17. Bahr R, Krosshaug T. Understanding injury mechanisms: a key component of preventing injuries in sport. Br J Sports Med. 2005;39(6):324-9.
18. Finch C. A new framework for research leading to sports injury prevention. J Sci Med Sport. 2006;9(1-2):3-9; discussion 10.
19. Costello JT, Bieuzen F, Bleakley CM. Where are all the female participants in Sports and Exercise Medicine research? Eur J Sport Sci. 2014;14(8):847-51.
20. Hägglund M, Waldén M, Ekstrand J. Injuries among male and female elite football players. Scand J Med Sci Sports. 2009;19(6):819-27.
21. Larruskain J, Lekue JA, Diaz N, Odriozola A, Gil SM. A comparison of injuries in elite male and female football players: A five-season prospective study. Scand J Med Sci Sports. 2018;28(1):237-45.
22. Okholm Kryger K, Wang A, Mehta R, Impellizzeri F, Massey A, Harrison M, et al. Can we evidence-base injury prevention and management in women's football? A scoping review. Res Sports Med. 2022:1-16.
23. Nassis GP, Brito J, Tomás R, Heiner-Møller K, Harder P, Kryger KO, et al. Elite women's football: Evolution and challenges for the years ahead. Scand J Med Sci Sports. 2021.
24. Clarsen B, Bahr R. Matching the choice of injury/illness definition to study setting, purpose and design: one size does not fit all! Br J Sports Med. 2014;48(7):510-2.
25. Clarsen B, Myklebust G, Bahr R. Development and validation of a new method for the registration of overuse injuries in sports injury epidemiology: the Oslo Sports Trauma Research Centre (OSTRC) overuse injury questionnaire. Br J Sports Med. 2013;47(8):495-502.

26. Ekstrand J, Hägglund M, Waldén M. Injury incidence and injury patterns in professional football: the UEFA injury study. Br J Sports Med. 2011;45(7):553-8.
27. Ekstrand J, Hägglund M, Waldén M. Epidemiology of muscle injuries in professional football (soccer). Am J Sports Med. 2011;39(6):1226-32.
28. Ekstrand J, Waldén M, Hägglund M. Hamstring injuries have increased by 4% annually in men's professional football, since 2001: a 13-year longitudinal analysis of the UEFA Elite Club injury study. Br J Sports Med. 2016;50(12):731-7.
29. Ekstrand J, Healy JC, Waldén M, Lee JC, English B, Hägglund M. Hamstring muscle injuries in professional football: the correlation of MRI findings with return to play. Br J Sports Med. 2012;46(2):112-7.
30. Woods C, Hawkins RD, Maltby S, Hulse M, Thomas A, Hodson A. The Football Association Medical Research Programme: an audit of injuries in professional football--analysis of hamstring injuries. Br J Sports Med. 2004;38(1):36-41.
31. Askling CM, Tengvar M, Thorstensson A. Acute hamstring injuries in Swedish elite football: a prospective randomised controlled clinical trial comparing two rehabilitation protocols. Br J Sports Med. 2013;47(15):953-9.
32. Green B, Bourne MN, van Dyk N, Pizzari T. Recalibrating the risk of hamstring strain injury (HSI) - A 2020 systematic review and meta-analysis of risk factors for index and recurrent HSI in sport. Br J Sports Med. 2020.
33. Opar DA, Williams MD, Shield AJ. Hamstring strain injuries: factors that lead to injury and re-injury. Sports Med. 2012;42(3):209-26.
34. Petersen J, Thorborg K, Nielsen MB, Budtz-Jørgensen E, Hölmich P. Preventive effect of eccentric training on acute hamstring injuries in men's soccer: a cluster-randomized controlled trial. Am J Sports Med. 2011;39(11):2296-303.
35. van der Horst N, Smits DW, Petersen J, Goedhart EA, Backx FJ. The preventive effect of the nordic hamstring exercise on hamstring injuries in amateur soccer players: a randomized controlled trial. Am J Sports Med. 2015;43(6):1316-23.
36. Arnason A, Andersen TE, Holme I, Engebretsen L, Bahr R. Prevention of hamstring strains in elite soccer: an intervention study. Scand J Med Sci Sports. 2008;18(1):40-8.
37. Askling C, Karlsson J, Thorstensson A. Hamstring injury occurrence in elite soccer players after preseason strength training with eccentric overload. Scand J Med Sci Sports. 2003;13(4):244-50.

38. Opar DA, Piatkowski T, Williams MD, Shield AJ. A novel device using the Nordic hamstring exercise to assess eccentric knee flexor strength: a reliability and retrospective injury study. J Orthop Sports Phys Ther. 2013;43(9):636-40.
39. Pollard CW, Opar DA, Williams MD, Bourne MN, Timmins RG. Razor hamstring curl and Nordic hamstring exercise architectural adaptations: Impact of exercise selection and intensity. Scand J Med Sci Sports. 2019;29(5):706-15.
40. Presland JD, Timmins RG, Bourne MN, Williams MD, Opar DA. The effect of Nordic hamstring exercise training volume on biceps femoris long head architectural adaptation. Scand J Med Sci Sports. 2018;28(7):1775-83.
41. Behan FP, Vermeulen R, Whiteley R, Timmins RG, Ruddy JD, Opar DA. The Dose-Response of the Nordic Hamstring Exercise on Biceps Femoris Architecture and Eccentric Knee Flexor Strength: A Randomized Interventional Trial. Int J Sports Physiol Perform. 2022;17(4):646-54.
42. Cadu JP, Goreau V, Lacourpaille L. A Very Low Volume of Nordic Hamstring Exercise Increases Maximal Eccentric Strength and Reduces Hamstring Injury Rate in Professional Soccer Players. J Sport Rehabil. 2022:1-6.
43. Timmins RG, Filopoulos D, Nguyen V, Giannakis J, Ruddy JD, Hickey JT, et al. Sprinting, Strength, and Architectural Adaptations Following Hamstring Training in Australian Footballers. Scand J Med Sci Sports. 2021;31(6):1276-89.
44. Bahr R, Thorborg K, Ekstrand J. Evidence-based hamstring injury prevention is not adopted by the majority of Champions League or Norwegian Premier League football teams: the Nordic Hamstring survey. Br J Sports Med. 2015;49(22):1466-71.
45. Chesterton P, Tears C, Wright M, Portas MD. Hamstring injury prevention practices and compliance of the Nordic hamstring program in English professional football. Translational Sports Medicine. 2021;4(2):214-22.
46. Fuller CW. Assessing the Return on Investment of Injury Prevention Procedures in Professional Football. Sports Med. 2019;49(4):621-9.
47. Cuthbert M, Ripley N, McMahon JJ, Evans M, Haff GG, Comfort P. The Effect of Nordic Hamstring Exercise Intervention Volume on Eccentric Strength and Muscle Architecture Adaptations: A Systematic Review and Meta-analyses. Sports Med. 2019.
48. Fuller CW, Ekstrand J, Junge A, Andersen TE, Bahr R, Dvorak J, et al. Consensus statement on injury definitions and data collection procedures in studies of football (soccer) injuries. Scand J Med Sci Sports. 2006;16(2):83-92.

49. Waldén M, Mountjoy M, McCall A, Serner A, Massey A, Tol JL, et al. Football-specific extension of the IOC consensus statement: methods for recording and reporting of epidemiological data on injury and illness in sport 2020. Br J Sports Med. 2023.
50. Orchard JW, Meeuwisse W, Derman W, Hägglund M, Soligard T, Schwellnus M, et al. Sport Medicine Diagnostic Coding System (SMDCS) and the Orchard Sports Injury and Illness Classification System (OSIICS): revised 2020 consensus versions. Br J Sports Med. 2020;54(7):397-401.
51. Tabben M, Whiteley R, Wik EH, Bahr R, Chamari K. Methods may matter in injury surveillance: "how" may be more important than "what, when or why". Biol Sport. 2020;37(1):3-5.
52. Wik EH, Materne O, Chamari K, Duque JDP, Horobeanu C, Salcinovic B, et al. Involving research-invested clinicians in data collection affects injury incidence in youth football. Scand J Med Sci Sports. 2019;29(7):1031-9.
53. Knowles SB, Marshall SW, Guskiewicz KM. Issues in estimating risks and rates in sports injury research. J Athl Train. 2006;41(2):207-15.
54. Fuller CW. Injury Risk (Burden), Risk Matrices and Risk Contours in Team Sports: A Review of Principles, Practices and Problems. Sports Med. 2018;48(7):1597-606.
55. Bahr R, Clarsen B, Ekstrand J. Why we should focus on the burden of injuries and illnesses, not just their incidence. Br J Sports Med. 2018;52(16):1018-21.
56. Clarsen B, Bahr R, Myklebust G, Andersson SH, Docking SI, Drew M, et al. Improved reporting of overuse injuries and health problems in sport: an update of the Oslo Sport Trauma Research Center questionnaires. Br J Sports Med. 2020;54(7):390-6.
57. Clarsen B, Rønsen O, Myklebust G, Flørenes TW, Bahr R. The Oslo Sports Trauma Research Center questionnaire on health problems: a new approach to prospective monitoring of illness and injury in elite athletes. Br J Sports Med. 2014;48(9):754-60.
58. Blokland D, Thijs KM, Backx FJ, Goedhart EA, Huisstede BM. No Effect of Generalized Joint Hypermobility on Injury Risk in Elite Female Soccer Players: A Prospective Cohort Study. Am J Sports Med. 2017;45(2):286-93.
59. Faude O, Junge A, Kindermann W, Dvorak J. Injuries in female soccer players: a prospective study in the German national league. Am J Sports Med. 2005;33(11):1694-700.
60. Gaulrapp H, Becker A, Walther M, Hess H. Injuries in women's soccer: a 1-year all players prospective field study of the women's Bundesliga (German premier league). Clin J Sport Med. 2010;20(4):264-71.

61. Giza E, Mithofer K, Farrell L, Zarins B, Gill T. Injuries in women's professional soccer. Br J Sports Med. 2005;39(4):212-6; discussion -6.

62. Horan D, Blake C, Hägglund M, Kelly S, Roe M, Delahunt E. Injuries in elite-level women's football-a two-year prospective study in the Irish Women's National League. Scand J Med Sci Sports. 2021.

63. Jacobson I, Tegner Y. Injuries among Swedish female elite football players: a prospective population study. Scand J Med Sci Sports. 2007;17(1):84-91.

64. Nilstad A, Andersen TE, Bahr R, Holme I, Steffen K. Risk factors for lower extremity injuries in elite female soccer players. Am J Sports Med. 2014;42(4):940-8.

65. Tegnander A, Olsen OE, Moholdt TT, Engebretsen L, Bahr R. Injuries in Norwegian female elite soccer: a prospective one-season cohort study. Knee Surg Sports Traumatol Arthrosc. 2008;16(2):194-8.

66. Meeuwisse WH. Assessing Causation in Sport Injury: A Multifactorial Model. Clinical Journal of Sport Medicine. 1994;4(3):166-70.

67. Meeuwisse WH, Tyreman H, Hagel B, Emery C. A dynamic model of etiology in sport injury: the recursive nature of risk and causation. Clin J Sport Med. 2007;17(3):215-9.

68. Windt J, Gabbett TJ. How do training and competition workloads relate to injury? The workload-injury aetiology model. Br J Sports Med. 2017;51(5):428-35.

69. Bahr R. Why screening tests to predict injury do not work-and probably never will...: a critical review. Br J Sports Med. 2016;50(13):776-80.

70. Bahr R, Holme I. Risk factors for sports injuries--a methodological approach. Br J Sports Med. 2003;37(5):384-92.

71. Ekstrand J, Bengtsson H, Waldén M, Davison M, Khan KM, Hägglund M. Hamstring injury rates have increased during recent seasons and now constitute 24% of all injuries in men's professional football: the UEFA Elite Club Injury Study from 2001/02 to 2021/22. Br J Sports Med. 2022;57(5):292-8.

72. Barnes C, Archer DT, Hogg B, Bush M, Bradley PS. The evolution of physical and technical performance parameters in the English Premier League. Int J Sports Med. 2014;35(13):1095-100.

73. Mullins K, Mac Colgáin D, Carton P. Incidence and severity of hamstring injuries in female athletes who play field sports: A systematic review with meta-analysis of prospective studies. J Orthop Sports Phys Ther. 2022:1-31.

74. Gilroy AM, MacPherson BR, Ross LM, Schünke M. Atlas of anatomy : [latin nomenclature]. Stuttgart: Thieme; 2009.

75. Gray H. Anatomy of the Human Body. 20th ed. 1918. https://www.bartleby.com/lit-hub/anatomy-of-the-human-body/. Accessed July 6, 2023.

76. Häggström M. Medical gallery of Mikael Häggström 2014. WikiJournal of Medicine 2014;1(2) DOI: 1015347/wjm/2014008 ISSN 2002-4436 Public Domain. 2014.

77. Askling C, Saartok T, Thorstensson A. Type of acute hamstring strain affects flexibility, strength, and time to return to pre-injury level. Br J Sports Med. 2006;40(1):40-4.

78. Askling CM, Malliaropoulos N, Karlsson J. High-speed running type or stretching-type of hamstring injuries makes a difference to treatment and prognosis. Br J Sports Med. 2012;46(2):86-7.

79. Ekstrand J, Lee JC, Healy JC. MRI findings and return to play in football: a prospective analysis of 255 hamstring injuries in the UEFA Elite Club Injury Study. Br J Sports Med. 2016;50(12):738-43.

80. Casamichana D, Castellano J, Castagna C. Comparing the physical demands of friendly matches and small-sided games in semiprofessional soccer players. J Strength Cond Res. 2012;26(3):837-43.

81. Dalton SL, Kerr ZY, Dompier TP. Epidemiology of Hamstring Strains in 25 NCAA Sports in the 2009-2010 to 2013-2014 Academic Years. Am J Sports Med. 2015;43(11):2671-9.

82. Kraemer R, Knobloch K. A soccer-specific balance training program for hamstring muscle and patellar and achilles tendon injuries: an intervention study in premier league female soccer. Am J Sports Med. 2009;37(7):1384-93.

83. Danielsson A, Horvath A, Senorski C, Alentorn-Geli E, Garrett WE, Cugat R, et al. The mechanism of hamstring injuries - a systematic review. BMC Musculoskelet Disord. 2020;21(1):641.

84. Kenneally-Dabrowski CJB, Brown NAT, Lai AKM, Perriman D, Spratford W, Serpell BG. Late swing or early stance? A narrative review of hamstring injury mechanisms during high-speed running. Scand J Med Sci Sports. 2019;29(8):1083-91.

85. Thelen DG, Chumanov ES, Hoerth DM, Best TM, Swanson SC, Li L, et al. Hamstring muscle kinematics during treadmill sprinting. Med Sci Sports Exerc. 2005;37(1):108-14.

86. Chumanov ES, Heiderscheit BC, Thelen DG. The effect of speed and influence of individual muscles on hamstring mechanics during the swing phase of sprinting. J Biomech. 2007;40(16):3555-62.

87. Schache AG, Wrigley TV, Baker R, Pandy MG. Biomechanical response to hamstring muscle strain injury. Gait Posture. 2009;29(2):332-8.

88. Heiderscheit BC, Hoerth DM, Chumanov ES, Swanson SC, Thelen BJ, Thelen DG. Identifying the time of occurrence of a hamstring strain injury during treadmill running: a case study. Clin Biomech (Bristol, Avon). 2005;20(10):1072-8.
89. Freckleton G, Pizzari T. Risk factors for hamstring muscle strain injury in sport: a systematic review and meta-analysis. Br J Sports Med. 2013;47(6):351-8.
90. Arnason A, Sigurdsson SB, Gudmundsson A, Holme I, Engebretsen L, Bahr R. Risk factors for injuries in football. Am J Sports Med. 2004;32(1 Suppl):5s-16s.
91. Prodromos CC, Han Y, Rogowski J, Joyce B, Shi K. A meta-analysis of the incidence of anterior cruciate ligament tears as a function of gender, sport, and a knee injury-reduction regimen. Arthroscopy. 2007;23(12):1320-5.e6.
92. Waldén M, Hägglund M, Magnusson H, Ekstrand J. Anterior cruciate ligament injury in elite football: a prospective three-cohort study. Knee Surg Sports Traumatol Arthrosc. 2011;19(1):11-9.
93. Lievens E, Van Vossel K, Van de Casteele F, Wezenbeek E, Deprez D, Matthys S, et al. Muscle Fibre Typology as a Novel Risk Factor for Hamstring Strain Injuries in Professional Football (Soccer): A Prospective Cohort Study. Sports Med. 2022;52(1):177-85.
94. Green B, Bourne MN, Pizzari T. Isokinetic strength assessment offers limited predictive validity for detecting risk of future hamstring strain in sport: a systematic review and meta-analysis. Br J Sports Med. 2018;52(5):329-36.
95. Opar DA, Williams MD, Timmins RG, Hickey J, Duhig SJ, Shield AJ. Eccentric hamstring strength and hamstring injury risk in Australian footballers. Med Sci Sports Exerc. 2015;47(4):857-65.
96. van Dyk N, Bahr R, Burnett AF, Whiteley R, Bakken A, Mosler A, et al. A comprehensive strength testing protocol offers no clinical value in predicting risk of hamstring injury: a prospective cohort study of 413 professional football players. Br J Sports Med. 2017;51(23):1695-702.
97. van Dyk N, Bahr R, Whiteley R, Tol JL, Kumar BD, Hamilton B, et al. Hamstring and Quadriceps Isokinetic Strength Deficits Are Weak Risk Factors for Hamstring Strain Injuries: A 4-Year Cohort Study. Am J Sports Med. 2016;44(7):1789-95.
98. Mjølsnes R, Arnason A, Østhagen T, Raastad T, Bahr R. A 10-week randomized trial comparing eccentric vs. concentric hamstring strength training in well-trained soccer players. Scand J Med Sci Sports. 2004;14(5):311-7.

99. Bourne MN, Duhig SJ, Timmins RG, Williams MD, Opar DA, Al Najjar A, et al. Impact of the Nordic hamstring and hip extension exercises on hamstring architecture and morphology: implications for injury prevention. Br J Sports Med. 2017;51(5):469-77.

100. Timmins RG, Bourne MN, Shield AJ, Williams MD, Lorenzen C, Opar DA. Short biceps femoris fascicles and eccentric knee flexor weakness increase the risk of hamstring injury in elite football (soccer): a prospective cohort study. Br J Sports Med. 2016;50(24):1524-35.

101. Duhig S, Shield AJ, Opar D, Gabbett TJ, Ferguson C, Williams M. Effect of high-speed running on hamstring strain injury risk. Br J Sports Med. 2016;50(24):1536-40.

102. Ruddy JD, Pollard CW, Timmins RG, Williams MD, Shield AJ, Opar DA. Running exposure is associated with the risk of hamstring strain injury in elite Australian footballers. Br J Sports Med. 2018;52(14):919-28.

103. Schuermans J, Van Tiggelen D, Palmans T, Danneels L, Witvrouw E. Deviating running kinematics and hamstring injury susceptibility in male soccer players: Cause or consequence? Gait Posture. 2017;57:270-7.

104. Mair SD, Seaber AV, Glisson RR, Garrett WE, Jr. The role of fatigue in susceptibility to acute muscle strain injury. Am J Sports Med. 1996;24(2):137-43.

105. O'Sullivan L, Tanaka MJ. Sex-based Differences in Hamstring Injury Risk Factors. J Women's Sport Med. 2021;1(1):20-9.

106. Ekstrand J, Hallén A, Marin V, Gauffin H. Most modifiable risk factors for hamstring muscle injury in women's elite football are extrinsic and associated with the club, the team, and the coaching staff and not the players themselves: the UEFA Women's Elite Club Injury Study. Knee Surg Sports Traumatol Arthrosc. 2023.

107. Espinosa GA, Pöyhönen T, Aramendi JF, Samaniego JC, Knörr JIE, Kyröläinen H. Effects of an eccentric training programme on hamstring strain injuries in women football players. Biomedical Human Kinetics. 2015;7(1).

108. Wiesinger HP, Gressenbauer C, Kösters A, Scharinger M, Müller E. Device and method matter: A critical evaluation of eccentric hamstring muscle strength assessments. Scand J Med Sci Sports. 2020;30(2):217-26.

109. Whiteley R, Jacobsen P, Prior S, Skazalski C, Otten R, Johnson A. Correlation of isokinetic and novel hand-held dynamometry measures of knee flexion and extension strength testing. J Sci Med Sport. 2012;15(5):444-50.

110. Claudino JG, Cardoso Filho CA, Bittencourt NFN, Gonçalves LG, Couto CR, Quintão RC, et al. Eccentric Strength Assessment of Hamstring Muscles with New Technologies:

a Systematic Review of Current Methods and Clinical Implications. Sports Med Open. 2021;7(1):10.

111. van Dyk N, Witvrouw E, Bahr R. Interseason variability in isokinetic strength and poor correlation with Nordic hamstring eccentric strength in football players. Scand J Med Sci Sports. 2018;28(8):1878-87.

112. Wiesinger HP, Scharinger M, Kösters A, Gressenbauer C, Müller E. Specificity of eccentric hamstring training and the lack of consistency between strength assessments using conventional test devices. Sci Rep. 2021;11(1):13417.

113. Duhig SJ, Bourne MN, Buhmann RL, Williams MD, Minett GM, Roberts LA, et al. Effect of concentric and eccentric hamstring training on sprint recovery, strength and muscle architecture in inexperienced athletes. J Sci Med Sport. 2019;22(7):769-74.

114. Buchheit M, Cholley Y, Nagel M, Poulos N. The Effect of Body Mass on Eccentric Knee-Flexor Strength Assessed With an Instrumented Nordic Hamstring Device (Nordbord) in Football Players. Int J Sports Physiol Perform. 2016;11(6):721-6.

115. Goode AP, Reiman MP, Harris L, DeLisa L, Kauffman A, Beltramo D, et al. Eccentric training for prevention of hamstring injuries may depend on intervention compliance: a systematic review and meta-analysis. Br J Sports Med. 2015;49(6):349-56.

116. O'Brien J, Donaldson A, Finch CF. It will take more than an existing exercise programme to prevent injury. Br J Sports Med. 2016;50(5):264-5.

117. van der Horst N, Hoef SV, Otterloo PV, Klein M, Brink M, Backx F. Effective But Not Adhered to: How Can We Improve Adherence to Evidence-Based Hamstring Injury Prevention in Amateur Football? Clin J Sport Med. 2018.

118. Chesterton P, Draper G, Portas M, Tears C. The Uptake of Nordic Hamstring Exercise Program for Injury Prevention in Major League Soccer and Its Barriers to Implementation in Practice. J Sport Rehabil. 2022:1-6.

119. McCall A, Dupont G, Ekstrand J. Injury prevention strategies, coach compliance and player adherence of 33 of the UEFA Elite Club Injury Study teams: a survey of teams' head medical officers. Br J Sports Med. 2016;50(12):725-30.

120. Hotfiel T, Freiwald J, Hoppe MW, Lutter C, Forst R, Grim C, et al. Advances in Delayed-Onset Muscle Soreness (DOMS): Part I: Pathogenesis and Diagnostics. Sportverletz Sportschaden. 2018;32(4):243-50.

121. McHugh MP. Recent advances in the understanding of the repeated bout effect: the protective effect against muscle damage from a single bout of eccentric exercise. Scand J Med Sci Sports. 2003;13(2):88-97.

122. Behan FP, Opar DA, Vermeulen R, Timmins RG, Whiteley R. The dose-response of pain throughout a Nordic hamstring exercise intervention. Scand J Med Sci Sports. 2023;33(4):542-6.

123. Ekstrand J, Hägglund M, Kristenson K, Magnusson H, Waldén M. Fewer ligament injuries but no preventive effect on muscle injuries and severe injuries: an 11-year follow-up of the UEFA Champions League injury study. Br J Sports Med. 2013;47(12):732-7.

124. Alentorn-Geli E, Myer GD, Silvers HJ, Samitier G, Romero D, Lazaro-Haro C, et al. Prevention of non-contact anterior cruciate ligament injuries in soccer players. Part 2: a review of prevention programs aimed to modify risk factors and to reduce injury rates. Knee Surg Sports Traumatol Arthrosc. 2009;17(8):859-79.

125. Finch CF, White P, Twomey D, Ullah S. Implementing an exercise-training programme to prevent lower-limb injuries: considerations for the development of a randomised controlled trial intervention delivery plan. Br J Sports Med. 2011;45(10):791-6.

126. Freeman BW, Young WB, Talpey SW, Smyth AM, Pane CL, Carlon TA. The effects of sprint training and the Nordic hamstring exercise on eccentric hamstring strength and sprint performance in adolescent athletes. J Sports Med Phys Fitness. 2019;59(7):1119-25.

127. Clark R, Bryant A, Culgan JP, Hartley B. The effects of eccentric hamstring strength training on dynamic jumping performance and isokinetic strength parameters: a pilot study on the implications for the prevention of hamstring injuries. Physical Therapy in Sport. 2005;6(2):67-73.

128. Ishøi L, Hölmich P, Aagaard P, Thorborg K, Bandholm T, Serner A. Effects of the Nordic Hamstring exercise on sprint capacity in male football players: a randomized controlled trial. J Sports Sci. 2018;36(14):1663-72.

129. Krommes K, Petersen J, Nielsen MB, Aagaard P, Hölmich P, Thorborg K. Sprint and jump performance in elite male soccer players following a 10-week Nordic Hamstring exercise Protocol: a randomised pilot study. BMC Res Notes. 2017;10(1):669.

130. Ekstrand J, Bengtsson H, Walden M, Davison M, Hagglund M. Still poorly adopted in male professional football: but teams that used the Nordic Hamstring Exercise in team training had fewer hamstring injuries - a retrospective survey of 17 teams of the UEFA Elite Club Injury Study during the 2020-2021 season. BMJ Open Sport Exerc Med. 2022;8(3):e001368.

131. O'Brien J, Finch CF. Injury Prevention Exercise Programs for Professional Soccer: Understanding the Perceptions of the End-Users. Clin J Sport Med. 2017;27(1):1-9.

132. O'Brien J, Young W, Finch CF. The use and modification of injury prevention exercises by professional youth soccer teams. Scand J Med Sci Sports. 2017;27(11):1337-46.
133. Ralston GW, Kilgore L, Wyatt FB, Baker JS. The Effect of Weekly Set Volume on Strength Gain: A Meta-Analysis. Sports Med. 2017;47(12):2585-601.
134. Suchomel TJ, Nimphius S, Bellon CR, Stone MH. The Importance of Muscular Strength: Training Considerations. Sports Med. 2018;48(4):765-85.
135. Wilson JM, Marin PJ, Rhea MR, Wilson SM, Loenneke JP, Anderson JC. Concurrent training: a meta-analysis examining interference of aerobic and resistance exercises. J Strength Cond Res. 2012;26(8):2293-307.
136. Roberts BM, Nuckols G, Krieger JW. Sex Differences in Resistance Training: A Systematic Review and Meta-Analysis. J Strength Cond Res. 2020;34(5):1448-60.
137. UEFA. Women's Association Club Coefficients [Available from: https://www.uefa.com/nationalassociations/uefarankings/womenscountry/#/yr/2021.
138. Whiteley R, van Dyk N, Wangensteen A, Hansen C. Clinical implications from daily physiotherapy examination of 131 acute hamstring injuries and their association with running speed and rehabilitation progression. Br J Sports Med. 2018;52(5):303-10.
139. Askling CM, Tengvar M, Saartok T, Thorstensson A. Acute first-time hamstring strains during high-speed running: a longitudinal study including clinical and magnetic resonance imaging findings. Am J Sports Med. 2007;35(2):197-206.
140. Kerkhoffs GM, van Es N, Wieldraaijer T, Sierevelt IN, Ekstrand J, van Dijk CN. Diagnosis and prognosis of acute hamstring injuries in athletes. Knee Surg Sports Traumatol Arthrosc. 2013;21(2):500-9.
141. Comin J, Malliaras P, Baquie P, Barbour T, Connell D. Return to competitive play after hamstring injuries involving disruption of the central tendon. Am J Sports Med. 2013;41(1):111-5.
142. Pollock N, James SL, Lee JC, Chakraverty R. British athletics muscle injury classification: a new grading system. Br J Sports Med. 2014;48(18):1347-51.
143. Wangensteen A, Bahr R, Van Linschoten R, Almusa E, Whiteley R, Witvrouw E, et al. MRI appearance does not change in the first 7 days after acute hamstring injury-a prospective study. Br J Sports Med. 2017;51(14):1087-92.
144. Wangensteen A, Tol JL, Roemer FW, Bahr R, Dijkstra HP, Crema MD, et al. Intra- and interrater reliability of three different MRI grading and classification systems after acute hamstring injuries. Eur J Radiol. 2017;89:182-90.
145. Peetrons P. Ultrasound of muscles. Eur Radiol. 2002;12(1):35-43.

146. Fuller CW. Why Median Severity and Ordinal Scale Severity Values should not be used for Injury Burden Results: A Critical Review. Int J Sports Med. 2023.

147. MedCalc Software Ltd. Comparison of two rates [Available from: https://www.medcalc.org/calc/rate_comparison.php]

148. Moseid CH, Myklebust G, Fagerland MW, Clarsen B, Bahr R. The prevalence and severity of health problems in youth elite sports: A 6-month prospective cohort study of 320 athletes. Scand J Med Sci Sports. 2018;28(4):1412-23.

149. Horan D. Game changer! Injury surveillance in elite-level women's football in Ireland: thinking bigger and working together: University College Dublin; 2022.

150. Wangensteen A, Almusa E, Boukarroum S, Farooq A, Hamilton B, Whiteley R, et al. MRI does not add value over and above patient history and clinical examination in predicting time to return to sport after acute hamstring injuries: a prospective cohort of 180 male athletes. Br J Sports Med. 2015;49(24):1579-87.

151. Jakobsen JR, Krogsgaard MR. The Myotendinous Junction-A Vulnerable Companion in Sports. A Narrative Review. Front Physiol. 2021;12:635561.

152. Lacome M, Avrillon S, Cholley Y, Simpson BM, Guilhem G, Buchheit M. Hamstring Eccentric Strengthening Program: Does Training Volume Matter? Int J Sports Physiol Perform. 2019:1-27.

153. Ekstrand J, Hallén A, Gauffin H, Bengtsson H. Low adoption in women's professional football: teams that used the Nordic Hamstring Exercise in the team training had fewer match hamstring injuries. BMJ Open Sport Exerc Med. 2023;9(2):e001523.

154. Vianna KB, Rodrigues LG, Oliveira NT, Ribeiro-Alvares JB, Baroni BM. A Preseason Training Program With the Nordic Hamstring Exercise Increases Eccentric Knee Flexor Strength and Fascicle Length in Professional Female Soccer Players. Int J Sports Phys Ther. 2021;16(2):459-67.

155. Chaabene H, Negra Y, Moran J, Prieske O, Sammoud S, Ramirez-Campillo R, et al. Effects of an Eccentric Hamstrings Training on Components of Physical Performance in Young Female Handball Players. Int J Sports Physiol Perform. 2019:1-22.

156. Bengtsson H, Ortega Gallo PA, Ekstrand J. Injury epidemiology in professional football in South America compared with Europe. BMJ Open Sport Exerc Med. 2021;7(4):e001172.

157. Waldén M, Hägglund M, Orchard J, Kristenson K, Ekstrand J. Regional differences in injury incidence in European professional football. Scand J Med Sci Sports. 2013;23(4):424-30.

158. Nilstad A, Bahr R, Andersen TE. Text messaging as a new method for injury registration in sports: a methodological study in elite female football. Scand J Med Sci Sports. 2014;24(1):243-9.

159. Clarsen B, Bahr R, Heymans MW, Engedahl M, Midtsundstad G, Rosenlund L, et al. The prevalence and impact of overuse injuries in five Norwegian sports: Application of a new surveillance method. Scand J Med Sci Sports. 2015;25(3):323-30.

160. Harøy J, Clarsen B, Thorborg K, Hölmich P, Bahr R, Andersen TE. Groin Problems in Male Soccer Players Are More Common Than Previously Reported. Am J Sports Med. 2017;45(6):1304-8.

161. Drury B, Peacock D, Moran J, Cone C, Campillo RR. Different Interset Rest Intervals During the Nordic Hamstrings Exercise in Young Male Athletes. J Athl Train. 2021;56(9):952-9.

162. VALDPerformance. Female Professional Athletes: Nordic and Hip Ad/Ab Results. https://valdperformance.com/female-professional-athletes-nordic-and-hip-ad-ab-results/; 2021.

163. VALDPerformance. European Football Report Season 2019-20: Nordic Strength. https://valdperformance.com/nordic-strength/; 2020.

164. Fox A, Bonacci J, Hoffmann S, Nimphius S, Saunders N. Anterior cruciate ligament injuries in Australian football: should women and girls be playing? You're asking the wrong question. BMJ Open Sport Exerc Med. 2020;6(1):e000778.

165. Lie S, Rognerud A. Isak (15) får tre ganger så mye støtte av norsk fotball som Helle (15). NRK. 2022. https://www.nrk.no/sport/xl/isak-_15_-far-tre-ganger-sa-mye-stotte-av-norsk-fotball-som-helle-_15_-1.15979680. Accessed July 6, 2023.

Paper I-IV

Paper I

#ReadyToPlay: Health problems in women's football – a two-season prospective cohort study in the Norwegian premier league

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Abstract

Objectives: To describe the prevalence, incidence, and burden of all health problems in the Norwegian women's premier league.

Methods: During the 2020 and 2021 seasons, players in the Norwegian women's premier league reported all health problems (sudden onset injuries, gradual onset injuries and illnesses) weekly, using the Oslo Sports Trauma Research Centre Questionnaire on Health Problems. Team medical staff diagnosed reported problems using the Sport Medicine Diagnostic Coding System. We calculated average weekly prevalence, incidence and burden of all health problems reported.

Results: We included 294 players (age: 22±4 yrs) from 11 teams. Response rate to the weekly questionnaire was 79%. On average, 32% (95% CI: 31% to 33%) of the players reported at least one health problem at any time and 22% (95% CI: 21% to 23%) reported a substantial health problem negatively affecting their training volume or performance. The overall incidence was 10.7 health problems per 1000 h of football exposure. Sudden onset injuries were most severe (68% of the total time loss), followed by overuse injuries (25%) and illnesses (8%). Thigh was the most common injury location (26%), while knee injuries were most severe, causing 42% of the total injury time loss. ACL injuries alone caused 30% of the total injury time loss.

Conclusion: One in five players had a health problem negatively affecting their training volume or performance at any time. Sudden onset injuries represented the most burdensome health problem. Thigh injuries were most frequent while knee injuries, ACL injuries especially, were most severe.

What is already known on this topic:

- Gradual-onset injuries and illnesses is common in other sports but have not been studied with appropriate methods in women's football.
- Knee and ankle injuries have been the most common injury in women's football, and ACL injuries and concussions have received much attention. However, women's football is developing rapidly, and it is questionable how accurate previous literature reflects the current injury pattern.

What this study adds:

- This is the first study to record all health problems in women's football.
- Gradual-onset injuries were more common than previously reported, but sudden-onset injuries still caused the highest burden. Illnesses caused a minor burden.
- The most frequent diagnoses were all muscle injuries to the thigh, suggesting that the injury pattern might be changing. However, ACL injuries and concussion still represented major problems.

How this study might affect research, practice or policy:

- Recording time-loss injuries resulted in a similar injury pattern as recording all health problems and gives a reliable picture of the overall injury pattern in women's football.
- ACL injuries, concussions and thigh muscle injuries should be targeted areas for injury prevention in women's football. Future research should aim to study risk factors and injury mechanisms, and to develop preventative measures tailored to the needs of modern female football players.

Introduction

Women's football is on the rise. The interest, available resources provided and number of professional players has increased rapidly in the last decade [1]. The physical demands of the game have soared [2] and may have changed the injury risk, as well.

Most previous injury surveillance studies in top level women's football have reported knee and ankle as the most commonly injured locations and ligament injury as the most frequently affected tissue type [3-11]. Nearly all these studies, however, were conducted more than a decade ago. With the significant developments of women's football, it is questionable how accurate this literature reflects the current injury pattern [12]. Furthermore, all previous epidemiological studies on women's football have used a time-loss definition of injury, which likely has underestimated the number of overuse injuries, [13 14] as players often continue to train and play matches despite their symptoms.

Recording all health problems regardless of time-loss or medical attention has therefore been recommended [15], and the Oslo Sports Trauma Research Centre questionnaire on health problems (OSTRC-H) was developed, and later updated, to incorporate this broader definition [16-18]. When compared to traditional injury registration using a time-loss definition only, the OSTRC-H identified ten times more overuse injuries in elite athletes from various sports [17] and three times more groin problems in adult football players [19]. Despite comprising a substantial part of the health problems in other cohorts [18 20], illnesses have not been addressed in previous epidemiological studies in women's football.

To develop effective preventive measures tailored to the needs of modern female football players, we need reliable, up-to-date surveillance data [15 21]. Therefore, we aimed to describe the prevalence, incidence, and burden of all health problems in the Norwegian women's premier league.

Methods

Study design and participants

We conducted a two-season prospective cohort study in Toppserien, the Norwegian premier league of women's football (UEFA club coefficients ranking: 12th) [22], in the competitive season of 2020 and the pre- and competitive season of 2021. Before the start of the 2020 season, players and physiotherapists from the 10 teams in the league were invited to participate. In the 2021 season, we added the one promoted team and continued monitoring the one relegated team. New players who signed a contract during or between the two seasons were invited to take part in the project, and players who left the league were followed until they transferred outside the Norwegian premier league or retired. To be included in the study, players had to be part of the first team squad, have a signed contract, be at least 16 years old, and give their individual written informed consent to participate. The Norwegian Centre for Research Data (#662612) and the Norwegian School of Sports Sciences Ethics Board (#129-051219) approved the study.

Definitions

We defined a health problem as any condition that reduced a player's normal state of complete health, irrespective of its consequences on football participation or performance or whether she sought medical attention [15 23]. Health problems were divided into injuries or illnesses. An injury was defined as a tissue damage or other derangements of normal physical function [15 23], with sudden onset injuries caused by a single, clearly identifiable energy transfer, and gradual onset injuries by multiple accumulative bouts of energy transfer without a single, clearly identifiable event responsible for the injury [15 23]. Illness was defined as a complaint or disorder experienced by a player, not related to an injury [15 23]. Training exposure was recorded as hours of football-specific training [23] defined as all sessions involving the techniques and/or tactics of football [15 23]. Match was defined as organised scheduled play against an opposing team (including official matches, friendlies and junior/reserve team matches, but not internal training matches) [15 23].

Recording health problems and exposure

Players answered the updated version of the Oslo Sports Trauma Research Center questionnaire on health problems (OSTRC-H2) [16] weekly through a mobile app (AthleteMonitoring, Fitstats Inc., New Brunswick, Canada) for a total of 63 weeks (23 weeks from July to December 2020, 40 weeks from February to November 2021, separated by a 9 week recording break between seasons). We asked the players to respond to the following questions: 1) if the players had any health problems (regardless of time-loss) during the previous week, and if so, 2) how it had affected their training volume and 3) performance, and 4) to what extent they had experienced symptoms. Based on the answers from these four questions, we calculated a severity score between 0-100 for each health problem [16]. When players reported a new health problem, they also recorded the incident type (sudden onset injury, gradual onset injury or illness). For injuries, they recorded: body area, type of activity (match-play/football training/other training) and the injury mechanism (e.g. sprinting, tackled). For illnesses, they recorded which specific and general symptoms they had experienced. Players also recorded the date of the first symptom(s) and how many days of time loss the health problem had caused during the previous week. Health problems were classified as substantial if they lead to moderate or severe reductions in training volume or football performance [17], and as time-loss health problems if they caused absence from football training or match play. If players had several health problems in the same week, these steps were repeated for each problem, starting with the most severe. If players recorded the same problem multiple weeks, they had the option to choose the previously reported problem from a drop-down list and, hence, only had to report the number of days lost. Players also recorded hours of football-specific training and match exposure in their weekly report.

Before project start, the physiotherapists were educated on how to use the AthleteMonitoring software. Every Sunday, automatic SMS-reminders were sent to the players to complete the questionnaire. If a player did not respond, automatic reminders were sent daily until the questionnaire was completed. After 3 days, we (RA or ST) sent an SMS reminder to non-responders. We also asked team physiotherapists to encourage players to respond to the questionnaire.

The team physiotherapists (1 to 3 per team) in each team had access to their players' health reports. After examining the players, physiotherapists diagnosed the reported health problems using the Sports Medicine Diagnostic Coding System (SMDCS) [24] and, when appropriate, they had the opportunity to reassign the onset and location of the injury reported by the players. If players were followed-up by physiotherapists outside the team, we (RA or ST) contacted the physiotherapist to record the diagnosis, which then was registered into the application.

Data handling

The severity of a health problem was reported as 1) the total number of days lost and 2) the cumulative severity score [18] for that problem. The severity was calculated from resolved health problems only. Health problems not resolved were assigned the median time loss of resolved problems with a similar diagnosis. None of the ACL injuries reported were fully resolved before the study ended. Therefore, we estimated their time loss and severity score based on data from four players who had sustained ACL injuries prior to inclusion and returned to play during the study period. For players reporting injuries causing 7 days lost in the last week of recording in 2020 and in the first week of recording in 2021, we imputed time-loss (7 days per week) and severity score (100 per week) during the 9-week recording break between seasons. For incidents that involved multiple injuries, the severity of the primary injury was reported [15]. After the data collection, injuries were reclassified to match the revised 2020 consensus version of the SMDCS [24]. SMDCS codes that described similar injuries (e.g. muscle spasm, strain and tear in the same muscle or 1°, 2° and 3° sprains in the same ligament) were combined and reported as follows: quadriceps, hamstring, adductor, gastrocnemius and soleus muscle injuries, anterior cruciate ligament injuries, deltoid ligament sprains, lateral ankle ligament sprains, and tibiofibular ligament syndesmosis injuries.

Statistical analyses

All statistical analyses were conducted using R statistical software (version 3.6.1). The response rate was calculated as the number of responses to the questionnaire divided by the number of distributed questionnaires. We calculated the weekly prevalence of all health problems as the number of players reporting one or more problems each week, divided by the number of players responding to the questionnaire. Only health problems that occurred after players' inclusion were included in analyses of incidence, severity and burden. Overall incidence was reported as the number of health problems that occurred per 1000 h of football exposure. Football training injury incidence was reported as the number of injuries that occurred per 1000 h of football training, and match injury incidence was reported as the number of injuries occurring in matches per 1000 h of match-play. Severity was reported as the total number of days lost together with median days lost and quartiles, and in the following categories: 0 days, 1-3 days, 4-7 days, 8-28 days, 29-90 days, 91-180 days and >180 days [23]. Injury burden was reported as days lost per 1000 h of exposure and illustrated in risk matrices with incidence and mean severity [25]. Illness incidence was reported as the number of illnesses per player per 365 days. We compared overall incidence [26] between the pre- and competitive seasons, and the injury incidence in match-play versus football training with the significance level set at $p<0.05$.

Results

Participants and response rate

We included 294 players (age: 22±4 yrs) from 11 teams in our analyses, which was 93% of all invited players (figure 1). The players responded to 10544 of the 13420 questionnaires distributed, with a mean weekly response rate of 79% (range: 57-100%). Physiotherapists from 10 of the 11 teams diagnosed the reported health problems with SMDCS (injuries: 71%, illnesses: 38%, total: 63%).

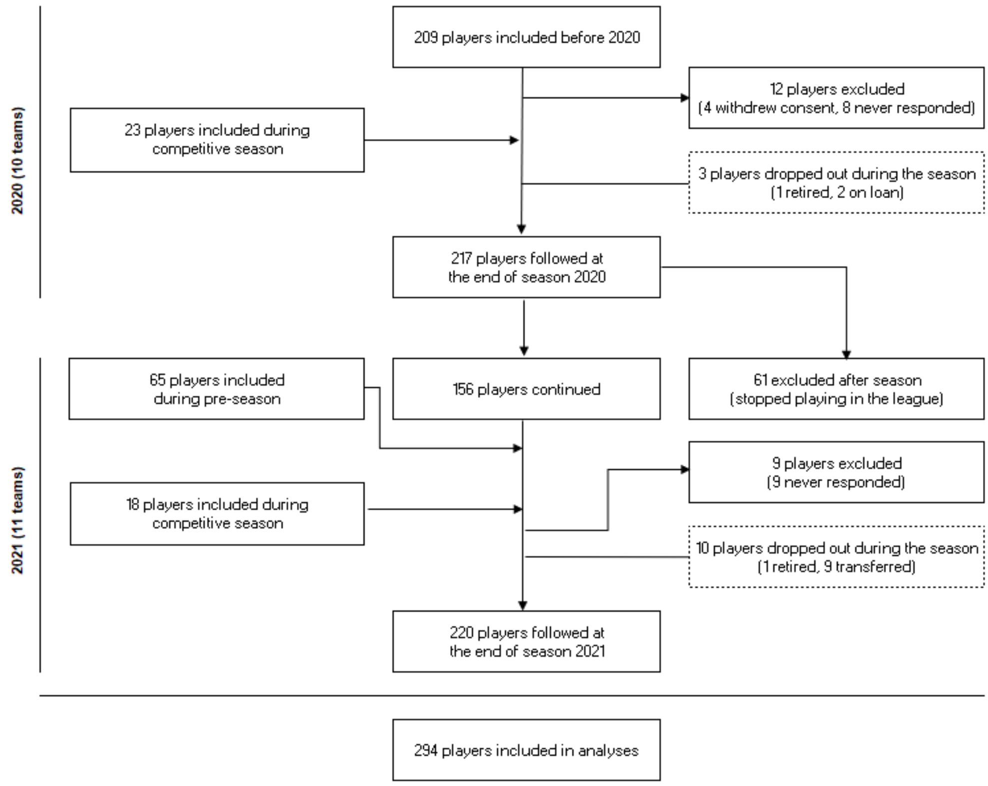

Figure 1: Flowchart of participants in the project. In 2021, we included the promoted team and continued to follow the relegated team. Players that transferred from the league or retired during the season were followed until drop-out (dotted boxes).

Prevalence

During the study period, 235 players (80%) reported at least one health problem affecting their participation or performance (median: 3, interquartile range: 2-4) and 215 players (73%) reported at least one substantial health problem (median: 2, interquartile range: 1-4). In total, 819 health problems were reported; 608 were considered substantial health problems and 652 caused time loss). The average weekly prevalence of health problems is shown in table 1. The prevalence of health problems was higher during the pre-season period of 2021 (37%, 95% CI: 36-39%) compared to the competitive seasons of 2020 (30%, 95% CI: 29-32%) and 2021 (32%, 95% CI: 30-33%).

Table 1. The average weekly prevalence of health problems.

	Mean (95% CI)
All health problems	**32% (31-33%)**
Injuries	30% (29-31%)
Sudden onset injuries	15% (15-16%)
Gradual onset injuries	15% (15-16%)
Illness	2% (2-3%)
Substantial health problems	**22% (21-23%)**

Injuries	20% (19-21%)
Sudden onset injuries	12% (11-12%)
Gradual onset injuries	8% (8-9%)
Illness	2% (2-2%)
Time-loss health problems	**23% (22-24%)**
Injuries	21% (20-22%)
Sudden onset injuries	12% (11-12%)
Gradual onset injuries	9% (9-10%)
Illness	2% (2-2%)

Incidence and severity

All health problems

Of the 819 health problems reported, 110 occurred prior to inclusion. Thus, 709 new health problems (44% sudden onset injuries, 35% gradual injuries and 21% illnesses) occurred during 66234 hours of football exposure (7351 match hours and 58884 training hours), resulting in an overall incidence of 10.7 health problems per 1000 h of football exposure (95% CI: 9.9-11.5). The incidence did not differ between the 2020 and 2021 competitive seasons (9.7 vs. 10.7 health problems per 1000 h, p=0.25), but was higher in the pre-season of 2021 compared to the competitive seasons (12.4 vs. 10.2 health problems per 1000 h, p=0.03).

The new health problems caused a median of 3 days lost (interquartile range: 1-7 days, range: 0-354 days, total number of days lost: 9466 days). Twenty percent caused no time-loss, 38% caused 1-3 days, 17% caused 4-7 days, 17% caused 8-28 days, 5% caused 29-90 days, 2% caused 91-180 days and 1% caused >180 days. Sudden onset injuries were most severe (68% of the total time loss, 62% of cumulative severity score), followed by gradual onset injuries (25% of total time loss, 28% of cumulative severity score) and illnesses (8% of total time loss, 10% of cumulative severity score).

Illnesses

On average players sustained 0.7 illnesses per player year (95% CI: 0.6-0.9). The median time loss of illnesses was 3 days (interquartile range: 1-5 days, range: 0-96 days, total number of days lost to illness: 717 days). We did not separate between organ systems because of the low diagnosis rate for illnesses (38%).

Injuries

The players sustained 558 new injuries (440 caused time-loss) in 66234 hours of football exposure, resulting in an overall injury incidence of 8.4 injuries (95% CI: 7.7-9.2) per 1000 h (6.6 time-loss injuries per 1000 h, 95% CI: 6.0-7.3). The injury incidence was greater during match play than in training (13.5 vs 3.6 injuries per 1000 h, p<0.0001). The most common injury locations were the thigh (26%), knee (15%) and ankle (14%) and the same body areas caused the largest proportion of total time loss (knee: 42%, ankle: 13% and thigh: 11%, total number of days lost to injury: 8749 days) and cumulative severity score (knee: 38%, thigh: 14%, ankle: 12%, total cumulative severity score: 155361) caused by injuries. Muscle injuries were most common (26% of all injuries), while injuries to ligament/joint capsule were most severe (caused 39% of days lost to injuries). ACL injuries alone caused 30% of the total injury time loss. Table 2 displays the number, incidence, time loss and burden of the body areas and injury diagnoses with the highest burden (see Table S1 for a complete data set).

Table 2: Number, incidence, time loss and injury burden of body areas and diagnoses for injury types with a burden of >2.5 days lost per 1000 h. Table S1 displays all injuries.

	Injuries	Incidence		Median time-loss		Burden	
Region, type, *diagnosis*	n (%)	Injuries per 1000 h (95% CI)		Days (interquartile range)		Days lost per 1000 h (95% CI)	
Head	16 (3%)	0.2	(0.1 to 0.4)	10.5	(3.5 to 22.3)	9.2	(8.5 to 9.9)
Nervous	12 (2%)	0.2	(0.1 to 0.3)	11.5	(6.5 to 22.8)	8.6	(7.9 to 9.32)
Concussion	11 (2%)	0.2	(0.1 to 0.3)	11.0	(5.0 to 24.5)	8.3	(7.7 to 9.1)
Lumbosacral	33 (6%)	0.5	(0.4 to 0.7)	1.0	(0.0 to 5.0)	3.7	(3.3 to 4.2)
Hip/groin	62 (11%)	0.9	(0.7 to 1.2)	2.0	(1.0 to 6.0)	10.0	(9.2 to 10.8)
Bone	6 (1%)	0.1	(0.0 to 0.2)	13.5	(4.5 to 78.8)	4.3	(3.8 to 4.8)
Pubic related groin injury	5 (1%)	0.1	(0.0 to 0.2)	6.0	(4.0 to 21.0)	2.8	(2.4 to 3.2)
Thigh	143 (26%)	2.2	(1.8 to 2.5)	3.0	(1.0 to 7.5)	14.7	(13.8 to 15.7)
Muscle/tendon	112 (20%)	1.7	(1.4 to 2.0)	4.0	(1.0 to 9.0)	13.8	(12.9 to 14.7)
Quadriceps muscle injury	34 (6%)	0.5	(0.4 to 0.7)	2.5	(1.5 to 7.0)	2.7	(2.3 to 3.1)
Hamstring muscle injury	38 (7%)	0.6	(0.4 to 0.8)	7.0	(3.0 to 13.0)	7.9	(7.3 to 8.6)
Adductor muscle injury	33 (6%)	0.5	(0.4 to 0.7)	4.0	(0.0 to 9.0)	3.1	(2.7 to 3.5)
Knee	86 (15%)	1.3	(1.1 to 1.6)	3.0	(1.0 to 13.0)	55.4	(53.7 to 57.2)
Cartilage/synovium/bursa	13 (2%)	0.2	(0.1 to 0.3)	3.0	(1.0 to 12.0)	6.9	(6.3 to 7.5)
Meniscal tear	2 (0%)	0.0	(0.0 to 0.1)	182.5	(95.5 to 269.8)	5.5	(5.0 to 6.1)
Ligament/joint capsule	18 (3%)	0.3	(0.2 to 0.4)	41.5	(8.3 to 325.0)	41.4	(39.9 to 43.0)
Anterior cruciate ligament injury	8 (1%)	0.1	(0.1 to 0.2)	325.0	(325.0 to 325.0)	39.3	(37.8 to 40.8)
Lower leg	38 (7%)	0.6	(0.4 to 0.8)	2.0	(0.0 to 6.8)	8.2	(7.5 to 8.9)
Muscle/tendon	20 (4%)	0.3	(0.2 to 0.5)	2.5	(1.0 to 8.0)	7.4	(6.7 to 8.0)
Gastrocnemius muscle injury	9 (2%)	0.1	(0.1 to 0.3)	1.0	(1.0 to 3.0)	2.8	(2.4 to 3.2)
Achilles Tendon rupture	1 (0%)	0.0	(0.0 to 0.1)	213.0	(213.0 to 213.0)	3.2	(2.8 to 3.7)
Ankle	79 (14%)	1.2	(1.0 to 1.5)	2.0	(1.0 to 7.0)	16.7	(15.8 to 17.7)
Bone	2 (0%)	0.0	0.0 to 0.1	108.0	(55.5 to 160.5)	3.3	(2.9 to 3.7)
Talus stress fracture	1 (0%)	0.0	(0.0 to 0.1)	213.0	(213.0 to 213.0)	3.2	(2.8 to 3.7)
Ligament/joint capsule	34 (6%)	0.5	(0.4 to 0.7)	2.5	(1.3 to 11.3)	9.3	(8.6 to 10.0)
Lateral ligament sprain	23 (4%)	0.4	(0.2 to 0.5)	2.0	(1.0 to 7.5)	2.8	(2.4 to 3.2)
Tibiofibular ligament syndesmosis injury	3 (1%)	0.1	(0.0 to 0.1)	127.5	(80.5 to 174.3)	5.8	(5.2 to 6.4)
Foot	66 (12%)	1.0	(0.8 to 1.3)	3.0	(1.0 to 14.0)	11.8	(11.0 to 12.7)
Bone	10 (2%)	0.2	(0.1 to 0.3)	16.0	(7.8 to 63.3)	5.2	(4.6 to 5.7)

Injury burden

Figure 2 illustrates the incidence and severity of injuries for the body regions with the highest injury burden. The diagnoses causing the highest injury burden were ACL injuries (39.3 days lost per 1000h), concussion (8.3 days lost per 1000 h) and hamstring muscle injuries (7.9 days lost per 1000 h).

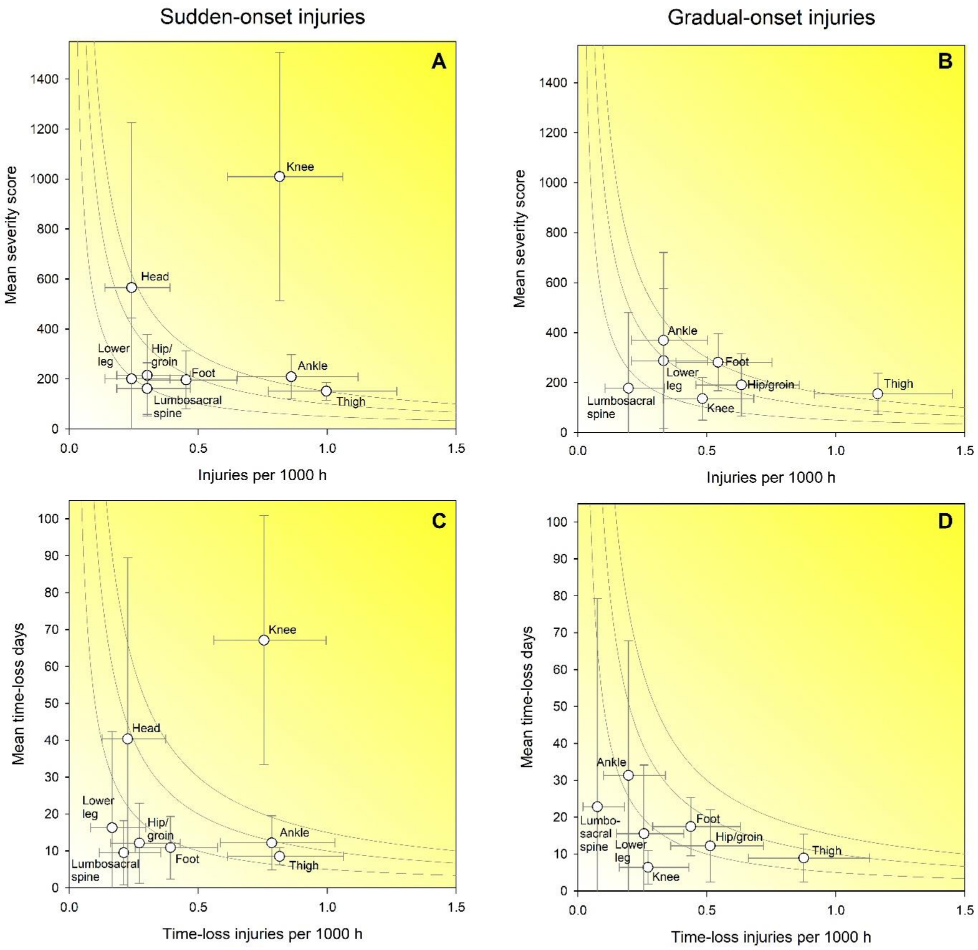

Figure 2. Risk matrices illustrating the incidence of all injuries with (a) sudden and (b) gradual onset and their mean cumulative severity score, and the incidence of time-loss injuries with (c) sudden and (d) gradual onset with mean days lost. Only the body regions with the highest injury burden are presented. Darker yellow represents greater injury burden and the curved lines indicate equal injury burden. Error bars displays 95% confidence intervals.

Discussion

This is the first study in women's premier league football to record all health problems, including illnesses, irrespective of time-loss and medical attention. The results document that, at any given time, one in five players (22%) reported a substantial health problem. Gradual onset injuries were more common than previously reported, but sudden-onset injuries still caused the greatest burden.

Muscle injury was the most common injury type, but ligament injuries caused the greatest burden, particularly ACL injuries, responsible for 30% of the total number of days lost to injuries.

Prevalence and player availability

Of the 22% of players reporting a substantial health problem at any given time, the majority (20%) were due to injury, and only 2% illnesses. While team sport athletes report a lower prevalence of illness compared to athletes from other sports [18 27], both seasons in this study included periods with Covid-19 restrictions that likely prevented transmission of infections. Although the prevalence of substantial health problems is comparable to studies using the same methodology in other sports [18 27-30], our data highlight that health problems, especially injuries, do represent a concern in women's football. In a normal training week, for a typical Norwegian premier league team with a squad of 22 players, seven players were experiencing a health problem and for five of these, their performance and participation was at least moderately reduced. Low player availability limits training content, reduces training quality and negatively affects player and team development and football performance [31-33].

Incidence

The incidence of 6.6 time-loss injuries per 1000 h is comparable to recent studies from women's premier league football. Seven (of eight) Irish teams (UEFA club coefficient ranking: 31st-33rd) had 7.9 injuries per 1000 h during the 2018 and 2019 seasons [7], seven (of 13) teams in the Dutch/Belgian premier league (UEFA club coefficients ranking: 17th) had 8.4 injuries per 1000 h in the 2014/15 season [3], and one Spanish team followed from 2010-2015 (UEFA club coefficient ranking: 6th-11th) had 6.3 injuries per 1000 h [34]. However, our injury rate was higher than most of the early studies from women's premier league football (conducted between 2000-2010, 3.3 to 5.5 injuries per 1000 h) [5 6 8-10], with a few exceptions (6.2 to 6.8 injuries per 1000 h) [4 11]. A direct comparison between our results and previous studies should be made with care, as they have all used medical staff to report which has been found to capture fewer time-loss injuries compared to player registrations [35]. Still, it seems clear that the injury rate in women's football is going in the wrong direction. In contrast, the injury rate in men's football has decreased during the same period [36]. Increasing demands of the sport, combined with low availability of medical care, strength and conditioning support and facilities [37] and the fact that many female players still have to combine their football career with their academic or working career, may contribute to the escalation in injury rate. With the resources in women's football increasing [1], the current data emphasize that medical support, injury prevention and load management measures should be given priority.

Injury types, locations and diagnoses

Thigh and muscle injuries were the most commonly injured body location and tissue type. This is most likely related to the rapidly increasing intensity and physical demands in women's football [2]. Ligament and knee injuries represented the greatest injury burden, especially ACL injuries, which caused 30% of the total injury time-loss. It is well known that the risk of ACL injury is 2-3 times higher for female compared to male football players [38 39]. We also know that effective preventive programs, albeit not necessarily targeted or adapted to the elite player, do exist [40] but we do not know whether or how these are being implemented. It should also be noted that although the incidence of concussions was low and the median severity was 11 days, it was the second most burdensome injury diagnosis. This was due to some concussions causing major time-loss, from three weeks to almost a year. Women can have more prolonged symptoms after concussion compared to men [41], and therefore should be carefully monitored after sustaining concussion to avoid long term consequences.

Similar injury pattern regardless of injury definition

We observed a greater proportion of gradual-onset injuries than previously reported in women's premier league football [4-7 9 11]. This was expected, as previous studies have recorded time-loss injuries only. Players often continue training and playing through pain; many gradual-onset injuries are therefore not captured when a time-loss definition is used. The OSTRC-H severity score was designed to better reflect the consequences of gradual-onset injuries [17]. However, sudden-onset injuries were still the most burdensome both measured by days lost and severity score. Although the total number of injuries recorded and the proportion of gradual- vs sudden-onset injuries depend on the injury definition, the injury pattern was nearly the same whether all injuries or only time-loss injuries were included (figure 2). We therefore argue that recording only time-loss injuries and expressing severity by the number of days lost gives a reliable picture of the overall injury pattern in women's football. Studies of overuse injuries should still use non-time-loss approach. Implementing a surveillance system where players report all health problems weekly (or even daily) may yield significant clinical benefit by helping medical staff identify health problems and intervene early.

Methodological considerations

The main strengths of this project include the prospective design, the high number of players from all the teams in the league, and the two-season duration. This should ensure good external validity for women's premier league football, although injury rates and patterns may differ between regions [42 43]. The combined use of player's self-reporting and team physiotherapists providing the diagnoses grants the benefits of both methods: self-reporting identifies more health problems than injury recording by medical staff [17 35], while team medical staff provides detailed information that cannot reliably be recorded by players. Medical staff diagnosed 71% of the injuries, and the undiagnosed injuries were of minor severity, causing 7% of the total injury time-loss. The diagnosis rate of illnesses (38%) was low, so our data does not provide much detail about these.

The OSTRC-H2 is dependent on players providing honest information. As team physiotherapists had access to the player reports, it is possible that some players were reluctant to report problems if they were concerned it could reduce their chances of being selected for matches. While the OSTRC-H2 allows players to report problems such as mental illness and eating disorders, no such problems were reported. This was probably because players were hesitant to report these, not that they do not exist in this cohort. To provide valid data, a high response rate is required. The overall response rate in the current study was 79%, similar to what was reported in a study of Norwegian Olympic and Paralympic athletes over a 40-week period [18], but lower than what has been reported in some shorter-duration studies [19 44]. The response rate to the questionnaire fell over the course of both seasons, most likely due to reporting fatigue. We observed a relatively constant prevalence throughout the competitive seasons, but it is possible that reporting fatigue has increased the threshold for reporting minor problems towards the end of the seasons [44]. As players did not respond to the questionnaire for 9 weeks between seasons, we do not have data on health problems sustained in this period and may have underestimated the severity of some problems that occurred toward the end of the 2020 season. We wanted team medical staff to use the surveillance system as a practical tool, which may have allowed them to detect problems and intervene early and may have reduced the severity of some health problems [18].

Clinical implications

The fact that one in five players had a substantial health problem at any given time, the high rate of muscle injuries and massive injury burden caused by ACL injuries and concussions cannot be tolerated. This calls for action. The rapid and encouraging developments taking place in women's football must be accompanied with increased medical and strength and conditioning support to ensure player well-being. Also, when developing, young girls must be given the same access to facilities and educated coaches as boys to be prepared for the demands of the game. Currently, we are far from having enough research to support the decision-making for coaching and medical staff in women's football. Injury risk factors and mechanisms need to be identified and understood, as these are not necessarily the same as in men's football. While we know ACL injuries can be effectively prevented in women's football, we have negligible data on how to prevent other major concerns for female players: muscle injuries and concussion. Exercises like the Nordic Hamstrings and the Copenhagen Adduction exercises have been found to be effective in reducing the risk of hamstrings and adductor injuries in male football players, but their preventative effect on female players remains to be researched. Preventative measures tailored to the needs of the modern female footballer must be developed, tested and constantly re-evaluated to follow the accelerated development of women's football.

Patient and public involvement: Participants were not involved in the design, reporting or dissemination plans of the study.

Equity, diversity and inclusion statement: All players in the Norwegian women's premier league were invited to participate, but speaking Norwegian or English was necessary to be able to answer the OSTRC-H questionnaire. The authors are all from Nordic countries but consists of both women and men and includes both junior and senior researchers. The authors have background as medical doctors, physiotherapists, football coaches and teachers.

Contributorship: RA and ST shares first authorship and contributed equally to this paper. All authors were involved in the design of the study. RA and ST were responsible for the contact with the players and physiotherapists during the data collection period. BC performed the descriptive statistical analyses. RA and ST drafted the manuscript together and all authors contributed in revising the manuscript and gave their final approval of the submitted version.

Competing interests: None to declare.

Data Availability Statement: Data are available upon reasonable request.

Ethical approval: Approved by The Norwegian Centre for Research Data (#662612) and the Norwegian School of Sports Sciences Ethics Board (#129-051219).

References

1. UEFA. Women's football across the national associations 2017, 2018.
2. Bradley P, Scott D. Physical analysis of the FIFA Women's World Cup France 2019, 2019.
3. Blokland D, Thijs KM, Backx FJ, Goedhart EA, Huisstede BM. No Effect of Generalized Joint Hypermobility on Injury Risk in Elite Female Soccer Players: A Prospective Cohort Study. Am J Sports Med 2017;**45**(2):286-93 doi: 10.1177/0363546516676051 [published Online First: 2017/02/02].
4. Faude O, Junge A, Kindermann W, Dvorak J. Injuries in female soccer players: a prospective study in the German national league. Am J Sports Med 2005;**33**(11):1694-700 doi: 10.1177/0363546505275011 [published Online First: 2005/08/12].

5. Gaulrapp H, Becker A, Walther M, Hess H. Injuries in women's soccer: a 1-year all players prospective field study of the women's Bundesliga (German premier league). Clin J Sport Med 2010;**20**(4):264-71 doi: 10.1097/JSM.0b013e3181e78e33 [published Online First: 2010/07/08].
6. Giza E, Mithofer K, Farrell L, Zarins B, Gill T. Injuries in women's professional soccer. Br J Sports Med 2005;**39**(4):212-6; discussion 12-6 doi: 10.1136/bjsm.2004.011973 [published Online First: 2005/03/29].
7. Horan D, Blake C, Hägglund M, Kelly S, Roe M, Delahunt E. Injuries in elite-level women's football-a two-year prospective study in the Irish Women's National League. Scand J Med Sci Sports 2021 doi: 10.1111/sms.14062 [published Online First: 2021/11/01].
8. Hägglund M, Waldén M, Ekstrand J. Injuries among male and female elite football players. Scand J Med Sci Sports 2009;**19**(6):819-27 doi: 10.1111/j.1600-0838.2008.00861.x [published Online First: 2008/11/05].
9. Jacobson I, Tegner Y. Injuries among Swedish female elite football players: a prospective population study. Scand J Med Sci Sports 2007;**17**(1):84-91 doi: 10.1111/j.1600-0838.2006.00524.x [published Online First: 2007/02/20].
10. Nilstad A, Andersen TE, Bahr R, Holme I, Steffen K. Risk factors for lower extremity injuries in elite female soccer players. Am J Sports Med 2014;**42**(4):940-8 doi: 10.1177/0363546513518741 [published Online First: 2014/02/07].
11. Tegnander A, Olsen OE, Moholdt TT, Engebretsen L, Bahr R. Injuries in Norwegian female elite soccer: a prospective one-season cohort study. Knee Surg Sports Traumatol Arthrosc 2008;**16**(2):194-8 doi: 10.1007/s00167-007-0403-z [published Online First: 2007/09/28].
12. Okholm Kryger K, Wang A, Mehta R, et al. Can we evidence-base injury prevention and management in women's football? A scoping review. Res Sports Med 2022:1-16 doi: 10.1080/15438627.2022.2038161 [published Online First: 2022/02/16].
13. Bahr R. No injuries, but plenty of pain? On the methodology for recording overuse symptoms in sports. Br J Sports Med 2009;**43**(13):966-72 doi: 10.1136/bjsm.2009.066936 [published Online First: 2009/12/01].
14. Clarsen B, Bahr R. Matching the choice of injury/illness definition to study setting, purpose and design: one size does not fit all! Br J Sports Med 2014;**48**(7):510-2 doi: 10.1136/bjsports-2013-093297 [published Online First: 2014/03/13].
15. Bahr R, Clarsen B, Derman W, et al. International Olympic Committee consensus statement: Methods for recording and reporting of epidemiological data on injury and illness in sports 2020 (including STROBE Extension for Sport Injury and Illness Surveillance—STROBE-SIIS). Br J Sports Med 2020.
16. Clarsen B, Bahr R, Myklebust G, et al. Improved reporting of overuse injuries and health problems in sport: an update of the Oslo Sport Trauma Research Center questionnaires. Br J Sports Med 2020;**54**(7):390-96 doi: 10.1136/bjsports-2019-101337 [published Online First: 2020/02/16].
17. Clarsen B, Myklebust G, Bahr R. Development and validation of a new method for the registration of overuse injuries in sports injury epidemiology: the Oslo Sports Trauma Research Centre (OSTRC) overuse injury questionnaire. Br J Sports Med 2013;**47**(8):495-502 doi: 10.1136/bjsports-2012-091524 [published Online First: 2012/10/06].
18. Clarsen B, Rønsen O, Myklebust G, Flørenes TW, Bahr R. The Oslo Sports Trauma Research Center questionnaire on health problems: a new approach to prospective monitoring of illness and injury in elite athletes. Br J Sports Med 2014;**48**(9):754-60 doi: 10.1136/bjsports-2012-092087 [published Online First: 2013/02/23].
19. Harøy J, Clarsen B, Thorborg K, Hölmich P, Bahr R, Andersen TE. Groin Problems in Male Soccer Players Are More Common Than Previously Reported. Am J Sports Med 2017;**45**(6):1304-08 doi: 10.1177/0363546516687539 [published Online First: 2017/03/17].

20. Brink MS, Visscher C, Arends S, Zwerver J, Post WJ, Lemmink KA. Monitoring stress and recovery: new insights for the prevention of injuries and illnesses in elite youth soccer players. Br J Sports Med 2010;**44**(11):809-15 doi: 10.1136/bjsm.2009.069476 [published Online First: 2010/06/01].
21. van Mechelen W, Hlobil H, Kemper HC. Incidence, severity, aetiology and prevention of sports injuries. A review of concepts. Sports Med 1992;**14**(2):82-99 doi: 10.2165/00007256-199214020-00002 [published Online First: 1992/08/01].
22. UEFA. *Women's Association Club Coefficients*. https://www.uefa.com/nationalassociations/uefarankings/womenscountry/#/yr/2021 (accessed April 26, 2023).
23. Waldén M, Mountjoy M, McCall A, et al. Football-specific extension of the IOC consensus statement: methods for recording and reporting of epidemiological data on injury and illness in sport 2020. Br J Sports Med 2023 doi: 10.1136/bjsports-2022-106405 [published Online First: 20230106].
24. Orchard JW, Meeuwisse W, Derman W, et al. Sport Medicine Diagnostic Coding System (SMDCS) and the Orchard Sports Injury and Illness Classification System (OSIICS): revised 2020 consensus versions. Br J Sports Med 2020;**54**(7):397-401 doi: 10.1136/bjsports-2019-101921 [published Online First: 20200229].
25. Fuller CW. Why Median Severity and Ordinal Scale Severity Values should not be used for Injury Burden Results: A Critical Review. Int J Sports Med 2023 doi: 10.1055/a-1983-0040 [published Online First: 20230120].
26. MedCalc Software Ltd. *Comparison of two rates*. https://www.medcalc.org/calc/rate_comparison.php (Version 20.218; accessed April 26, 2023)
27. Moseid CH, Myklebust G, Fagerland MW, Clarsen B, Bahr R. The prevalence and severity of health problems in youth elite sports: A 6-month prospective cohort study of 320 athletes. Scand J Med Sci Sports 2018;**28**(4):1412-23 doi: 10.1111/sms.13047 [published Online First: 20180219].
28. Nordstrøm A, Bahr R, Clarsen B, Talsnes O. Prevalence and Burden of Self-Reported Health Problems in Junior Male Elite Ice Hockey Players: A 44-Week Prospective Cohort Study. Am J Sports Med 2021:3635465211032979 doi: 10.1177/03635465211032979 [published Online First: 2021/08/17].
29. Nordstrøm A, Bahr R, Talsnes O, Clarsen B. Prevalence and Burden of Health Problems in Male Elite Ice Hockey Players: A Prospective Study in the Norwegian Professional League. Orthop J Sports Med 2020;**8**(2):2325967120902407 doi: 10.1177/2325967120902407 [published Online First: 2020/03/05].
30. Moen C, Andersen TE, Clarsen B, Madsen-Kaarød G, Dalen-Lorentsen T. Prevalence and burden of health problems in top-level football referees. Sci Med Footb 2022:1-8 doi: 10.1080/24733938.2022.2055782 [published Online First: 20220418].
31. Eirale C, Tol JL, Farooq A, Smiley F, Chalabi H. Low injury rate strongly correlates with team success in Qatari professional football. Br J Sports Med 2013;**47**(12):807-8 doi: 10.1136/bjsports-2012-091040 [published Online First: 2012/08/21].
32. Hägglund M, Waldén M, Magnusson H, Kristenson K, Bengtsson H, Ekstrand J. Injuries affect team performance negatively in professional football: an 11-year follow-up of the UEFA Champions League injury study. Br J Sports Med 2013;**47**(12):738-42 doi: 10.1136/bjsports-2013-092215 [published Online First: 2013/05/07].
33. Larruskain J, Lekue JA, Martin-Garetxana I, Barrio I, McCall A, Gil SM. Injuries are negatively associated with player progression in an elite football academy. Science and Medicine in Football 2021:1-10 doi: 10.1080/24733938.2021.1943756.

34. Larruskain J, Lekue JA, Diaz N, Odriozola A, Gil SM. A comparison of injuries in elite male and female football players: A five-season prospective study. Scand J Med Sci Sports 2018;**28**(1):237-45 doi: 10.1111/sms.12860 [published Online First: 2017/02/17].
35. Nilstad A, Bahr R, Andersen TE. Text messaging as a new method for injury registration in sports: a methodological study in elite female football. Scand J Med Sci Sports 2014;**24**(1):243-9 doi: 10.1111/j.1600-0838.2012.01471.x [published Online First: 2012/04/28].
36. Ekstrand J, Spreco A, Bengtsson H, Bahr R. Injury rates decreased in men's professional football: an 18-year prospective cohort study of almost 12 000 injuries sustained during 1.8 million hours of play. Br J Sports Med 2021 doi: 10.1136/bjsports-2020-103159 [published Online First: 2021/02/07].
37. Horan D. Game changer! Injury surveillance in elite-level women's football in Ireland: thinking bigger and working together. University College Dublin, 2022.
38. Waldén M, Hägglund M, Magnusson H, Ekstrand J. Anterior cruciate ligament injury in elite football: a prospective three-cohort study. Knee Surg Sports Traumatol Arthrosc 2011;**19**(1):11-9 doi: 10.1007/s00167-010-1170-9 [published Online First: 2010/06/10].
39. Montalvo AM, Schneider DK, Silva PL, et al. 'What's my risk of sustaining an ACL injury while playing football (soccer)?' A systematic review with meta-analysis. Br J Sports Med 2019;**53**(21):1333-40 doi: 10.1136/bjsports-2016-097261 [published Online First: 2018/03/31].
40. Crossley KM, Patterson BE, Culvenor AG, Bruder AM, Mosler AB, Mentiplay BF. Making football safer for women: a systematic review and meta-analysis of injury prevention programmes in 11 773 female football (soccer) players. Br J Sports Med 2020 doi: 10.1136/bjsports-2019-101587 [published Online First: 2020/04/08].
41. McGroarty NK, Brown SM, Mulcahey MK. Sport-Related Concussion in Female Athletes: A Systematic Review. Orthop J Sports Med 2020;**8**(7):2325967120932306 doi: 10.1177/2325967120932306 [published Online First: 20200716].
42. Bengtsson H, Ortega Gallo PA, Ekstrand J. Injury epidemiology in professional football in South America compared with Europe. BMJ Open Sport Exerc Med 2021;**7**(4):e001172 doi: 10.1136/bmjsem-2021-001172 [published Online First: 20211001].
43. Waldén M, Hägglund M, Orchard J, Kristenson K, Ekstrand J. Regional differences in injury incidence in European professional football. Scand J Med Sci Sports 2013;**23**(4):424-30 doi: 10.1111/j.1600-0838.2011.01409.x [published Online First: 2011/11/19].
44. Clarsen B, Bahr R, Heymans MW, et al. The prevalence and impact of overuse injuries in five Norwegian sports: Application of a new surveillance method. Scand J Med Sci Sports 2015;**25**(3):323-30 doi: 10.1111/sms.12223 [published Online First: 2014/04/02].

Table S1: Number, incidence, time loss, severity score and injury burden by body regions, tissue types and diagnoses for all recorded injuries.

Body region Tissue type *Diagnoses*	**Injuries** N (%)	**Incidence** Injuries per 1000 h (95% CI)	**Time loss** Median days lost (interquartile range)	**OSTRC-H severity score** Median severity score (interquartile range)	**Injury burden** Days lost per 1000 h (95% CI)
Head	16 (3%)	0.24 (0.14 to 0.38)	10.5 (3.5 to 22.3)	196.3 (69.0 to 317.0)	9.2 (8.5 to 9.9)
Nervous	12 (2%)	0.18 (0.10 to 0.31)	11.5 (6.5 to 22.8)	204.8 (144.8 to 317.0)	8.6 (7.9 to 9.3)
Concussion	11 (2%)	0.17 (0.09 to 0.29)	11.0 (5.0 to 24.5)	200.5 (113.5 to 334.0)	8.3 (7.7 to 9.1)
Post concussion syndrome	1 (0%)	0.02 (0.00 to 0.07)	17.0 (17.0 to 17.0)	300.0 (300.0 to 300.0)	0.3 (0.2 to 0.4)
Bone	1 (0%)	0.02 (0.00 to 0.07)	1.0 (1.0 to 1.0)	42.0 (42.0 to 42.0)	0.0 (0.0 to 0.1)
Facial fracture	1 (0%)	0.02 (0.00 to 0.07)	1.0 (1.0 to 1.0)	42.0 (42.0 to 42.0)	0.0 (0.0 to 0.1)
Undiagnosed	3 (1%)	0.05 (0.01 to 0.12)	7.0 (5.5 to 16.5)	100.5 (87.5 to 266.5)	0.6 (0.4 to 0.8)
Neck	3 (1%)	0.05 (0.01 to 0.12)	4.0 (2.5 to 4.5)	67.5 (67.0 to 67.0)	0.2 (0.1 to 0.3)
Muscle/tendon	3 (1%)	0.05 (0.01 to 0.12)	4.0 (2.5 to 4.5)	67.5 (67.0 to 67.0)	0.2 (0.1 to 0.3)
Cervical strain / whiplash	2 (0%)	0.03 (0.01 to 0.10)	4.5 (4.3 to 4.8)	67.8 (67.0 to 67.0)	0.1 (0.1 to 0.3)
Suboccipital muscle strain	1 (0%)	0.02 (0.00 to 0.07)	1.0 (1.0 to 1.0)	67.0 (67.0 to 67.0)	0.0 (0.0 to 0.1)
Shoulder	7 (1%)	0.11 (0.05 to 0.21)	0.0 (0.0 to 1.5)	83.5 (49.5 to 110.5)	0.1 (0.0 to 0.2)
Cartilage/synovium/bursa	1 (0%)	0.02 (0.00 to 0.07)	1.0 (1.0 to 1.0)	379.0 (379.0 to 379.0)	0.0 (0.0 to 0.1)
Impingement syndrome/subacromial bursitis	1 (0%)	0.02 (0.00 to 0.07)	1.0 (1.0 to 1.0)	379.0 (379.0 to 379.0)	0.0 (0.0 to 0.1)
Ligament/joint capsule	1 (0%)	0.02 (0.00 to 0.07)	0.0 (0.0 to 0.0)	57.0 (57.0 to 57.0)	0.0 (0.0 to 0.0)
Anterior subluxation (initial)	1 (0%)	0.02 (0.00 to 0.07)	0.0 (0.0 to 0.0)	57.0 (57.0 to 57.0)	0.0 (0.0 to 0.0)
Superficial tissues/skin	1 (0%)	0.02 (0.00 to 0.07)	0.0 (0.0 to 0.0)	8.0 (8.0 to 8.0)	0.0 (0.0 to 0.0)
Shoulder Contusion	1 (0%)	0.02 (0.00 to 0.07)	0.0 (0.0 to 0.0)	8.0 (8.0 to 8.0)	0.0 (0.0 to 0.0)
Undiagnosed	4 (1%)	0.06 (0.02 to 0.14)	1.0 (0.0 to 2.0)	88.0 (72.8 to 101.8)	0.1 (0.0 to 0.1)
Elbow	1 (0%)	0.02 (0.00 to 0.07)	21.0 (21.0 to 21.0)	412.0 (412.0 to 412.0)	0.3 (0.2 to 0.5)
Bone	1 (0%)	0.02 (0.00 to 0.07)	21.0 (21.0 to 21.0)	412.0 (412.0 to 412.0)	0.3 (0.2 to 0.5)
Radial head fracture	1 (0%)	0.02 (0.00 to 0.07)	21.0 (21.0 to 21.0)	412.0 (412.0 to 412.0)	0.3 (0.2 to 0.5)
Forearm	1 (0%)	0.02 (0.00 to 0.07)	14.0 (14.0 to 14.0)	249.0 (249.0 to 249.0)	0.2 (0.1 to 0.4)
Bone	1 (0%)	0.02 (0.00 to 0.07)	14.0 (14.0 to 14.0)	249.0 (249.0 to 249.0)	0.2 (0.1 to 0.4)
Radius fracture (including Colles')	1 (0%)	0.02 (0.00 to 0.07)	14.0 (14.0 to 14.0)	249.0 (249.0 to 249.0)	0.2 (0.1 to 0.4)
Wrist	1 (0%)	0.02 (0.00 to 0.07)	3.0 (3.0 to 3.0)	293.0 (293.0 to 293.0)	0.1 (0.0 to 0.1)
Ligament/joint capsule	1 (0%)	0.02 (0.00 to 0.07)	3.0 (3.0 to 3.0)	293.0 (293.0 to 293.0)	0.1 (0.0 to 0.1)
Wrist sprain	1 (0%)	0.02 (0.00 to 0.07)	3.0 (3.0 to 3.0)	293.0 (293.0 to 293.0)	0.1 (0.0 to 0.1)
Hand	7 (1%)	0.11 (0.05 to 0.21)	4.0 (1.5 to 8.5)	200.5 (128.0 to 225.5)	0.6 (0.4 to 0.8)
Bone	2 (0%)	0.03 (0.01 to 0.10)	3.5 (3.3 to 3.8)	215.8 (199.8 to 231.3)	0.1 (0.1 to 0.2)
Proximal phalyngeal fracture of fingers	1 (0%)	0.02 (0.00 to 0.07)	3.0 (3.0 to 3.0)	184.0 (184.0 to 184.0)	0.1 (0.0 to 0.1)
Distal phalyngeal fracture of fingers	1 (0%)	0.02 (0.00 to 0.07)	4.0 (4.0 to 4.0)	247.0 (247.0 to 247.0)	0.1 (0.0 to 0.1)
Ligament/joint capsule	2 (0%)	0.03 (0.01 to 0.10)	9.5 (7.3 to 11.8)	217.8 (208.5 to 225.5)	0.3 (0.2 to 0.4)
Ulnar collateral ligament 3° sprain -acute (skier's thumb)	1 (0%)	0.02 (0.00 to 0.07)	5.0 (5.0 to 5.0)	200.0 (200.0 to 200.0)	0.1 (0.0 to 0.2)
Finger distal interphalyngeal joint dislocation	1 (0%)	0.02 (0.00 to 0.07)	14.0 (14.0 to 14.0)	234.0 (234.0 to 234.0)	0.2 (0.1 to 0.4)
Non-specific	2 (0%)	0.03 (0.01 to 0.10)	0.0 (0.0 to 0.0)	56.0 (48.8 to 64.3)	0.0 (0.0 to 0.0)
Other hand injury	2 (0%)	0.03 (0.01 to 0.10)	0.0 (0.0 to 0.0)	56.0 (48.8 to 64.3)	0.0 (0.0 to 0.0)

Body region Tissue type *Diagnoses*	Injuries N (%)	Incidence Injuries per 1000 h (95% CI)	Time loss Median days lost (interquartile range)	OSTRC-H severity score Median severity score (interquartile range)	Injury burden Days lost per 1000 h (95% CI)
Undiagnosed	1 (0%)	0.02 (0.00 to 0.07)	12.0 (12.0 to 12.0)	217.0 (217.0 to 217.0)	0.2 (0.1 to 0.3)
Chest	7 (1%)	0.11 (0.05 to 0.21)	2.0 (1.0 to 2.5)	51.5 (37.5 to 121.5)	0.5 (0.4 to 0.7)
Bone	2 (0%)	0.03 (0.01 to 0.10)	14.0 (8.0 to 20.0)	258.0 (187.8 to 329.3)	0.4 (0.3 to 0.6)
Rib fracture	1 (0%)	0.02 (0.00 to 0.07)	26.0 (26.0 to 26.0)	400.0 (400.0 to 400.0)	0.4 (0.3 to 0.6)
Rib contusion	1 (0%)	0.02 (0.00 to 0.07)	2.0 (2.0 to 2.0)	117.0 (117.0 to 117.0)	0.0 (0.0 to 0.1)
Superficial tissues/skin	2 (0%)	0.03 (0.01 to 0.10)	0.5 (0.3 to 0.8)	42.8 (37.5 to 46.5)	0.0 (0.0 to 0.1)
Thoracic contusion	2 (0%)	0.03 (0.01 to 0.10)	0.5 (0.3 to 0.8)	42.8 (37.5 to 46.5)	0.0 (0.0 to 0.1)
Non-specific	1 (0%)	0.02 (0.00 to 0.07)	3.0 (3.0 to 3.0)	126.0 (126.0 to 126.0)	0.1 (0.0 to 0.1)
Other chest injury	1 (0%)	0.02 (0.00 to 0.07)	3.0 (3.0 to 3.0)	126.0 (126.0 to 126.0)	0.1 (0.0 to 0.1)
Undiagnosed	2 (0%)	0.03 (0.01 to 0.10)	1.5 (1.3 to 1.8)	37.8 (35.3 to 39.8)	0.1 (0.0 to 0.1)
Lumbosacral	33 (6%)	0.50 (0.35 to 0.69)	1.0 (0.0 to 5.0)	51.0 (24.0 to 118.0)	3.7 (3.3 to 4.2)
Muscle/tendon	7 (1%)	0.11 (0.05 to 0.21)	0.0 (0.0 to 3.5)	59.5 (16.0 to 100.0)	0.3 (0.2 to 0.5)
Paralumbar muscle strain	7 (1%)	0.11 (0.05 to 0.21)	0.0 (0.0 to 3.5)	59.5 (16.0 to 100.0)	0.3 (0.2 to 0.5)
Nervous	1 (0%)	0.02 (0.00 to 0.07)	59.0 (59.0 to 59.0)	900.0 (900.0 to 900.0)	0.9 (0.7 to 1.1)
Lumbar nerve root impingement	1 (0%)	0.02 (0.00 to 0.07)	59.0 (59.0 to 59.0)	900.0 (900.0 to 900.0)	0.9 (0.7 to 1.1)
Bone	1 (0%)	0.02 (0.00 to 0.07)	18.0 (18.0 to 18.0)	498.0 (498.0 to 498.0)	0.3 (0.2 to 0.4)
Lumbar spine fracture	1 (0%)	0.02 (0.00 to 0.07)	18.0 (18.0 to 18.0)	498.0 (498.0 to 498.0)	0.3 (0.2 to 0.4)
Cartilage/synovium/bursa	1 (0%)	0.02 (0.00 to 0.07)	0.0 (0.0 to 0.0)	33.0 (33.0 to 33.0)	0.0 (0.0 to 0.0)
Lumbar facet syndrome	1 (0%)	0.02 (0.00 to 0.07)	0.0 (0.0 to 0.0)	33.0 (33.0 to 33.0)	0.0 (0.0 to 0.0)
Non-specific	10 (2%)	0.15 (0.08 to 0.27)	1.0 (0.0 to 3.0)	42.0 (24.0 to 116.0)	1.8 (1.5 to 2.1)
Other Lumbar injury	1 (0%)	0.02 (0.00 to 0.07)	104.0 (104.0 to 104.0)	1840.0 (1840.0 to 1840.0)	1.6 (1.3 to 1.9)
Non-specific low back pain / mechanical pain	9 (2%)	0.14 (0.07 to 0.25)	0.0 (0.0 to 3.0)	33.0 (24.0 to 110.0)	0.2 (0.1 to 0.4)
Undiagnosed	13 (2%)	0.20 (0.11 to 0.33)	1.0 (0.0 to 5.0)	34.0 (24.0 to 92.0)	0.5 (0.3 to 0.7)
Abdomen	4 (1%)	0.06 (0.02 to 0.14)	3.5 (2.3 to 4.0)	80.0 (46.5 to 112.8)	0.2 (0.1 to 0.3)
Muscle/tendon	2 (0%)	0.03 (0.01 to 0.10)	1.5 (0.8 to 2.3)	71.3 (52.0 to 90.0)	0.1 (0.0 to 0.1)
Abdominal wall strain	2 (0%)	0.03 (0.01 to 0.10)	1.5 (0.8 to 2.3)	71.3 (52.0 to 90.0)	0.1 (0.0 to 0.1)
Non-specific	1 (0%)	0.02 (0.00 to 0.07)	4.0 (4.0 to 4.0)	51.0 (51.0 to 51.0)	0.1 (0.0 to 0.1)
Other abdominal injury	1 (0%)	0.02 (0.00 to 0.07)	4.0 (4.0 to 4.0)	51.0 (51.0 to 51.0)	0.1 (0.0 to 0.1)
Undiagnosed	1 (0%)	0.02 (0.00 to 0.07)	4.0 (4.0 to 4.0)	124.0 (124.0 to 124.0)	0.1 (0.0 to 0.1)
Hip/groin	62 (11%)	0.94 (0.72 to 1.19)	2.0 (1.0 to 6.0)	68.0 (48.0 to 145.5)	10.0 (9.2 to 10.8)
Muscle/tendon	14 (3%)	0.21 (0.12 to 0.35)	5.0 (2.0 to 9.3)	120.3 (86.0 to 323.8)	1.8 (1.5 to 2.2)
Iliopsoas strain	10 (2%)	0.15 (0.08 to 0.27)	6.0 (3.3 to 9.3)	125.3 (116.3 to 393.5)	1.5 (1.2 to 1.8)
Gluteus medius strain	2 (0%)	0.03 (0.01 to 0.10)	11.0 (6.5 to 15.5)	241.5 (171.3 to 311.8)	0.3 (0.2 to 0.5)
Sports Hernia	2 (0%)	0.03 (0.01 to 0.10)	0.0 (0.0 to 0.0)	72.0 (68.3 to 76.8)	0.0 (0.0 to 0.0)
Bone	6 (1%)	0.09 (0.04 to 0.19)	13.5 (4.5 to 78.8)	217.8 (90.8 to 825.0)	4.3 (3.8 to 4.8)
Pubic stress fracture	1 (0%)	0.02 (0.00 to 0.07)	98.0 (98.0 to 98.0)	1000.0 (1000.0 to 1000.0)	1.5 (1.2 to 1.8)
Osteitis Pubis	5 (1%)	0.08 (0.03 to 0.17)	6.0 (4.0 to 21.0)	135.0 (76.0 to 300.0)	2.8 (2.4 to 3.2)
Cartilage/synovium/bursa	2 (0%)	0.03 (0.01 to 0.10)	52.0 (33.0 to 71.0)	838.0 (511.8 to 1165.3)	1.6 (1.3 to 1.9)

Body region Tissue type *Diagnoses*	**Injuries** N (%)	**Incidence** Injuries per 1000 h (95% CI)	**Time loss** Median days lost (interquartile range)	**OSTRC-H severity score** Median severity score (interquartile range)	**Injury burden** Days lost per 1000 h (95% CI)
Hip labral tear	1 (0%)	0.02 (0.00 to 0.07)	90.0 (90.0 to 90.0)	1492.0 (1492.0 to 1492.0)	1.4 (1.1 to 1.7)
Greater trochanteric bursitis / snapping hip syndrome	1 (0%)	0.02 (0.00 to 0.07)	14.0 (14.0 to 14.0)	185.0 (185.0 to 185.0)	0.2 (0.1 to 0.4)
Superficial tissues/skin	1 (0%)	0.02 (0.00 to 0.07)	0.0 (0.0 to 0.0)	16.0 (16.0 to 16.0)	0.0 (0.0 to 0.0)
Hip Contusion	1 (0%)	0.02 (0.00 to 0.07)	0.0 (0.0 to 0.0)	16.0 (16.0 to 16.0)	0.0 (0.0 to 0.0)
Non-specific	14 (3%)	0.21 (0.12 to 0.35)	2.0 (1.0 to 6.5)	63.5 (48.8 to 148.8)	1.5 (1.2 to 1.8)
Other hip injury	14 (3%)	0.21 (0.12 to 0.35)	2.0 (1.0 to 6.5)	63.5 (48.8 to 148.8)	1.5 (1.2 to 1.8)
Undiagnosed	25 (4%)	0.38 (0.25 to 0.55)	2.0 (1.0 to 2.0)	50.0 (33.0 to 58.0)	0.8 (0.6 to 1.0)
Thigh	143 (26%)	2.16 (1.83 to 2.54)	3.0 (1.0 to 7.5)	91.5 (41.0 to 179.0)	14.7 (13.8 to 15.7)
Muscle/tendon	112 (20%)	1.69 (1.40 to 2.03)	4.0 (1.0 to 9.0)	102.0 (50.0 to 208.8)	13.8 (12.9 to 14.7)
Quadriceps muscle injury	34 (6%)	0.51 (0.36 to 0.71)	2.5 (1.0 to 7.0)	91.0 (33.3 to 146.5)	2.7 (2.3 to 3.1)
Hamstring muscle injury	38 (7%)	0.57 (0.41 to 0.78)	7.0 (3.0 to 13.0)	163.0 (100.3 to 312.3)	7.9 (7.3 to 8.6)
Adductor muscle injury	33 (6%)	0.50 (0.35 to 0.69)	4.0 (0.0 to 9.0)	118.0 (50.0 to 202.0)	3.1 (2.7 to 3.5)
Sartorius strain	2 (0%)	0.03 (0.01 to 0.10)	1.0 (1.0 to 1.0)	59.0 (46.5 to 71.5)	0.0 (0.0 to 0.1)
Quadraceps contusion	5 (1%)	0.08 (0.03 to 0.17)	1.0 (0.0 to 2.0)	50.0 (41.0 to 59.0)	0.2 (0.1 to 0.3)
Bone	1 (0%)	0.02 (0.00 to 0.07)	3.0 (3.0 to 3.0)	74.0 (74.0 to 74.0)	0.1 (0.0 to 0.1)
Ischium growth plate / physeal injury	1 (0%)	0.02 (0.00 to 0.07)	3.0 (3.0 to 3.0)	74.0 (74.0 to 74.0)	0.1 (0.0 to 0.1)
Non-specific	3 (1%)	0.05 (0.01 to 0.12)	1.0 (0.5 to 2.0)	33.0 (45074 to 94.5)	0.1 (0.0 to 0.1)
Other thigh injury	3 (1%)	0.05 (0.01 to 0.12)	1.0 (0.5 to 2.0)	33.0 (45074 to 94.5)	0.1 (0.0 to 0.1)
Undiagnosed	27 (5%)	0.41 (0.27 to 0.58)	1.0 (0.0 to 2.5)	41.5 (45074 to 71.0)	0.8 (0.6 to 1.1)
Knee	86 (15%)	1.30 (1.05 to 1.60)	3.0 (1.0 to 13.0)	103.0 (50.3 to 246.0)	55.4 (53.7 to 57.2)
Muscle/tendon	10 (2%)	0.15 (0.08 to 0.27)	1.0 (0.0 to 2.8)	82.8 (45011 to 207.8)	0.5 (0.3 to 0.6)
Biceps Femoris tendinopathy	1 (0%)	0.02 (0.00 to 0.07)	13.0 (13.0 to 13.0)	393.0 (393.0 to 393.0)	0.2 (0.1 to 0.3)
Pes anserine tendinopathy	2 (0%)	0.03 (0.01 to 0.10)	0.0 (0.0 to 0.0)	40.0 (28.0 to 52.0)	0.0 (0.0 to 0.0)
Patellar tendinopathy	6 (1%)	0.09 (0.04 to 0.19)	2.0 (0.5 to 2.8)	137.8 (50.0 to 207.8)	0.3 (0.2 to 0.4)
Popliteus tendinopathy	1 (0%)	0.02 (0.00 to 0.07)	0.0 (0.0 to 0.0)	16.0 (16.0 to 16.0)	0.0 (0.0 to 0.0)
Bone	1 (0%)	0.02 (0.00 to 0.07)	9.0 (9.0 to 9.0)	202.0 (202.0 to 202.0)	0.1 (0.1 to 0.3)
Intrarticular fracture of femur	1 (0%)	0.02 (0.00 to 0.07)	9.0 (9.0 to 9.0)	202.0 (202.0 to 202.0)	0.1 (0.1 to 0.3)
Cartilage/synovium/bursa	13 (2%)	0.20 (0.11 to 0.33)	3.0 (1.0 to 12.0)	143.0 (24.0 to 200.0)	6.9 (6.3 to 7.5)
Loose body of knee	1 (0%)	0.02 (0.00 to 0.07)	37.0 (37.0 to 37.0)	1252.0 (1252.0 to 1252.0)	0.6 (0.4 to 0.8)
Patellofemoral chondromalacia	1 (0%)	0.02 (0.00 to 0.07)	1.0 (1.0 to 1.0)	24.0 (24.0 to 24.0)	0.0 (0.0 to 0.1)
Patellofemoral pain syndrome	3 (1%)	0.05 (0.01 to 0.12)	0.0 (0.0 to 1.5)	45070 (24.0 to 83.5)	0.1 (0.0 to 0.1)
Meniscal tear	2 (0%)	0.03 (0.01 to 0.10)	182.5 (95.3 to 269.8)	1500.8 (850.0 to 2150.0)	5.5 (5.0 to 6.1)
Fat pad syndrome / plica	2 (0%)	0.03 (0.01 to 0.10)	2.0 (1.5 to 2.5)	50.5 (41.8 to 59.3)	0.1 (0.0 to 0.1)
Knee bursitis - prepatellar; infrapatellar; pes anserine	4 (1%)	0.06 (0.02 to 0.14)	12.0 (9.0 to 14.3)	184.3 (144.0 to 204.3)	0.7 (0.5 to 0.9)
Ligament/joint capsule	18 (3%)	0.27 (0.17 to 0.42)	41.5 (8.3 to 325.0)	662.0 (142.8 to 5168.0)	41.4 (39.9 to 43.0)
Medial collateral ligament injury	9 (2%)	0.14 (0.07 to 0.25)	8.0 (4.0 to 19.0)	140.0 (116.0 to 307.0)	2.0 (1.7 to 2.3)
Lateral collateral ligament 1° sprain- acute	1 (0%)	0.02 (0.00 to 0.07)	13.0 (13.0 to 13.0)	268.0 (268.0 to 268.0)	0.2 (0.1 to 0.3)
Anterior cruciate ligament injury	8 (1%)	0.12 (0.06 to 0.23)	325.0 (325.0 to 325.0)	5168.0 (5168.0 to 5168.0)	39.3 (37.8 to 40.8)

Body region Tissue type *Diagnoses*	**Injuries** N (%)	**Incidence** Injuries per 1000 h (95% CI)	**Time loss** Median days lost (interquartile range)	**OSTRC-H severity score** Median severity score (interquartile range)	**Injury burden** Days lost per 1000 h (95% CI)
Superficial tissues/skin	6 (1%)	0.09 (0.04 to 0.19)	2.0 (1.0 to 8.3)	50.3 (48.5 to 175.5)	0.4 (0.3 to 0.6)
Knee contusion	6 (1%)	0.09 (0.04 to 0.19)	2.0 (1.0 to 8.3)	50.3 (48.5 to 175.5)	0.4 (0.3 to 0.6)
Non-specific	17 (3%)	0.26 (0.16 to 0.40)	4.0 (2.0 to 8.0)	92.0 (65.0 to 200.0)	4.7 (4.2 to 5.2)
Other knee injury	17 (3%)	0.26 (0.16 to 0.40)	4.0 (2.0 to 8.0)	92.0 (65.0 to 200.0)	4.7 (4.2 to 5.2)
Undiagnosed	21 (4%)	0.32 (0.20 to 0.48)	2.0 (1.0 to 3.0)	67.0 (42.0 to 113.0)	1.4 (1.2 to 1.8)
Lower leg	38 (7%)	0.57 (0.41 to 0.78)	2.0 (0.3 to 6.8)	59.8 (32.3 to 148.8)	8.2 (7.5 to 8.9)
Muscle/tendon	20 (4%)	0.30 (0.19 to 0.46)	2.5 (1.0 to 8.0)	62.0 (32.8 to 212.8)	7.4 (6.7 to 8.0)
Other leg muscle strain	1 (0%)	0.02 (0.00 to 0.07)	5.0 (5.0 to 5.0)	59.0 (59.0 to 59.0)	0.1 (0.0 to 0.2)
Gastrocnemius muscle injury	9 (2%)	0.14 (0.07 to 0.25)	1.0 (1.0 to 3.0)	42.0 (24.0 to 68.0)	2.8 (2.4 to 3.2)
Soleus muscle injury	3 (1%)	0.05 (0.01 to 0.12)	1.0 (0.5 to 2.0)	32.0 (28.0 to 45.5)	0.1 (0.0 to 0.1)
Peroneus strain	1 (0%)	0.02 (0.00 to 0.07)	7.0 (7.0 to 7.0)	209.0 (209.0 to 209.0)	0.1 (0.1 to 0.2)
Achilles tendinopathy	5 (1%)	0.08 (0.03 to 0.17)	7.0 (2.0 to 21.0)	118.0 (67.0 to 690.0)	1.1 (0.9 to 1.4)
Achilles Tendon rupture	1 (0%)	0.02 (0.00 to 0.07)	213.0 (213.0 to 213.0)	2576.0 (2576.0 to 2576.0)	3.2 (2.8 to 3.7)
Bone	3 (1%)	0.05 (0.01 to 0.12)	10.0 (5.5 to 11.5)	185.5 (122.0 to 234.5)	0.4 (0.2 to 0.5)
Medial tibial stress syndrome	3 (1%)	0.05 (0.01 to 0.12)	10.0 (5.5 to 11.5)	185.5 (122.0 to 234.5)	0.4 (0.2 to 0.5)
Superficial tissues/skin	4 (1%)	0.06 (0.02 to 0.14)	0.0 (0.0 to 1.0)	59.0 (48.8 to 76.0)	0.1 (0.0 to 0.1)
Leg contusion	4 (1%)	0.06 (0.02 to 0.14)	0.0 (0.0 to 1.0)	59.0 (48.8 to 76.0)	0.1 (0.0 to 0.1)
Non-specific	1 (0%)	0.02 (0.00 to 0.07)	0.0 (0.0 to 0.0)	41.0 (41.0 to 41.0)	0.0 (0.0 to 0.0)
Other leg injury	1 (0%)	0.02 (0.00 to 0.07)	0.0 (0.0 to 0.0)	41.0 (41.0 to 41.0)	0.0 (0.0 to 0.0)
Undiagnosed	10 (2%)	0.15 (0.08 to 0.27)	1.5 (0.3 to 2.8)	45167 (18.0 to 56.3)	0.4 (0.2 to 0.5)
Ankle	79 (14%)	1.19 (0.95 to 1.48)	2.0 (1.0 to 7.0)	66.0 (41.0 to 199.5)	16.7 (15.8 to 17.7)
Muscle/tendon	4 (1%)	0.06 (0.02 to 0.14)	21.0 (0.8 to 44.8)	412.8 (45158 to 831.8)	1.5 (1.2 to 1.8)
Ankle extensor tendinopathy	2 (0%)	0.03 (0.01 to 0.10)	21.0 (11.0 to 31.0)	476.0 (250.5 to 701.5)	0.6 (0.5 to 0.9)
Ankle extensor tenonsynovitis (including lace bite)	1 (0%)	0.02 (0.00 to 0.07)	0.0 (0.0 to 0.0)	8.0 (8.0 to 8.0)	0.0 (0.0 to 0.0)
Ankle extensor tendon rupture	1 (0%)	0.02 (0.00 to 0.07)	56.0 (56.0 to 56.0)	800.0 (800.0 to 800.0)	0.9 (0.7 to 1.1)
Nervous	1 (0%)	0.02 (0.00 to 0.07)	6.0 (6.0 to 6.0)	175.0 (175.0 to 175.0)	0.1 (0.0 to 0.2)
Tarsal tunnel syndrome	1 (0%)	0.02 (0.00 to 0.07)	6.0 (6.0 to 6.0)	175.0 (175.0 to 175.0)	0.1 (0.0 to 0.2)
Bone	2 (0%)	0.03 (0.01 to 0.10)	108.0 (55.5 to 160.5)	1672.5 (925.3 to 2419.8)	3.3 (2.9 to 3.7)
Talus stress fracture	1 (0%)	0.02 (0.00 to 0.07)	213.0 (213.0 to 213.0)	3167.0 (3167.0 to 3167.0)	3.2 (2.8 to 3.7)
Talar dome contusion	1 (0%)	0.02 (0.00 to 0.07)	3.0 (3.0 to 3.0)	178.0 (178.0 to 178.0)	0.1 (0.0 to 0.1)
Cartilage/synovium/bursa	3 (1%)	0.05 (0.01 to 0.12)	0.0 (0.0 to 0.5)	45070 (16.0 to 36.0)	0.0 (0.0 to 0.1)
Anterior ankle impingement	1 (0%)	0.02 (0.00 to 0.07)	0.0 (0.0 to 0.0)	8.0 (8.0 to 8.0)	0.0 (0.0 to 0.0)
Posterior ankle impingement	2 (0%)	0.03 (0.01 to 0.10)	0.5 (0.3 to 0.8)	36.8 (30.0 to 42.0)	0.0 (0.0 to 0.1)
Ligament/joint capsule	34 (6%)	0.51 (0.36 to 0.71)	2.5 (1.3 to 11.3)	73.3 (48.5 to 237.5)	9.3 (8.6 to 10.0)
Deltoid ligament sprain	7 (1%)	0.11 (0.05 to 0.21)	7.0 (1.5 to 10.5)	159.5 (73.0 to 300.5)	0.7 (0.5 to 0.9)
Lateral ligament sprain	23 (4%)	0.35 (0.23 to 0.51)	2.0 (1.5 to 7.5)	51.5 (42.0 to 138.0)	2.8 (2.4 to 3.2)
Tibiofibular ligament syndesmosis injury	3 (1%)	0.05 (0.01 to 0.12)	127.5 (80.8 to 174.3)	1277.3 (922.8 to 1632.3)	5.8 (5.2 to 6.4)
Ankle functional instability	1 (0%)	0.02 (0.00 to 0.07)	1.0 (1.0 to 1.0)	65.0 (65.0 to 65.0)	0.0 (0.0 to 0.1)

Body region Tissue type *Diagnoses*	**Injuries** N (%)	**Incidence** Injuries per 1000 h (95% CI)	**Time loss** Median days lost (interquartile range)	**OSTRC-H severity score** Median severity score (interquartile range)	**Injury burden** Days lost per 1000 h (95% CI)
Superficial tissues/skin	3 (1%)	0.05 (0.01 to 0.12)	1.0 (1.0 to 2.5)	32.5 (45074 to 168.0)	0.1 (0.0 to 0.2)
Ankle contusion	3 (1%)	0.05 (0.01 to 0.12)	1.0 (1.0 to 2.5)	32.5 (45074 to 168.0)	0.1 (0.0 to 0.2)
Non-specific	6 (1%)	0.09 (0.04 to 0.19)	1.0 (0.3 to 1.8)	41.8 (34.3 to 73.3)	0.5 (0.3 to 0.7)
Other ankle injury	6 (1%)	0.09 (0.04 to 0.19)	1.0 (0.3 to 1.8)	41.8 (34.3 to 73.3)	0.5 (0.3 to 0.7)
Undiagnosed	26 (5%)	0.39 (0.26 to 0.57)	2.0 (1.0 to 4.0)	66.0 (41.3 to 167.0)	2.1 (1.7 to 2.4)
Foot	66 (12%)	1.00 (0.78 to 1.26)	3.0 (1.0 to 14.0)	109.0 (60.3 to 282.8)	11.8 (11.0 to 12.7)
Muscle/tendon	7 (1%)	0.11 (0.05 to 0.21)	13.0 (7.0 to 17.0)	304.0 (166.5 to 551.5)	1.4 (1.2 to 1.8)
Plantar fasciitis	7 (1%)	0.11 (0.05 to 0.21)	13.0 (7.0 to 17.0)	304.0 (166.5 to 551.5)	1.4 (1.2 to 1.8)
Bone	10 (2%)	0.15 (0.08 to 0.27)	16.0 (7.8 to 63.3)	271.3 (130.0 to 975.3)	5.2 (4.6 to 5.7)
Calcaneal fracture	1 (0%)	0.02 (0.00 to 0.07)	18.0 (18.0 to 18.0)	300.0 (300.0 to 300.0)	0.3 (0.2 to 0.4)
Metatarsal fracture (2-4)	1 (0%)	0.02 (0.00 to 0.07)	14.0 (14.0 to 14.0)	242.0 (242.0 to 242.0)	0.2 (0.1 to 0.4)
5th metatarsal fracture/ Jones' fracture	1 (0%)	0.02 (0.00 to 0.07)	103.0 (103.0 to 103.0)	1585.0 (1585.0 to 1585.0)	1.6 (1.3 to 1.9)
Phalyngeal fracture- toes	1 (0%)	0.02 (0.00 to 0.07)	0.0 (0.0 to 0.0)	41.0 (41.0 to 41.0)	0.0 (0.0 to 0.0)
Pump bumps	1 (0%)	0.02 (0.00 to 0.07)	1.0 (1.0 to 1.0)	91.0 (91.0 to 91.0)	0.0 (0.0 to 0.1)
Heel spur	1 (0%)	0.02 (0.00 to 0.07)	77.0 (77.0 to 77.0)	1092.0 (1092.0 to 1092.0)	1.2 (0.9 to 1.4)
Cuboid stress fracture	1 (0%)	0.02 (0.00 to 0.07)	71.0 (71.0 to 71.0)	1338.0 (1338.0 to 1338.0)	1.1 (0.8 to 1.3)
Navicular stress fracture	1 (0%)	0.02 (0.00 to 0.07)	40.0 (40.0 to 40.0)	625.0 (625.0 to 625.0)	0.6 (0.4 to 0.8)
Sesamoiditis	1 (0%)	0.02 (0.00 to 0.07)	10.0 (10.0 to 10.0)	193.0 (193.0 to 193.0)	0.2 (0.1 to 0.3)
Calcaneal apohysitis/ Sever's disease	1 (0%)	0.02 (0.00 to 0.07)	7.0 (7.0 to 7.0)	109.0 (109.0 to 109.0)	0.1 (0.1 to 0.2)
Cartilage/synovium/bursa	1 (0%)	0.02 (0.00 to 0.07)	38.0 (38.0 to 38.0)	603.0 (603.0 to 603.0)	0.6 (0.4 to 0.8)
Turf toe	1 (0%)	0.02 (0.00 to 0.07)	38.0 (38.0 to 38.0)	603.0 (603.0 to 603.0)	0.6 (0.4 to 0.8)
Ligament/joint capsule	1 (0%)	0.02 (0.00 to 0.07)	62.0 (62.0 to 62.0)	1035.0 (1035.0 to 1035.0)	0.9 (0.7 to 1.2)
Lisfranc injury	1 (0%)	0.02 (0.00 to 0.07)	62.0 (62.0 to 62.0)	1035.0 (1035.0 to 1035.0)	0.9 (0.7 to 1.2)
Superficial tissues/skin	6 (1%)	0.09 (0.04 to 0.19)	2.0 (1.3 to 2.8)	112.8 (71.5 to 134.0)	0.2 (0.1 to 0.4)
Foot contusion	6 (1%)	0.09 (0.04 to 0.19)	2.0 (1.3 to 2.8)	112.8 (71.5 to 134.0)	0.2 (0.1 to 0.4)
Non-specific	15 (3%)	0.23 (0.13 to 0.36)	2.0 (0.5 to 5.0)	71.0 (53.0 to 127.0)	1.4 (1.1 to 1.7)
Other foot injury	11 (2%)	0.17 (0.09 to 0.29)	2.0 (1.5 to 4.0)	71.0 (63.0 to 102.0)	0.8 (0.6 to 1.1)
Metatarsalgia	2 (0%)	0.03 (0.01 to 0.10)	18.5 (11.8 to 25.3)	405.3 (277.8 to 533.3)	0.6 (0.4 to 0.8)
Excessive supination / pes cavus	2 (0%)	0.03 (0.01 to 0.10)	0.0 (0.0 to 0.0)	36.0 (34.3 to 38.8)	0.0 (0.0 to 0.0)
Undiagnosed	26 (5%)	0.39 (0.26 to 0.57)	2.0 (1.0 to 6.5)	87.5 (51.0 to 136.5)	2.1 (1.8 to 2.5)
Region unspecified	4 (1%)	0.06 (0.02 to 0.14)	4.0 (0.8 to 7.5)	66.5 (32.8 to 131.3)	0.3 (0.2 to 0.4)

Paper II

#ReadyToPlay: Hamstring injuries in women's football – a two-season prospective cohort study in the Norwegian women's premier league

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Abstract

In this two-season prospective cohort study (2020-2021) we aimed to describe the characteristics, clinical findings and magnetic resonance imaging (MRI) findings of hamstring injuries in the Norwegian women's premier league. Hamstring injuries were examined by team physiotherapists using a standardised clinical examination and injury form. Injury location and severity (modified Peetrons classification) were graded based on MRI by two independent radiologists. Fifty-three hamstring injuries were clinically examined, 31 of these with MRI. Hamstring injuries caused 8 days (median) lost from football (interquartile range: 3-15 days, range: 0-188 days), most were non-contact and occurred during sprinting. Gradual-onset (53%) and sudden-onset injuries (47%) were evenly distributed. The injuries examined with MRI were classified as grade 0 (52%), grade 1 (16%) or grade 2 (29%). One proximal tendinopathy case was not graded. Grade 2 injuries caused more time loss than grade 0 (19±8 vs. 7±7 days, $p=0.002$). Of injuries with MRI changes, 60% were in the m. biceps femoris, mainly the muscle-tendon junction, and 40% in the m. semimembranosus, most in the proximal tendon. Compared to previous findings from men's football, a higher proportion of hamstring injuries in women's football had a gradual onset and involved the m. semimembranosus, particularly its proximal tendon.

Keywords: Football, women, female, injuries, injury, hamstring

Introduction

Training and match demands in women's football have soared during the last decades [1, 2], and may have altered the injury risk players face. Hamstring injuries are now one of the most common injury types in the women's game [3], as it has been in men's football for years [4-6]. Preventing injuries is essential for football teams as they can negatively affect performance and player development [7-10].

Preventive measures should be sport-specific [11] and consider sex, level of competition and injury profile to inform the content [12]. The fundamental first steps to develop effective injury prevention programs are to obtain information about the nature of injuries and how they happen [11]. When assessing hamstring injuries it is considered important to take a careful history, palpate the muscle bellies, and test knee flexion against resistance [13]. Imaging to provide information about the injury is also useful, preferably by magnetic resonance imaging (MRI), the most accurate and reliable imaging method to classify hamstring injuries [13, 14].

While hamstring injuries in men's football are well described in the literature [15], there is currently limited data available on the nature of hamstring injuries and their mechanisms in female football players [16]. Applying what we know from men's football is unlikely to provide a complete understanding of injuries in women's football [17]. Currently, most injury prevention programs are believed to be less effective for female compared to male football players [12], and one reason for this could be that preventative programs for most injury types have been developed based on data from men only.

Therefore, we aimed to describe the characteristics, clinical findings and MRI findings of hamstring injuries in women's football.

Materials and methods

Study design and participants

This in depth-study of hamstring injuries was based on a two-season prospective cohort study (2020 and 2021) in the Norwegian premier league of women's football (Toppserien, UEFA club coefficients ranking[18]: 12th), where 294 players (age: 22±4 yrs.) self-reported all health problems weekly [19]. In the current project, all hamstring injuries meeting our severity criteria (see below) were clinically examined by the team physiotherapists using a standardised protocol and investigated with MRI.

The project was approved by the Norwegian School of Sports Sciences ethics board (#129-051219) and the Norwegian Centre for Research Data (#662612). The players included were part of a premier league club's first team squad, were >16 years old and provided individual written consent to participate.

Definitions

Players were asked to report all health problems, meaning any condition causing a reduction in their normal state of full health, irrespective of its consequence on sports participation or performance or whether the player sought medical attention [20-22]. A hamstring injury was defined as an injury to the posterior thigh that negatively affected the player's participation or performance. Subsequent hamstring injuries to the same thigh and tissue that occurred after the index injury had fully recovered was defined as recurrences [20]. Injuries were classified as non-contact, indirect contact or direct contact [20]. Sudden-onset injuries were caused by a single, clearly identifiable energy transfer, and gradual-onset injuries were caused by multiple accumulative bouts of energy transfer without a single, clearly identifiable event responsible for the injury [20]. Injuries with gradual onset at first followed by sudden deterioration of the injury were classified as gradual-onset injuries with a sudden deterioration. Training was defined as physical activities performed by the player aimed at maintaining or improving their skills, physical condition and/or performance in football, with sub-categories football training and strength and conditioning [20, 21]. Match was defined as organised scheduled match play between opposing teams (not including internal training matches) [20, 21].

Player's self-reporting of injuries

The players included in the prospective cohort study self-reported all health problems by answering the updated version of the Oslo Sports Trauma Research Center questionnaire on health problems (OSTRC-H2) [22] weekly in a mobile app (AthleteMonitoring, Fitstats Inc., New Brunswick, Canada). The OSTRC-H2 consists of four questions asking if the players had any health problem during the previous week, and if so, how it has affected their training volume and performance and to what extent they have experienced symptoms. If a player reported a new injury, she described the injury location, the activity (match/training/other), the mechanism of injury (e.g. sprinting, tackled), the date of injury occurrence, and how many days of absence the injury caused during the previous week. If the player had the same injury for several weeks, she could choose the previously reported injury from a drop-down list and only report days lost the subsequent weeks. When a player reported to no longer be affected by the injury, it was considered fully recovered.

Automatic reminders to complete the questionnaire were sent to the players every Sunday. If players did not respond, automatic reminders were sent every day of the week until the questionnaire was completed. Additionally, we (RA and ST) sent an SMS reminder to non-responders after 3 days. All teams had at least one physiotherapist with access to the players' reports that were responsible for following up the reported health problems.

Standardised examination and hamstring injury form

If a player sustained a hamstring injury, her team physiotherapist performed a standardised clinical examination and completed a hamstring injury form. We developed the examination and injury form based on the literature [13, 23-25] and presented this to the team physiotherapists prior to the start of the project.

The hamstring injury form provided information about the injury date, onset (sudden/gradual/gradual with sudden deterioration), activity (football training/match/other), leg (dominant/non-dominant), previous hamstring injuries, and the inciting event was described in free text and by choosing from one or more of the following options: sprinting, running, changing direction, jumping, landing, falling, shooting/passing, dribbling, tackling, lunging, reaching with leg, passive stretch and other. The physiotherapist then examined the player, reporting whether there was any visible hematoma, tenderness on palpation of the lateral or medial part of the hamstrings, the distance from the ischial tuberosity to the point of maximal tenderness, the length and width of the tender area, and if the player experienced pain during the maximal hip flexion active knee extension test (MHFAKE), outer-range strength test and mid-range strength test [23]. Lastly, the physiotherapists reported their diagnosis as free text.

The physiotherapists were instructed to perform the examination and submit the form to the research group as soon as possible after a player sustained a hamstring injury. To ensure no hamstring injuries were missed, we (RA) monitored all self-reported health problems each week and contacted the team physiotherapist whenever a posterior thigh injury had been reported. Hamstring injuries that were not self-reported (e.g. in players with low response rate) but identified by the team physiotherapist were also included.

MRI examination and assessment

If the hamstring injury caused >3 days lost or affected the player for ≥2 weeks in a row, an MRI appointment was ordered via the Norwegian Football Association's Sports Medicine Centre (Idrettens helsesenter) at a designated radiology clinic (Evidia or Unilabs) nearby the player's residence. All radiology clinics used MRI machines with a field strength of 1.5 T. MR sequences included T1, T2, Short Tau Inversion Recovery (STIR), and proton-density (PD) with fat saturation and were performed in coronal, axial and sagittal planes.

Two experienced musculoskeletal radiologists (AL and RP) blinded to clinical status assessed and scored the injuries on a standardised MRI scoring form based on the literature [15, 24, 26-29]. They scored all cases independently following the 2021 season and, in cases of disagreement, they reached consensus after re-assessing the scans together. Before commencing, they were familiarised with the scoring form by assessing, discussing and agreeing on hamstring injury MRIs from patients not involved in the project.

If there were more than one lesion on the same MRI, each lesion was scored separately; the most severe injury was considered the primary lesion. In the scoring form, they first defined which muscle were involved and the location of the injury as follows: (1) proximal tendon, i.e. free tendon proximal to muscle fibre attachment, (2) proximal muscle-tendon junction, i.e. proximal intramuscular tendon and attached muscle fibres, (3) proximal muscle-belly, i.e. muscle proximal to the midpoint of the whole muscle-belly, (4) distal muscle-tendon junction, i.e. distal intramuscular tendon and attached muscle fibres, (5) distal muscle-belly, i.e. muscle distal to the midpoint of the whole muscle-belly, and (6) distal tendon, i.e. free tendon distal to muscle fibre attachment [24, 28]. They also evaluated whether the injury had myofascial involvement and if there were signs of structural damage to the free or intramuscular tendon, either by a focal defect separating proximal and distal parts of the tendon, or waviness (in place of the normal straight margins) suggesting loss of structural tension [26]. The distance from the most cranial pole of the injury to the most caudal part of the ischial tuberosity was measured [24], and the site of injury was defined as the proximal, middle or distal third of the muscle. The proximal third was considered to be above the lower margin of the gluteus maximus and the distal third below the origin of the short head of biceps femoris [27]. The injury severity was graded with an MRI modification of Peetrons classification (grade 0: negative MRI, grade 1: edema but no architectural distortion to muscle or tendon, grade 2: architectural disruption indicating partial tear of muscle or tendon, grade 3: total muscle or tendon rupture) [15, 29, 30].

Statistical analyses

Statistical analyses were done in IBM SPSS Statistics 28.0. The distance from the injury to the ischial tuberosity evaluated on MRI was reported as the mean of the measurements of the two radiologists. The time loss was the total number of days of absence the players reported in their weekly reports. We analysed the difference in time loss between injuries with different severity and onset using one-way analysis of variance, and Tukey HSD as post hoc test. Shapiro-Wilk test and Levene's test were used to test the assumptions of normality and homogeneity of variances, respectively. The significance level was set at $p<0.05$.

Results

During the 2020 and 2021 seasons, 73 hamstring injuries were reported to occur during training or match play (Figure 1) by either player's self-reports (N=59) or directly from the team physiotherapists (N=14). Twenty self-reported hamstring injuries (median: 2 days lost, interquartile range: 0- 3 days) were not examined clinically because the team physiotherapist did not consider them to be injuries but represent muscle soreness or muscle fatigue, or the player recovered before the physiotherapist were able to examine her. Standardised examinations were completed of 53 hamstring injuries in 42 different players (age: 25±5 yrs., positions: goalkeepers 2%, central defenders 21%, fullbacks 19%, central midfielders 19%, wingers 26%, strikers 12%). Six injuries (11%) were recurrences, occurring 117 days (median, interquartile range: 60-346 days) following the index injury. Five players suffered hamstring injuries to both thighs. Thirty-one injuries were investigated using MRI. Two players had two MRIs of the same thigh taken (32-59 days apart), and three players had MRIs of both thighs.

FIGURE 1 HERE

Injury history and clinical examination

The median time from injury occurrence to clinical examination by a physiotherapist was 3 days (interquartile range: 1-10 days, range: 0-29 days). Nineteen of the 42 players who sustained a hamstring injury (45%) reported having had a hamstring injury prior to the start of the project. The characteristics of the 53 injuries are presented in Table 1. Of the match injuries, 54% occurred during the first half, 21% during the second half and 25% had their first symptoms during the match but the player completed the match before reporting the problem to their physiotherapist.

TABLE 1 HERE

The physiotherapists reported 1.3±0.8 (range: 0-4) injury mechanisms per injury (Figure 2). Sprinting and running were the most frequently reported mechanisms. Most hamstring injuries (94%) had a non-contact mechanism; in two cases (4%) there was indirect contact (one injury with missing data).

FIGURE 2 HERE

For 91% of the injuries (48 of 53), the players reported palpation tenderness, most often located to the medial hamstring muscles (Table 1). The point with maximal palpation tenderness was 11±10 cm (range: 0-32 cm) distal to the ischial tuberosity (N=39, missing data for 9 injuries), and the length and width of the painful area was 4±4 cm (range: 1-19 cm) and 3±2 cm (range: 1-12 cm), respectively (N=47, missing data for 1 injury). Most players (81%) reported pain in the injured thigh during at least one of the three clinical tests; MHFAKE-test (43%), outer-range strength test (64%), mid-range strength test (60%). At the time of assessment, none of the injuries had a visible hematoma.

Time loss was reported for 39 of the 53 injuries (missing data from the 14 injuries not self-reported). Hamstring injuries caused 8 days (median) of absence from full unrestricted football activity (interquartile range: 3-15 days, range: 0-188 days). There were no significant differences in time loss between injuries with sudden onset (13±9, 95% CI: 8-18 days, N=16), gradual onset (20±47, 95% CI: 0-46 days, N=15) and gradual onset with sudden deterioration (7±4, 95% CI: 4-10 days, N=8). Index injuries caused 8 days (median) absence (interquartile range: 2-13 days, range 0-188 days, N=35), while recurrences caused 20 days (interquartile range: 5-29, range 3-29, N=4).

MRI analyses

MRIs were taken 26 days (median) after the reported injury date (interquartile range: 13-38 days, range: 3-122 days). Sixteen of the 31 injuries assessed by MRI were grade 0 (52%), 5 were grade 1 (16%) and 9 grade 2 (29%). There were no grade 3 injuries, and one injury (3%) was diagnosed as a proximal tendinopathy, and not given a severity grade. Two grade 2 injuries in the m. semimembranosus also had a secondary lesion, one located in the distal and one in the proximal common tendon. Only the primary lesions are included in the analyses.

Nearly all injuries in the m. biceps femoris long head involved the proximal or distal muscle-tendon junction, while injuries in m. semimembranosus were mainly located to the proximal tendon (Figure 3 and 4). No injuries involved the m. biceps femoris short head or the m. semitendinosus. Few injuries had myofascial involvement (3/15) or waviness of the tendon (1/15), none had focal defects separating the proximal from the distal part of the tendon.

FIGURE 3 AND 4 HERE

In the 15 injuries with MRI findings, the distance from the ischial tuberosity to the most proximal part of the lesion was 10±8 cm (N=14, missing data for one injury in the distal third because the image did not include the ischial tuberosity). Four injuries (27%) were located to the proximal third (BF_{LH}: 0, SM: 4), seven (47%) to the distal third (BF_{LH}: 6, SM: 1), two injuries (13%) were in the middle third (BF_{LH}: 2, SM: 0) and two (13%) spanned both the proximal and middle third (BF_{LH}: 1, SM: 1).

Grade 2 injuries caused significantly longer absence (19±8 days, 95% CI: 13-25 days, N=9) compared to grade 0 injuries (7±7 days, 95% CI: 3-11 days, N=12, p=0.002) and injuries examined clinically but not with MRI (5±4 days, 95% CI: 3-7 days, N=13, p<0.001). There was no significant difference between grade 2 and grade 1 injuries (11±12 days, 95% CI: 0 to 30 days, N=4, p=0.24). The injury diagnosed as a tendinopathy to the proximal tendon of m. semimembranosus caused 188 days of time loss.

FIGURE 5 HERE

Discussion

This is the first study to describe the characteristics of hamstring injuries in women's football. Sudden-onset and gradual-onset injuries were evenly distributed. Most injuries occurred during sprinting or running and had no structural changes on MRI. MRI severity grade was associated with days lost from full unrestricted football training or matches. Injuries to the m. biceps femoris long head were mainly located in the muscle-tendon junction, while injuries to the m. semimembranosus were mainly in the proximal tendon.

Injury mechanisms

Nearly all injuries were non-contact and the most injuries occurred sprinting and running, in line with previously reported data in both women's [31, 32] and men's football [15, 33]. In a recent systematic video analysis of hamstring injuries in men's football, all sprint-related hamstring injuries occurred during linear acceleration or high-speed running [34]. The demand for sprinting and high-intensity running in women's football is increasing rapidly [1], likely also increasing the risk of hamstring injuries. Therefore, risk factors for hamstring injuries in women's football should be investigated and specific preventative measures developed and tested.

Injury onset

The proportion of hamstring injuries with gradual onset (53%) was higher than reported in men's football (34-36%) [6, 15]. Overuse complaints have been reported to be more frequent in female than male football players [35]. However, our use of three categories for injury onset (sudden/gradual/gradual with sudden deterioration) rather than two (sudden/gradual) [20] may have contributed to the difference. Using self-reporting to identify injuries may also contribute to identify more gradual onset injuries compared to a traditional injury surveillance using a time-loss definition [36, 37].

Time-loss and recurrence

Hamstring injuries caused 8 days (median) of absence from full unrestricted football activity. This is similar to what has previously been reported in women's football: In the Irish league hamstring injuries caused 8 days lost (median) [3], 12 days lost (median) was reported in a study of a Spanish premier league team [38] and 10.5 days lost (mean) was reported in a German premier league team before implementing a prevention program in a crossover study [32]. Similar time loss has also been reported in men's football [6, 39].

Recurrences constituted 11% of all hamstring injuries, similar to the 12-16% reported in men's football [6, 15, 39]. Time loss for recurrences have previously been reported to be higher compared to the index injuries [4, 5], although not for hamstring injuries specifically [15]. We did not formally compare time loss between index injuries (median: 8 days, interquartile range: 2-13 days) and recurrences (median: 20 days, interquartile range: 5-29 days) due to the low number of recurrences.

Injury severity

About half the injuries examined by MRI did not show any structural changes. This could result from the large portion of gradual onset injuries identified. In men's football, overuse injuries dominated grade 0 hamstring injuries [15], and our data show that half of the grade 0 injuries had gradual onset compared to one in ten of the grade 2 injuries. However, also in men's football, with MRIs taken within 24-48 h after injury occurrence, most hamstring injuries show no signs of fibre disruption (13% grade 0 and 57% grade 1) [15]. We were not able to perform the MRIs within the same short time span. While MRI appearance do not change during the first 7 days after injury [28], the time from injury occurrence to MRI investigation exceeded this for most injuries in our study and may have contributed to the large proportion of grade 0 injuries.

Grade 2 injuries caused longer time loss than grade 0. An association between severity grade and time-loss has also been reported in men's football [15]. Still, we would not recommend clubs to routinely examine all hamstring injuries with MRI as it does not add value in predicting time to return to sport over patient history and clinical examination [40]. The limited resources should be prioritised elsewhere.

Injury location

As many as 40% of injuries with MRI changes were located in the m. semimembranosus. This is in contrast to findings in men's football, where the majority of hamstring injuries involve the m. biceps femoris (69-84%) and only 11-12% involve m. semimembranosus [15, 33, 39]. Nearly all injuries in the m. biceps femoris involved the muscle-tendon junction, which is considered highly susceptible to injuries [41]. Most injuries in the m. semimembranosus were found in the proximal tendon and addressing this should be a prevention priority in female players.

Strengths and limitations

The strengths of this study include the prospective design and the combined use of player's self-reporting and team physiotherapists to record hamstring injuries. Injuries were examined clinically shortly after occurring, and the clinical characteristics of the injuries were reported on a standardised injury form by all physiotherapists. We lack, however, data on the inter-rater agreement of this reporting. Two consultant radiologists scored the MRIs separately which reduces the risk of bias in interpreting the images. Good inter-rater reliability of the measures included in our MRI scoring form have been reported [29]. The time loss data (Figure 5) support the likelihood that the most severe injuries were examined with MRI. A limitation to our study is that we only have time loss data from the self-reported injuries (74% of all injuries), but for these, the players' weekly response rate from the injury occurred to it was recovered was excellent (93%). However, the few missing responses and four players that stopped responding before their injury was fully recovered have likely caused a small underestimation of days lost. The duration of the season periods and the match calendar during the project period differed slightly from regular seasons because of the Covid-19 pandemic.

Perspectives

Most hamstring injuries in women's football are non-contact and occur during sprinting and running, as reported in men's football. Therefore, we expect that the rapidly increasing demands to sprinting in women's football will increase the risk of hamstring injuries. Future studies should investigate risk factors for hamstring injuries in female football players and explore why the m. semimembranosus seem more susceptible to injury than in their male counterparts. We would argue that future preventative measures should be developed and tested and should aim to target both injuries to the muscle-tendon junction of the m. biceps femoris and to the proximal tendon of m. semimembranosus. Although radiological severity grade was associated with days lost from full unrestricted football activity, routinely examining hamstring injuries with MRI is neither clinically indicated nor cost-efficient. We recommend women's football teams to prioritise resources elsewhere.

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Conflict of interest: The authors declare no conflict of interest.

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Data availability: The data that support the findings of this study are available from the corresponding author upon reasonable request.

Author contributions: RA, ST, TEA, MM and RB designed the study, and developed the clinical examination and injury form. RA, AL, RP and RB developed the MRI scoring form. RA and ST were responsible for the contact with players and physiotherapists. AL and RP analysed and scored all injuries examined with MRI. RA analysed the data and drafted the manuscript, all other authors interpreted the data, reviewed the manuscript, and approved the content of the final version.

References

1. Bradley, P. and D. Scott, *Physical analysis of the FIFA Women's World Cup France 2019*. 2019.
2. UEFA, *WOMEN'S FOOTBALL ACROSS THE NATIONAL ASSOCIATIONS 2014-15*. 2015.
3. Horan, D., et al., *Injuries in elite-level women's football-a two-year prospective study in the Irish Women's National League.* Scand J Med Sci Sports, 2021.
4. Ekstrand, J., M. Hägglund, and M. Waldén, *Injury incidence and injury patterns in professional football: the UEFA injury study.* Br J Sports Med, 2011. **45**(7): p. 553-8.
5. Ekstrand, J., M. Hägglund, and M. Waldén, *Epidemiology of muscle injuries in professional football (soccer).* Am J Sports Med, 2011. **39**(6): p. 1226-32.
6. Ekstrand, J., M. Waldén, and M. Hägglund, *Hamstring injuries have increased by 4% annually in men's professional football, since 2001: a 13-year longitudinal analysis of the UEFA Elite Club injury study.* Br J Sports Med, 2016. **50**(12): p. 731-7.
7. Eirale, C., et al., *Low injury rate strongly correlates with team success in Qatari professional football.* Br J Sports Med, 2013. **47**(12): p. 807-8.
8. Hägglund, M., et al., *Injuries affect team performance negatively in professional football: an 11-year follow-up of the UEFA Champions League injury study.* Br J Sports Med, 2013. **47**(12): p. 738-42.
9. Whiteley, R., et al., *Match High-Speed Running Distances Are Often Suppressed After Return From Hamstring Strain Injury in Professional Footballers.* Sports Health, 2020: p. 1941738120964456.
10. Larruskain, J., et al., *Injuries are negatively associated with player progression in an elite football academy.* Science and Medicine in Football, 2021: p. 1-10.
11. van Mechelen, W., H. Hlobil, and H.C. Kemper, *Incidence, severity, aetiology and prevention of sports injuries. A review of concepts.* Sports Med, 1992. **14**(2): p. 82-99.
12. Crossley, K.M., et al., *Making football safer for women: a systematic review and meta-analysis of injury prevention programmes in 11 773 female football (soccer) players.* Br J Sports Med, 2020.

13. Kerkhoffs, G.M., et al., *Diagnosis and prognosis of acute hamstring injuries in athletes.* Knee Surg Sports Traumatol Arthrosc, 2013. **21**(2): p. 500-9.
14. Crema, M.D., et al., *Imaging techniques for muscle injury in sports medicine and clinical relevance.* Curr Rev Musculoskelet Med, 2015. **8**(2): p. 154-61.
15. Ekstrand, J., et al., *Hamstring muscle injuries in professional football: the correlation of MRI findings with return to play.* Br J Sports Med, 2012. **46**(2): p. 112-7.
16. Mullins, K., D. Mac Colgáin, and P. Carton, *Incidence and severity of hamstring injuries in female athletes who play field sports: A systematic review with meta-analysis of prospective studies.* J Orthop Sports Phys Ther, 2022: p. 1-31.
17. Okholm Kryger, K., et al., *Can we evidence-base injury prevention and management in women's football? A scoping review.* Res Sports Med, 2022: p. 1-16.
18. UEFA. *Women's Association Club Coefficients*. [cited 2023 13th March]; Available from: https://www.uefa.com/nationalassociations/uefarankings/womenscountry/#/yr/2021.
19. Amundsen, R., et al., *#ReadyToPlay: Health problems in women's football – a two-season prospective cohort study in the Norwegian premier league.* [submitted], 2023.
20. Bahr, R., et al., *International Olympic Committee consensus statement: Methods for recording and reporting of epidemiological data on injury and illness in sports 2020 (including STROBE Extension for Sport Injury and Illness Surveillance—STROBE-SIIS).* Br J Sports Med, 2020.
21. Waldén, M., et al., *Football-specific extension of the IOC consensus statement: methods for recording and reporting of epidemiological data on injury and illness in sport 2020.* Br J Sports Med, 2023.
22. Clarsen, B., et al., *Improved reporting of overuse injuries and health problems in sport: an update of the Oslo Sport Trauma Research Center questionnaires.* Br J Sports Med, 2020. **54**(7): p. 390-396.
23. Whiteley, R., et al., *Clinical implications from daily physiotherapy examination of 131 acute hamstring injuries and their association with running speed and rehabilitation progression.* Br J Sports Med, 2018. **52**(5): p. 303-310.
24. Askling, C.M., et al., *Acute first-time hamstring strains during high-speed running: a longitudinal study including clinical and magnetic resonance imaging findings.* Am J Sports Med, 2007. **35**(2): p. 197-206.
25. Hägglund, M., et al., *Methods for epidemiological study of injuries to professional football players: developing the UEFA model.* Br J Sports Med, 2005. **39**(6): p. 340-6.
26. Comin, J., et al., *Return to competitive play after hamstring injuries involving disruption of the central tendon.* Am J Sports Med, 2013. **41**(1): p. 111-5.
27. Pollock, N., et al., *British athletics muscle injury classification: a new grading system.* Br J Sports Med, 2014. **48**(18): p. 1347-51.
28. Wangensteen, A., et al., *MRI appearance does not change in the first 7 days after acute hamstring injury-a prospective study.* Br J Sports Med, 2017. **51**(14): p. 1087-1092.
29. Wangensteen, A., et al., *Intra- and interrater reliability of three different MRI grading and classification systems after acute hamstring injuries.* Eur J Radiol, 2017. **89**: p. 182-190.
30. Peetrons, P., *Ultrasound of muscles.* Eur Radiol, 2002. **12**(1): p. 35-43.
31. Dalton, S.L., Z.Y. Kerr, and T.P. Dompier, *Epidemiology of Hamstring Strains in 25 NCAA Sports in the 2009-2010 to 2013-2014 Academic Years.* Am J Sports Med, 2015. **43**(11): p. 2671-9.
32. Kraemer, R. and K. Knobloch, *A soccer-specific balance training program for hamstring muscle and patellar and achilles tendon injuries: an intervention study in premier league female soccer.* Am J Sports Med, 2009. **37**(7): p. 1384-93.
33. Askling, C.M., M. Tengvar, and A. Thorstensson, *Acute hamstring injuries in Swedish elite football: a prospective randomised controlled clinical trial comparing two rehabilitation protocols.* Br J Sports Med, 2013. **47**(15): p. 953-9.

34. Gronwald, T., et al., *Hamstring injury patterns in professional male football (soccer): a systematic video analysis of 52 cases.* Br J Sports Med, 2021.
35. Hägglund, M., M. Waldén, and J. Ekstrand, *Injuries among male and female elite football players.* Scand J Med Sci Sports, 2009. **19**(6): p. 819-27.
36. Clarsen, B., G. Myklebust, and R. Bahr, *Development and validation of a new method for the registration of overuse injuries in sports injury epidemiology: the Oslo Sports Trauma Research Centre (OSTRC) overuse injury questionnaire.* Br J Sports Med, 2013. **47**(8): p. 495-502.
37. Harøy, J., et al., *Groin Problems in Male Soccer Players Are More Common Than Previously Reported.* Am J Sports Med, 2017. **45**(6): p. 1304-1308.
38. Larruskain, J., et al., *A comparison of injuries in elite male and female football players: A five-season prospective study.* Scand J Med Sci Sports, 2018. **28**(1): p. 237-245.
39. Ekstrand, J., J.C. Lee, and J.C. Healy, *MRI findings and return to play in football: a prospective analysis of 255 hamstring injuries in the UEFA Elite Club Injury Study.* Br J Sports Med, 2016. **50**(12): p. 738-43.
40. Wangensteen, A., et al., *MRI does not add value over and above patient history and clinical examination in predicting time to return to sport after acute hamstring injuries: a prospective cohort of 180 male athletes.* Br J Sports Med, 2015. **49**(24): p. 1579-87.
41. Jakobsen, J.R. and M.R. Krogsgaard, *The Myotendinous Junction-A Vulnerable Companion in Sports. A Narrative Review.* Front Physiol, 2021. **12**: p. 635561.

Tables

Table 1. Characteristics of the hamstring injuries examined clinically (N=53) and with MRI (N=31).

	Injuries examined clinically	Injuries examined by MRI
Thigh		
Dominant	22 (42%)	13 (42%)
Non-dominant	31 (58%)	18 (58%)
Onset		
Sudden onset	25 (47%)	14 (45%)
Gradual onset*	28 (53%)	17 (55%)
Season period		
Pre-season	21 (40%)	12 (39%)
In season	32 (60%)	19 (61%)
Activity		
Football training	26 (49%)	15 (48%)
Football match play	24 (45%)	14 (45%)
Strength and conditioning	1 (2%)	1 (3%)
Not reported	2 (4%)	1 (3%)
Pain location by palpation		
Lateral	16 (30%)	9 (29%)
Medial	21 (40%)	14 (45%)
Medial and lateral	7 (13%)	4 (13%)
Ischial tuberosity	4 (8%)	2 (6%)
No pain during palpation	5 (9%)	2 (6%)

*Eight of the gradual onset injuries examined clinically, and six of those examined by MRI were reported as “gradual onset with sudden deterioration”.

Figures

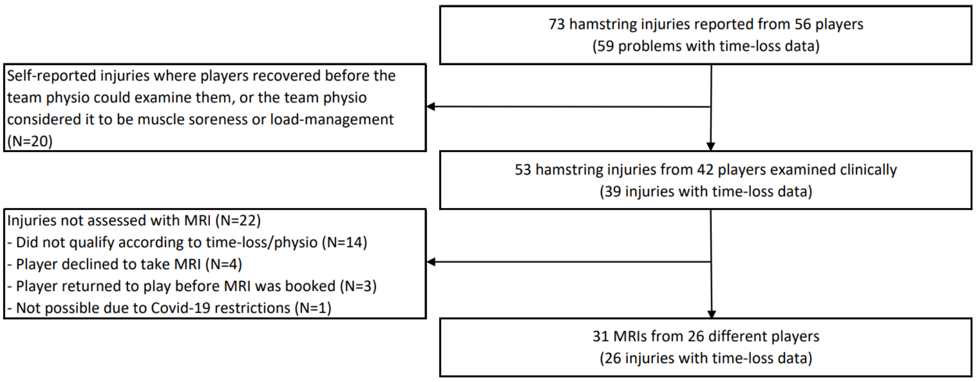

Figure 1. Flow chart of the reported hamstring injuries. We have time-loss data from the self-reported injuries only, not from the injuries identified directly by the team physiotherapist (N=14).

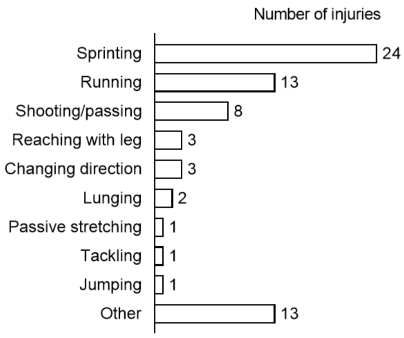

Figure 2. Mechanisms of hamstring injuries. More than one mechanism could be reported for the same injury. No injuries occurred during dribbling, falling or landing.

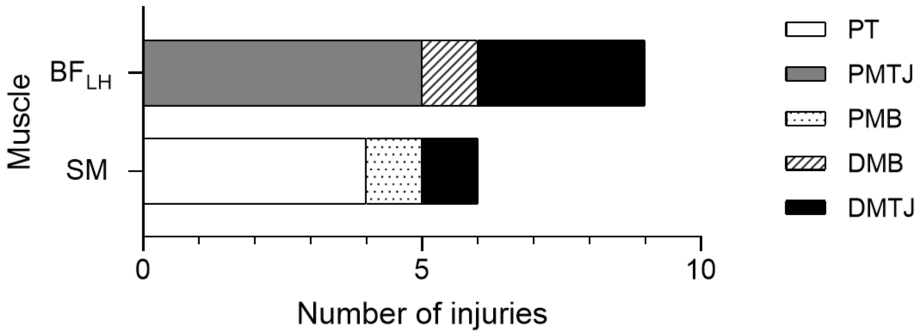

Figure 3. The location of the primary lesions found on MRI. BF$_{LH}$: m. biceps femoris (long head), SM: m. semimembranosus, PT: proximal tendon, PMTJ: proximal muscle-tendon junction, PMB: proximal muscle belly, DMTJ: distal muscle-tendon junction.

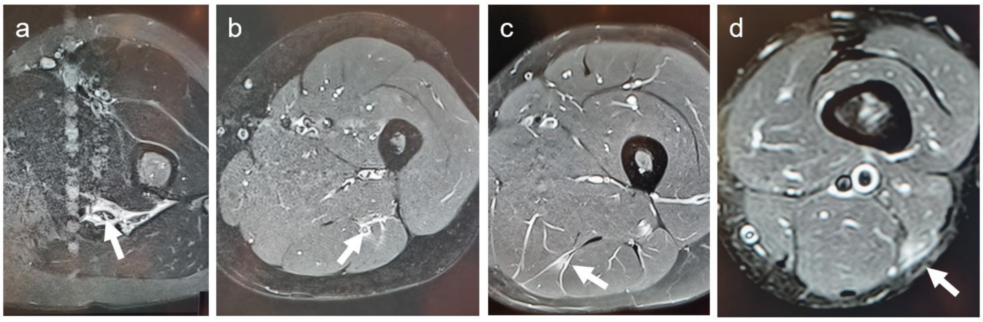

Figure 4. Axial proton density-weighted fat saturated MRI of injuries classified as (a) grade 2 injury in the proximal tendon of m. semimembranosus, (b) grade 2 injury in the proximal muscle-tendon junction of m. biceps femoris long head, (c) grade 1 injury with myofascial involvement in the proximal muscle belly of semimembranosus, and (d) grade 1 injury in the distal muscle-tendon junction of m. biceps femoris long head.

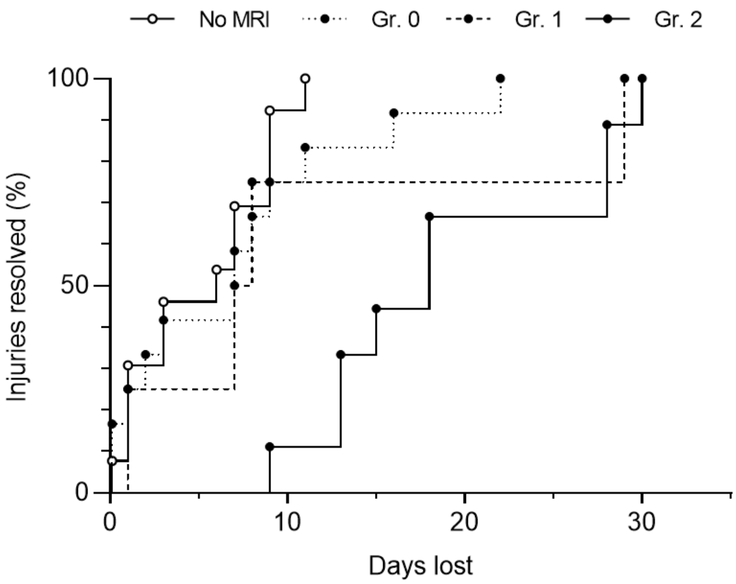

Figure 5. Days lost before injuries were recovered for hamstring injuries examined clinically but not with MRI (N=13), injuries of radiological grade 0 (N=12), grade 1 (N=3) and grade 2 (N=9). One tendinopathy with 188 days lost is not included in the figure because the MRI severity was not graded.

Paper III

Section Specialty Area: **Sports Medicine & Orthopaedics**

Performing NordBord-testing with additional weight affects the maximal eccentric force measured - do not compare apples to oranges

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Abstract

Background: The NordBord, a test device based on the Nordic hamstring exercise, is commonly used to measure maximal eccentric hamstring force. The ability to control the final 20° of the motion has been adopted as a criterion to add weight when testing, without substantial evidence. We investigated if adding weight to testing affected the maximal force measured, and if there were differences between players who could and could not control the final 20°.

Methods: Female (n=84) and male (n=56) football players performed NordBord testing with 0, 5 and 10 kg added weight. Ability to control the final 20° of the test was decided by visual inspection during the test without added weight, as per previously published studies.

Results: Maximal force was higher when tested with 5 kg (females: +2%, p<0.001, males: +4%, p<0.001) and 10 kg (females: +5%, p<0.001, males: +6%, p<0.001) compared to 0 kg. This was the case for both players who could control the final 20° of the test (5 kg: + 4%, p<0.001, 10 kg: + 7%, p<0.001) and those who could not (5 kg: +3%, p<0.001, 10 kg, +4%, p<0.001).

Conclusion: Both players who could and could not control the final 20° of the NordBord test demonstrated higher maximal force when adding weight to testing. Therefore, this should not be used to decide if players should perform testing with or without weight. Either all participants or none should be tested with weight, and the same approach should be used both for pre- and post-testing.

Keywords: eccentric training, hamstring, injury prevention, strength, nordic hamstring exercise, football.

Introduction

Hamstring injuries represent a big problem in most sports involving high-speed running [1-10]. Systematic eccentric strength training reduces the risk of hamstring injuries [11-14]; testing maximal eccentric hamstring strength has therefore become common practice both in research and the real-world setting of these sports.

The eccentric strengthening exercise most used in research aiming to prevent hamstring injuries is the Nordic hamstring exercise [11 13 14]. Consequently, a test device that measures the maximal eccentric hamstring force during the Nordic hamstring exercise (NordBord, Vald Performance, Albion, Australia) has been developed [15] and is now commonly used in both research [16] and by elite teams in various sports. During the test, the player's ankles are secured by braces attached to load cells. These measure the maximal eccentric hamstring force when the athlete leans forward, using their hamstring muscles to resist the forward falling motion for as long as possible (i.e. performs the Nordic hamstring exercise). The Nordic hamstring exercise is intended to be supramaximal, and a prerequisite for the NordBord-test is that the subject reaches a "critical point" where the external load from gravity acting on the upper body exceeds their maximal eccentric hamstring strength [15]. However, some athletes are able to control the forward falling motion throughout the full range of motion of the exercise. These players will never reach the "critical point" and the test will therefore not be able to measure their maximal eccentric hamstring strength as intended.

Some studies have addressed this problem. To ensure that supramaximal intensity is achieved, study participants who were able to control the forward falling movement during the final 10-20° before full extension have performed training while holding weight plates, increasing the weight over the intervention period [17-23]. Several of these studies have used the same criterion when testing maximal eccentric hamstring force with NordBord [18-22]. As maximal eccentric hamstring force measured by NordBord is largely dependent on body mass [24], performing the test with added weight could possibly affect the outcome, irrespective of changes in eccentric hamstring strength. This would be critical, especially if using different weights for pre- and post-tests when evaluating the effect of a training intervention or comparing groups that have performed the testing with different weights. Currently, there are no published data on how performing the Nordbord test with added weight affects the measured maximal force.

Therefore, we aimed to investigate how adding extra weight when performing the NordBord test affected the maximal eccentric hamstring force recorded in male and female football players, and if there were any differences between players who were able to control the forward falling movement during the final part of the range of motion and those who could not.

Methods

Trial design and participants

We tested the maximal eccentric hamstring force of 140 football players (84 females: 171±6 cm, 65±6 kg, 22±4 yrs; 56 males: 183±6 cm, 78±9 kg, 24±4 yrs). The female players were from six different Norwegian premier league teams and performed the testing as part of annual pre-season testing at the Norwegian Football Association Sport Medicine Clinic before the 2021 season. The male players played for three 1st division teams (professional, 2nd tier) and were tested at their team facility prior to the 2022 season. All participants were above 16 years old, part of the team's first team squad, free of injury and gave their individual consent to participate. The study was approved by The Norwegian Centre for Research Data and the Norwegian School of Sports Sciences Ethics Committee.

Strength testing

Eccentric hamstring strength was tested in a Nordic hamstring test device [15] (NordBord v. 1.0, Vald Performance, Albion, Australia). All players were using the Nordic hamstring exercise as part of their weekly training routine, eliminating the need for familiarisation with the test [15]. During the test, players knelt on the board and had their ankles secured by ankle hooks attached to uniaxial load cells. We instructed them to cross their arms in front of their chest, move slowly forward without bending their hip and use their hamstring muscles to maximally resist the forward falling motion for as long as possible. Players performed three submaximal warm-up repetitions, before performing three test sets with maximal effort: First three repetitions with no added weight, then one repetition with a 5 kg weight vest and finally one repetition with a 10 kg weight vest. The three test sets with maximal effort were separated by 1-min breaks [25]. For the set performed without added weight we assessed, by visual inspection, if the player was able to control the forward falling movement during the final 20° of the range of motion or not [18 19]. Players were considered to have control if they were able to resist during the final 20°, and to not have control if they reached their "critical point" before the final 20°. In a separate test session after the 2022 season, ten of the male players with control during the test without added weight, were re-tested and performed the test not only with 0, 5 and 10 kg added weight, but also with 15 and 20 kg. For all test sets, we recorded the maximal force (N) produced in the right and left leg. The results are reported as the average of the maximal force recorded from the right and left leg in absolute terms (N) and relative to body weight (N/kg).

Statistical analysis

All statistical analyses were performed using SPSS (IBM SPSS Statistics v. 28.0, Armonk, New York, USA). Normality was tested with Kolmogorov-Smirnov test. Repeated measures analysis of variances (ANOVA) was used to analyse differences in maximal eccentric hamstring force between tests performed with different weight. This was done separately for female and male players, players with and without control during the final 20°, and for the male players that performed the extra test session with up to 20 kg added weight. Greenhouse-Geisser adjustment were performed if the assumption of sphericity was violated. We used independent sample t-tests to compare the change in maximal eccentric force caused by adding weight to the test between players who were able to control the forward falling motion during the final 20° and players who could not. The significance level was set at p<0.05 for all tests.

Results

The absolute and relative eccentric force produced during the NordBord test with 0 kg, 5 kg and 10 kg added weight are presented in Table 1. Maximal eccentric force was higher when the test was performed with 5 kg and 10 kg added weight than without added weight for both female (5 kg: +8 N, 95% CI: 5-12 N, p<0.001, 10 kg: +17 N, 95% CI: 13-21 N, p<0.001) and male players (5 kg: +18 N, 95% CI: 13-22 N, p>0.001, 10 kg: +27 N, 95% CI: 22-33 N, p>0.001). This was also the case for both players that could control the final 20° (5 kg: 16 N, 95% CI: 12-20 N, p<0.001, 10 kg: 28 N, 95% CI: 23-32 N, p>0.001, N=65) and not (5 kg: 9 N, 95% CI: 5-13 N, p<0.001, 10 kg: 15 N, 95% CI: 11-20 N, p<0.001, N=75).

TABLE 1 HERE

Thirty-three female (39%) and 32 male players (57%) were able to control the movement during the final 20° of the test without added weight. For female players, the increase in eccentric force when the test was performed with added weight did not differ between those who could and could not control the final 20° (5 kg, mean difference: 5 N, 95% CI: -3 to 12 N, p=0.22, 10 kg: 7 N, -1 to 15 N, p=0.10) (Figure 1). Male players with control increased the eccentric force more than those without control when the test was performed with 10 kg (17 N, 7 to 27 N, p=0.004), but not with 5 kg (6 N, -2 to 15 N, p=0.16) (Figure 1).

FIGURE 1 HERE

Of the ten players who were asked to also test with 15 and 20 kg added weight, four completed the test with 15 kg before declining to add more weight, while six also tested with 20 kg. Figure 2 illustrates the change in force measured when these players performed the test with added weights compared to without added weight. For the six players completing all five test sets, the maximal eccentric force was significantly higher when tested with 15 kg added weight compared to 10 kg (15N, 95% CI: 1-30 N, p=0.41), while there was no difference between the tests with 15 and 20 kg (-1 N, 95% CI: -22-23 N, p=0.95).

FIGURE 2 HERE

Discussion

The main finding of this study was that performing the NordBord test with additional weight increased the maximal eccentric force measured as compared to testing without additional weight. This was the case for both female and male players, for players who could control the final 20° of the test and players who could not.

A fundamental principle for all strength training is that load needs to be progressively increased. In the Nordic hamstring exercise, load is increased as the athlete can withstand the forward fall longer [26], but when subjects are able to control the full range of motion, additional load is needed. In the original study on the Nordic Hamstring Exercise, Mjølsnes et al. [26] proposed that load could be increased by adding speed to the starting phase of the motion [26], while later studies have added weight to the exercise for the same purpose [17-23]. Using the ability to control the final 10-20° to decide which players should train with added weight to ensure the Nordic hamstring exercise remains supramaximal seem reasonable. However, our results demonstrate that the same criterion cannot necessarily be applied to testing. If only players that are able to control the final 20° of the test should be tested with weight, one is assuming that players not able to control the final 20° will not benefit from adding weight. However, our results demonstrate that the maximal eccentric hamstring force measured in the Nordbord was significantly higher when players performed the test with added weight, regardless of the ability to control the forward falling motion during the final 20° (Figure 1 and Table 1).

The NordBord is now a commonly used method to measure maximal eccentric hamstring strength [16]. The assessment process is fast and provides immediate feedback [27], it is less expensive than isokinetic dynamometry and less operator dependent than handheld dynamometers [15]. Although high test-retest reliability have been found for testing without added weight [15], the incorporation of weight into the test when athletes can control the final 10-20°, seems to have been adopted without substantial evidence. Bourne et al. [17] were the first to add weight to Nordic hamstring training when participants developed sufficient strength to completely stop the movement in the final 10-20° of the range of motion, but did not mention using weights as part of testing. Several studies, however, seem to have adopted this as a criterion to decide if participants should perform Nordbord-testing with added weight, although the methods used are not described consistently. Two studies decided the weight used at testing based on the ability to control the movement during the final 10-20° [18 19]. Behan et al. [20] did not explicitly describe the use of weights during testing, but stated that methods where similar to the three previously mentioned studies [17-19]. Timmins et al. [21] stated that participants were tested with weight “as required”, and Cadu et al. [22] used weights if participants had sufficient strength “to control the descent”. Similar for all these training studies is that at participants were tested without or with low weight during pre-testing, based on their ability to control the final parts of the test. During the training interventions, at least some participants gradually progressed the weights used, and performed post-testing with higher weights compared to pre-testing. Despite relatively short training interventions of 6 weeks [18-20] and training volumes as low as three repetitions per week [22], these studies have found substantial increases in maximal strength, approximately 20-30% [18-20 22]. The systematic use of progressive overload and the similarity between the Nordic hamstring exercise and the NordBord test [28] has certainly contributed to these large improvements, but the added weight during post-testing may have inflated the results. Our results indicate that if participants were tested without weight during pre-testing and with weight during post-testing, this would cause a significant increase in the maximal force measured, regardless of any changes in strength. Additionally, for studies aiming to compare groups using different training volumes or exercises [18-20], the testing approach may have biased the results. As an example Behan et al. [20] compared four groups using different training volumes of the Nordic hamstring exercise, and reported that 80% of participants performing training and post-testing with added weight (range: 5-20 kg) were in the two higher-volume training groups of their study.

Performing the test without added weight, however, may also be problematic. If players are able to stop the movement during the final part of the test, this do not necessarily require their maximal force. No matter how much stronger these players become during a training intervention, the force required to stop the movement during the final part of the test is likely to be the same. Testing these players without weight could therefore mask any changes in maximal strength. One solution to these problems, used by Duhig et al. [23] and also mentioned by Pollard et al. [19], is to gradually increase the added weight until the player reaches a plateau in force. Figure 2 shows that the maximal eccentric hamstring force reached a plateau when players performed additional sets beyond 10 kg. How much weight is needed before the maximal force plateaus is likely highly individual and depends on the player's maximal eccentric hamstring strength but also other factors, such as body proportions, body mass, where the critical point occurs and the muscles' force-length relationship. If this approach is taken, all players, regardless of their ability to control the forward falling motion during the final 20°, should be tested with weight. An alternative method is to have all players perform several test sets with gradually increasing weight, but only compare tests were the same weight have been used when performing the analyses. This prevents that differences in the weight used impacts the results but necessitates estimating the required weight for the post-testing before the commencement of the project. With either of these approaches, one should be aware that athletes may be reluctant to perform the NordBord test with much added weight. Few players in our study agreed to be tested beyond 10 kg. Of the ten players who accepted, four players declined adding weight beyond 15 kg and the remaining six did not want to go beyond 20 kg, despite not all of them reaching a plateau in the force measured. Fear of muscle soreness is one of the main challenges in obtaining adherence to injury prevention programs from football players [29 30], and could also be a problem with NordBord-testing with added weight.

Methodological considerations

One strength of the study is that we tested a high number of both female and male players. That the test was performed with gradually increasing weight rather than in a randomised order could, theoretically, have affected the force measured in the later sets both negatively and positively. Fatigue may have negatively affected the maximal force the players could produce in the latter sets. We consider this unlikely, as it has been shown that 1-minute break between sets was sufficient to maintain the force-production qualities between sets when the Nordic hamstring exercise was performed using the NordBord [25]. On the other hand, players could have experienced a learning effect throughout the test and therefore performed better in the later sets. We also consider this unlikely as all players used the Nordic hamstring exercise as part of their weekly training routine and therefore were familiar with the exercise. Most players had also been tested in the NordBord as part of annual pre-season testing previous seasons. That players were experienced with the exercise is substantiated by the high maximal eccentric force they displayed; the female players (mean: 335 N) were slightly stronger than what has been reported from elite female athletes from different football codes (mean: 250-275 N) [31], and the male players' results (mean: 431 N) were comparable to results from men's Premier League and Champion's League football (400-425 N) [32]. Using visual inspection to determine which players are able to control the forward falling motion during the final 20° motion is likely tester dependent. The intra- and interrater reliability of this categorisation has not been tested and may be low. It is, nonetheless, an approach that has been adopted by several previous studies to decide which players should train and be tested with added weight [17-23]. The analysis of players performing the test with up to 20 kg added weight should be interpreted with care because of low statistical power. Also, the number of multiple comparisons may have increased the risk of making a type I error.

Perspectives

Caution is needed when comparing NordBord tests that incorporate different weights during pre- vs. post-testing. In the future, the ability to control the final 20° of the forward falling motion should not be used as a criterion to decide which players should be tested with added weight; either all players should be tested with weight, or none. If the NordBord test is performed with added weight, we recommend either: 1) to gradually increase the weight until the force plateaus for all players on all tests, or 2) to only compare tests where the same weight is used. When studies conduct NordBord testing with added weight, the testing protocol used should be described in detail.

Conflict of interest: None to declare.

Data availability statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

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References

1. Ekstrand J, Hägglund M, Kristenson K, Magnusson H, Waldén M. Fewer ligament injuries but no preventive effect on muscle injuries and severe injuries: an 11-year follow-up of the UEFA Champions League injury study. Br J Sports Med 2013;**47**(12):732-7 doi: 10.1136/bjsports-2013-092394 [published Online First: 2013/07/03].
2. Woods C, Hawkins RD, Maltby S, Hulse M, Thomas A, Hodson A. The Football Association Medical Research Programme: an audit of injuries in professional football--analysis of hamstring injuries. Br J Sports Med 2004;**38**(1):36-41 doi: 10.1136/bjsm.2002.002352 [published Online First: 2004/01/31].
3. Horan D, Blake C, Hägglund M, Kelly S, Roe M, Delahunt E. Injuries in elite-level women's football-a two-year prospective study in the Irish Women's National League. Scand J Med Sci Sports 2022;**32**(1):177-90 doi: 10.1111/sms.14062 [published Online First: 2021/11/01].
4. Hägglund M, Waldén M, Ekstrand J. Injuries among male and female elite football players. Scand J Med Sci Sports 2009;**19**(6):819-27 doi: 10.1111/j.1600-0838.2008.00861.x [published Online First: 2008/11/05].
5. Orchard J, Seward H. Epidemiology of injuries in the Australian Football League, seasons 1997-2000. Br J Sports Med 2002;**36**(1):39-44 doi: 10.1136/bjsm.36.1.39 [published Online First: 2002/02/28].
6. Brooks JH, Fuller CW, Kemp SP, Reddin DB. Epidemiology of injuries in English professional rugby union: part 2 training Injuries. Br J Sports Med 2005;**39**(10):767-75 doi: 10.1136/bjsm.2005.018408 [published Online First: 2005/09/27].
7. Brooks JH, Fuller CW, Kemp SP, Reddin DB. Epidemiology of injuries in English professional rugby union: part 1 match injuries. Br J Sports Med 2005;**39**(10):757-66 doi: 10.1136/bjsm.2005.018135 [published Online First: 2005/09/27].
8. Feeley BT, Kennelly S, Barnes RP, et al. Epidemiology of National Football League training camp injuries from 1998 to 2007. Am J Sports Med 2008;**36**(8):1597-603 doi: 10.1177/0363546508316021 [published Online First: 2008/04/30].
9. Roe M, Murphy JC, Gissane C, Blake C. Hamstring injuries in elite Gaelic football: an 8-year investigation to identify injury rates, time-loss patterns and players at increased risk. Br J Sports Med 2018;**52**(15):982-88 doi: 10.1136/bjsports-2016-096401 [published Online First: 2016/11/01].

10. Edouard P, Branco P, Alonso JM. Muscle injury is the principal injury type and hamstring muscle injury is the first injury diagnosis during top-level international athletics championships between 2007 and 2015. Br J Sports Med 2016;**50**(10):619-30 doi: 10.1136/bjsports-2015-095559 [published Online First: 2016/02/19].
11. Arnason A, Andersen TE, Holme I, Engebretsen L, Bahr R. Prevention of hamstring strains in elite soccer: an intervention study. Scand J Med Sci Sports 2008;**18**(1):40-8 doi: 10.1111/j.1600-0838.2006.00634.x [published Online First: 2007/03/16].
12. Askling C, Karlsson J, Thorstensson A. Hamstring injury occurrence in elite soccer players after preseason strength training with eccentric overload. Scand J Med Sci Sports 2003;**13**(4):244-50 [published Online First: 2003/07/16].
13. Petersen J, Thorborg K, Nielsen MB, Budtz-Jørgensen E, Hölmich P. Preventive effect of eccentric training on acute hamstring injuries in men's soccer: a cluster-randomized controlled trial. Am J Sports Med 2011;**39**(11):2296-303 doi: 10.1177/0363546511419277 [published Online First: 2011/08/10].
14. van der Horst N, Smits DW, Petersen J, Goedhart EA, Backx FJ. The preventive effect of the nordic hamstring exercise on hamstring injuries in amateur soccer players: a randomized controlled trial. Am J Sports Med 2015;**43**(6):1316-23 doi: 10.1177/0363546515574057 [published Online First: 2015/03/22].
15. Opar DA, Piatkowski T, Williams MD, Shield AJ. A novel device using the Nordic hamstring exercise to assess eccentric knee flexor strength: a reliability and retrospective injury study. J Orthop Sports Phys Ther 2013;**43**(9):636-40 doi: 10.2519/jospt.2013.4837 [published Online First: 2013/07/28].
16. Claudino JG, Cardoso Filho CA, Bittencourt NFN, et al. Eccentric Strength Assessment of Hamstring Muscles with New Technologies: a Systematic Review of Current Methods and Clinical Implications. Sports Med Open 2021;**7**(1):10 doi: 10.1186/s40798-021-00298-7 [published Online First: 2021/01/29].
17. Bourne MN, Duhig SJ, Timmins RG, et al. Impact of the Nordic hamstring and hip extension exercises on hamstring architecture and morphology: implications for injury prevention. Br J Sports Med 2017;**51**(5):469-77 doi: 10.1136/bjsports-2016-096130 [published Online First: 2016/11/02].
18. Presland JD, Timmins RG, Bourne MN, Williams MD, Opar DA. The effect of Nordic hamstring exercise training volume on biceps femoris long head architectural adaptation. Scand J Med Sci Sports 2018;**28**(7):1775-83 doi: 10.1111/sms.13085 [published Online First: 2018/03/25].
19. Pollard CW, Opar DA, Williams MD, Bourne MN, Timmins RG. Razor hamstring curl and Nordic hamstring exercise architectural adaptations: Impact of exercise selection and intensity. Scand J Med Sci Sports 2019;**29**(5):706-15 doi: 10.1111/sms.13381 [published Online First: 2019/01/11].
20. Behan FP, Vermeulen R, Whiteley R, Timmins RG, Ruddy JD, Opar DA. The Dose-Response of the Nordic Hamstring Exercise on Biceps Femoris Architecture and Eccentric Knee Flexor Strength: A Randomized Interventional Trial. Int J Sports Physiol Perform 2022;**17**(4):646-54 doi: 10.1123/ijspp.2021-0276 [published Online First: 20220217].
21. Timmins RG, Filopoulos D, Nguyen V, et al. Sprinting, Strength, and Architectural Adaptations Following Hamstring Training in Australian Footballers. Scand J Med Sci Sports 2021;**31**(6):1276-89 doi: 10.1111/sms.13941 [published Online First: 2021/02/23].
22. Cadu JP, Goreau V, Lacourpaille L. A Very Low Volume of Nordic Hamstring Exercise Increases Maximal Eccentric Strength and Reduces Hamstring Injury Rate in Professional Soccer Players. J Sport Rehabil 2022:1-6 doi: 10.1123/jsr.2021-0445 [published Online First: 2022/07/28].
23. Duhig SJ, Bourne MN, Buhmann RL, et al. Effect of concentric and eccentric hamstring training on sprint recovery, strength and muscle architecture in inexperienced athletes. J Sci Med Sport 2019;**22**(7):769-74 doi: 10.1016/j.jsams.2019.01.010 [published Online First: 2019/02/18].

24. Buchheit M, Cholley Y, Nagel M, Poulos N. The Effect of Body Mass on Eccentric Knee-Flexor Strength Assessed With an Instrumented Nordic Hamstring Device (Nordbord) in Football Players. Int J Sports Physiol Perform 2016;**11**(6):721-26 doi: 10.1123/ijspp.2015-0513 [published Online First: 2015/12/08].
25. Drury B, Peacock D, Moran J, Cone C, Campillo RR. Different Interset Rest Intervals During the Nordic Hamstrings Exercise in Young Male Athletes. J Athl Train 2021;**56**(9):952-59 doi: 10.4085/318-20 [published Online First: 2021/09/17].
26. Mjølsnes R, Arnason A, Østhagen T, Raastad T, Bahr R. A 10-week randomized trial comparing eccentric vs. concentric hamstring strength training in well-trained soccer players. Scand J Med Sci Sports 2004;**14**(5):311-7 doi: 10.1046/j.1600-0838.2003.367.x [published Online First: 2004/09/25].
27. Giakoumis M, Pollock N, Mias E, et al. Eccentric hamstring strength in elite track and field athletes on the British Athletics world class performance program. Phys Ther Sport 2020;**43**:217-23 doi: 10.1016/j.ptsp.2020.03.008 [published Online First: 2020/04/12].
28. Wiesinger HP, Scharinger M, Kösters A, Gressenbauer C, Müller E. Specificity of eccentric hamstring training and the lack of consistency between strength assessments using conventional test devices. Sci Rep 2021;**11**(1):13417 doi: 10.1038/s41598-021-92929-y [published Online First: 2021/06/30].
29. McCall A, Dupont G, Ekstrand J. Injury prevention strategies, coach compliance and player adherence of 33 of the UEFA Elite Club Injury Study teams: a survey of teams' head medical officers. Br J Sports Med 2016;**50**(12):725-30 doi: 10.1136/bjsports-2015-095259 [published Online First: 2016/01/23].
30. Chesterton P, Draper G, Portas M, Tears C. The Uptake of Nordic Hamstring Exercise Program for Injury Prevention in Major League Soccer and Its Barriers to Implementation in Practice. J Sport Rehabil 2022:1-6 doi: 10.1123/jsr.2021-0262 [published Online First: 2022/03/11].
31. VALD Performance. Female Professional Athletes: Nordic and Hip Ad/Ab Results. https://valdperformance.com/female-professional-athletes-nordic-and-hip-ad-ab-results/, 2021.
32. VALD Performance. European Football Report Season 2019-20: Nordic Strength. https://valdperformance.com/nordic-strength/, 2020.

Figures

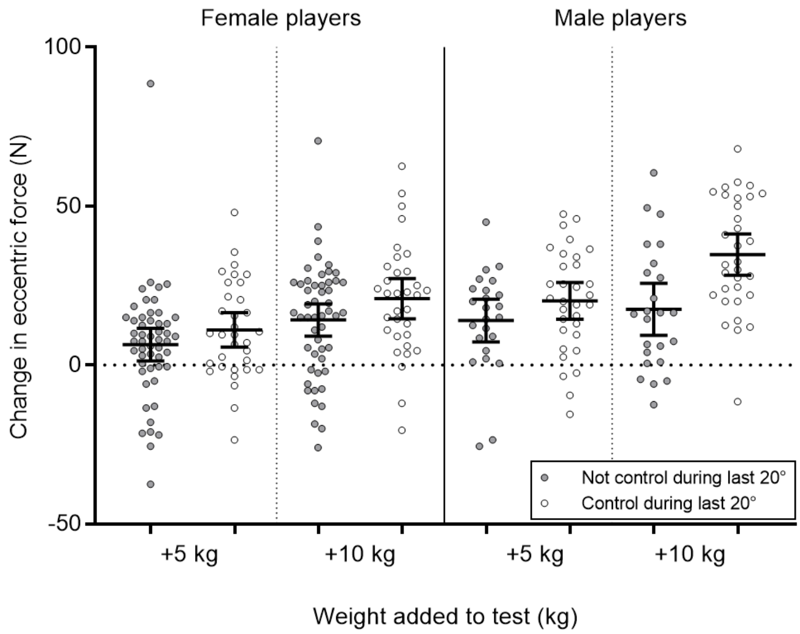

Figure 1. Difference in maximal eccentric force measured when the Nordbord-test was performed with 5 kg and 10 kg added weight compared to without added weight for female (N=84, left) and male players (N=56, right). Results are presented as mean with 95% confidence intervals. Circles represent individual results from players who could control the final 20° of the test without weight (white) and players who could not (grey).

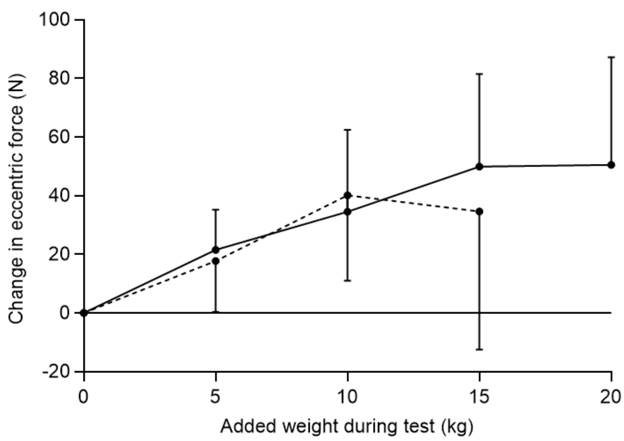

Figure 2. Change in maximal eccentric force measured when the test was performed with 5 kg, 10 kg, 15 kg and 20 kg added weight compared to without added weight (0 kg). Presented as mean±95% confidence intervals for players that performed the test up to 15 kg added weight (dashed lines, N=4) and 20 kg added weight (solid lines, N=6).

Tables

Table 1. Absolute and relative eccentric force (mean±SD) during the Nordbord test performed with 0, 5 and 10 kg added weight for female (N=84, 33 with control during the final 20°) and male players (N=56, 32 with control during the final 20°), as well as the mean percent change (with 95% CI) for the tests with 5 and 10 kg added weight.

	Total			**Control during final 20°**			**Not control during final 20°**		
	0 kg	5 kg	10 kg	0 kg	5 kg	10 kg	0 kg	5 kg	10 kg
Females									
Absolute force (N)	335±45	343±53	352±54	369±28	380±37	390±38	313±41	319±48	337±48
Relative force (N/kg)	5.1±0.6	5.3±0.7	5.4±0.7	5.5±0.4	5.7±0.5	5.9±0.5	4.9±0.6	5.0±0.7	5.1±0.7
Change (%)		2% (1-3%)	5% (4-6%)		3% (1-4%)	6% (4-7%)		2% (0-4%)	4% (3-6%)
Males									
Absolute force (N)	431±52	449±54	458±61	447±45	467±46	482±52	410±53	424±55	427±59
Relative force (N/kg)	5.5±0.5	5.8±0.6	5.9±0.7	5.8±0.3	6.1±0.4	6.3±0.4	5.2±0.5	5.4±0.6	5.4±0.6
Change (%)		4% (3-5%)	6% (5-7%)		5% (3-6%)	8% (6-9%)		4% (2-5%)	4% (2-6%)

Paper IV

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Research Article

Effects of High and Low Training Volume with the Nordic Hamstring Exercise on Hamstring Strength, Jump Height, and Sprint Performance in Female Football Players: A Randomised Trial

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The evidence-based hamstring strengthening programme for prevention of hamstring injuries is not adopted by football teams because of its high training volume. This study on female football players investigated if high-volume training with the Nordic hamstring exercise is more effective on hamstring strength, jump height, and sprint performance than low-volume training. We also examined the time course of changes in muscle strength during the intervention period. Forty-five female football players were randomised to a high- (21 sessions, 538 total reps) or low-volume group (10 sessions, 144 total reps) and performed an 8-week training intervention with the Nordic hamstring exercise during the preseason. We tested hamstring strength (maximal eccentric force with NordBord and maximal eccentric torque with isokinetic dynamometer), jump height, and 40 m sprint before and after the intervention. The NordBord test was also performed during training weeks 4 and 6. Both groups increased maximal eccentric force (high-volume: 29 N (10%), 95% CI: 19–38 N, $p < 0.001$, low-volume: 37 N (13%), 95% CI: 18–55 N, $p = 0.001$), but there were no between-group differences ($p = 0.38$). Maximal eccentric torque, jump height, and sprint performance did not change. Maximal eccentric force increased from the pretest to week 6 (20 N (7%), 95% CI: 8 to 31 N, $p < 0.001$), but not week 4 (8 N (3%), 95% CI: −2 to 18 N, $p = 0.22$). High training volume with the Nordic hamstrings exercise did not lead to greater adaptations in strength, jump height, or speed than a low-volume programme. Players in both groups had to train for at least 6 weeks to improve maximal eccentric force significantly.

1. Background

Women's elite football has developed rapidly during the last decade. The level of play has improved [1], there are more professional players [2, 3], and they face higher training loads and competition demands [4, 5]. Each of these factors may have altered injury risk. Hamstring injury has been the most common injury in men's elite football for years [6,7] and has now also become one of the most common injury types for women [8, 9]. Preventing the most common injuries is essential for football teams and players, as they affect team performance [10, 11], player performance [12, 13], and player development [14].

Male football players performing a programme using Nordic hamstring exercise can more than halve the risk of hamstring injuries [15, 16], probably by increasing eccentric hamstring strength and muscle fascicle length [17, 18]. Female elite football players can also increase their eccentric strength and fascicle length with a preseason programme of the Nordic hamstring exercise [19]. However, the long duration (8–13 weeks) and high training volumes (2–3 sessions per week, up to 30 repetitions per session) of these programmes reduce the chance of implementation [20]. In men's elite football, fewer than one fifth of teams report being fully compliant with the full evidence-based hamstring injury prevention programme [21, 22].

A programme of shorter duration and with lower training volume can facilitate implementation in the busy training and match schedules of elite teams but may attenuate the effects as there is a dose-response relationship between strength gain and training volume [23]. Interestingly, recreationally active men performing a high training volume of the Nordic hamstring exercise did not improve their eccentric strength more than those performing a low training volume (440 vs. 128 total reps over 6 weeks), and the muscular adaptations for both groups occurred early during the intervention [24]. However, the training volumes needed to improve strength can be affected by training status [25], concurrent training [26], and sex [27], so the results from recreationally active men may not be transferable to female football players.

Therefore, we conducted a training intervention with female football players where the primary aim was to determine if using the evidence-based high-volume programme of the Nordic hamstring exercise was more effective on hamstring strength, jump height, and speed than a low-volume programme. We also aimed to examine the time-course of changes in muscle strength during the 8-week intervention period and to compare the results on eccentric strength when assessed by two common testing devices, a Nordic hamstring testing device, and an isokinetic dynamometer.

2. Materials and Methods

2.1. Trial Design and Participants. We invited 45 players (21 ± 4 yrs, 169 ± 6 cm, 63 ± 8 kg) from two Norwegian 2nd tier women's football teams to participate in this randomised trial during their preseason period (Jan–Mar 2021). Both teams had 5–7 football training sessions and played one training match per week. The Norwegian Center for Research Data and the Norwegian School of Sports Sciences' Ethics Committee approved the study. All players included were members of the first team squads, above 16 years old, and gave their individual informed consent to participate.

2.2. Training Intervention. We randomised players within teams to a high- or low-volume group. Training prescriptions were based on previous studies [15, 24, 28] but adjusted to an 8-week intervention period to match the preseason (Table 1). Players performed the Nordic hamstring exercise in pairs after football training sessions (Figure 1). One player knelt on both knees, crossed the arms on her chest, had the partner hold her ankles, and then leaned slowly forward without flexing the hip while using her hamstrings to resist the falling motion for as long as she could. Players used their arms to buffer the fall and push themselves back up to the starting position. If players were able to control the fall throughout the range of motion, load was increased by adding speed to the starting phase of the motion [28]. Verbal encouragement was given during all repetitions to ensure maximal effort. Before every Nordic hamstrings session, players reported the maximal hamstring muscle soreness felt since the previous session on a numerical rating scale (0 = no pain, 1–3 = mild, 4–6 = moderate, 7–9 = severe, and 10 = worst pain imaginable). A researcher attended all Nordic hamstring training sessions to ensure high compliance, proper execution of the exercise and prevent contamination between groups. We aimed to have at least 48 h between Nordic hamstring sessions, but to adjust for the team training plan and match schedule only 24 h separated some sessions in the high-volume group.

Table 1: Training protocol for the high- and low-volume training groups.

	High-volume group		Low-volume group	
Week	Sessions	Sets and repetitions	Sessions	Sets and repetitions
1	1	2 × 5	1	2 × 4
2	2	2 × 6	2	4 × 6
3	3	3 × 6–8	2	4 × 6
4	3	3 × 8–10	1	2 × 4
5	3	3 × 12-10-8	1	2 × 4
6	3	3 × 12-10-8	1	2 × 4
7	3	3 × 12-10-8	1	2 × 4
8	3	3 × 12-10-8	1	2 × 4
Total	21	538	10	144

2.3. Testing Procedures and Outcomes. The pre- and posttests were conducted at the Norwegian School of Sports Sciences. Players performed a 15 min standardised warm-up led by a researcher, with cycling, running drills, and active stretching.

Maximal eccentric hamstring force was tested in a Nordic hamstring testing device [29] (NordBord v. 1.0, VALD Performance, Albion, Australia). Players knelt on the board and had their ankles secured by ankle hooks attached to uniaxial load cells. We instructed them to cross their arms in front of their chest, move slowly forward without bending their hip, and resist the forward falling motion for as long as possible. Players performed three submaximal warm-up repetitions with a subsequent 2 min break, before three sets with maximal effort consisting of three repetitions with no added weight, one repetition with a 5 kg weight vest and one repetition with a 10 kg weight vest. Verbal encouragement was given during the test to ensure maximal effort from the players. The three maximal sets were separated with 1 min breaks. The sets with added weight were included to ensure that all players reached a "breaking point," where they were unable to control the forward falling motion. We recorded the maximal force (N) produced in the right and left leg for each of the three sets, and the average from the right and left leg is reported.

Maximal isometric and eccentric knee flexor torque were tested unilaterally, right leg before left, in an isokinetic dynamometer (Humac Norm model 502140, Computer Sports Medicine Inc., Stoughton, MA, USA). Players were seated with 90 degrees hip flexion and the dynamometer aligned with the knee joint axis. Straps were fixed around the

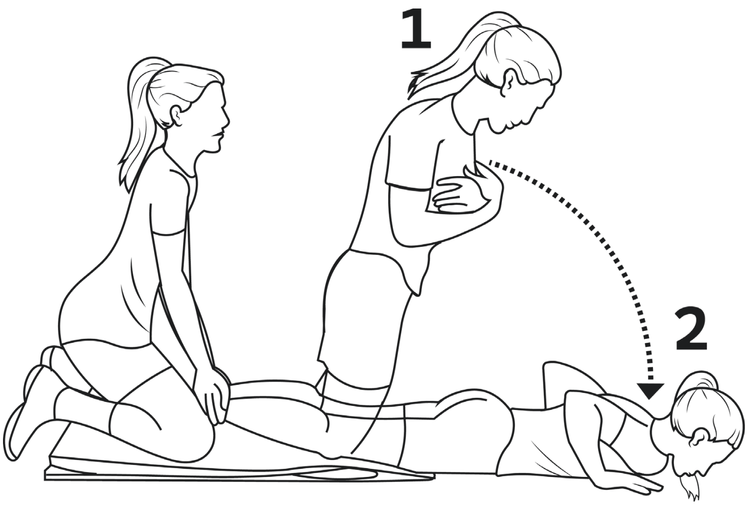

Figure 1: Illustration of how the Nordic hamstring exercise was performed.

hip, shoulders, and the thigh to minimise other movement. After a standardised warm-up with four isokinetic concentric repetitions of knee flexion (60 degrees/s) and 30 s rest, players performed isometric tests with the knee 90 degrees, 60 degrees, and 30 degrees from full extension. Players did two 5 s maximal voluntary contractions at each angle with 30 s rest between all repetitions. Then, players completed two submaximal repetitions and three maximal repetitions of eccentric knee extension at 60 degrees/s , with a 30 s break between the sets. We recorded the maximal torque (Nm) for each of the tests and report the results as the average of the right and left leg.

Countermovement jump height was measured on a force platform (HUR Labs, Kokkola, Finland) and calculated using the net impulse from the force-time curve. Players completed three attempts separated by 2 min breaks and jumped with hands on their hips and self-preferred kneeling depth. Only the highest jump height (cm) is reported.

40 m sprint was tested on an indoor running track. Wall-mounted photocells (Athletics Training System, IC Control Media and Sport, Bromma, Sweden) placed 1 m above the ground registered time every 10 m. Players started from a standing position with the front foot placed 30 cm behind the first photocells and had two trials separated by a 2 min break. We retained sprint times every 10 m (s) from the best trial for analysis.

Eccentric hamstring force was also assessed with the NordBord during training week 4 and 6, before a football training session, at the team training facility. Players had a short general warm-up and three submaximal repetitions before performing one set of three maximal repetitions without a weight vest.

All players and their coaches were asked to not perform any hard physical training the day before the pre- and posttests. At least two days separated the last training session with the Nordic hamstring exercise and the posttest.

2.4. Randomisation and Blinding. A person not involved in the assessment or training randomised the players with a 1 : 1 allocation within teams using a computer-generated list. All persons responsible for conducting the pre-, mid-, and post-tests were blinded to group allocation. The same equipment was used for all tests, and tests were performed by the same experienced testers on all occasions. The players, their coaches, and the researcher following up the Nordic hamstring training could not be blinded to group allocation.

2.5. Sample Size. From previous tests on all players in the Norwegian top division for women, we expected the average maximal eccentric hamstring force to be 300–350 N and the standard deviation to be 50 N. Based on previous studies, we expected a 30% increase in force (+100 N) in the high-volume group [24, 30] and 15% increase (+50 N) in the low-volume group [31, 32]. With a power of 80% and significance level at $p < 0.05$, a sample size of 16 participants per group was required to detect the expected between-group difference.

2.6. Statistical Analysis. All variables were tested for normality with the Shapiro–Wilk test. We used two-tailed paired t-tests to assess within-group differences between pre- and post-tests, ANCOVA (covariate: pretest results, fixed factor: group) for between-group differences in strength, jump, and sprint performance and unpaired t-tests for between-group differences in age, height, and mass. Differences in NordBord test results with 0 kg, 5 kg, and 10 kg added weight were analysed by repeated measures ANOVA. We imputed missing data (7% of values) from the NordBord tests in weeks 4 and 6 with the mean of the two closest tests and analysed strength over the four test occasions by split-plot ANOVA (within-factor: group, between-factor: time). We calculated the Pearson's correlation coefficient between the NordBord and the eccentric isokinetic dynamometer test. Compliance is expressed as the percentage of completed relative to assigned training sessions. Muscle soreness is the mean (±standard deviation) of all responses to the muscle soreness questionnaire. A p value of <0.05 was considered significant. A priori analyses were decided to be per protocol with compliance to the training intervention required to be ≥ 67%.

3. Results

3.1. Participant Flow. Thirty-two players completed the training intervention per protocol and were included in the analyses (Figure 2). The high-volume group completed 19 ± 2 of 21 planned Nordic hamstrings sessions (89%) and the low-volume group 9 ± 1 of 10 sessions (93%). Age (high volume: 21 ± 4 yrs, low volume: 20 ± 2 yrs, $p = 0.51$), height (high volume: 167 ± 6 cm, low volume: 170 ± 5 cm, $p = 0.16$), and body mass (high volume: 60 ± 6 kg, low volume: 64 ± 9 kg, $p = 0.11$) did not differ between groups.

3.2. Maximal Eccentric Force. Both groups increased their maximal eccentric force in the NordBord tests—with no (high volume: 292 ± 52 to 303 ± 47 N, $p = 0.01$, low volume: 296 ± 58 to 316 ± 46 N, $p = 0.01$), 5 kg (high volume: 292 ± 56 to 311 ± 53 N, $p < 0.001$, low volume: 293 ± 67 to 322 ± 49 N, $p = 0.01$), and 10 kg added weight (high volume: 294 ± 57 to 323 ± 58 N, $p < 0.001$, low volume: 293 ± 64 to 330 ± 51 N, $p = 0.001$) (Figure 3). The increase in maximal eccentric force did not differ between groups in the NordBord tests, regardless of added weight (0 kg: $p = 0.11$, 5 kg: $p = 0.25$, and 10 kg: $p = 0.38$).

Adding weight augmented the increase in maximal eccentric force from the pre- to the post-test ($p < 0.001$, partial eta squared = 0.47, observed power = 0.995). Pairwise comparisons showed that the increase was greater when tested with 10 kg added weight than with 5 kg (mean difference: 9 N, 95% CI: 1–16 N, $p = 0.018$) or 0 kg (mean difference: 17 N, 95% CI: 9–25 N, $p < 0.001$) added weight.

When including the two intermediate NordBord tests without added weight in week 4 and week 6, there was a main effect for time on maximal eccentric strength ($p < 0.001$), but no interaction between group and time ($p = 0.52$). Pairwise comparisons showed an increase in maximal eccentric force from the pretest to week 6 (mean change: 20 N, 95% CI: 8 to 31 N, $p < 0.001$) and to the posttest (mean change: 16 N, 95% CI: 5 to 27 N, $p = 0.002$), but not to week 4 (mean change: 8 N, 95% CI: −2 to 18 N, $p = 0.22$).

3.3. Maximal Eccentric and Isometric Torque. Maximal eccentric torque at 60 degrees/s did not change from the pre- to the post-test in either group (high volume: 118 ± 12 Nm to 118 ± 18, $p = 0.88$, low volume: 122 ± 21 to 121 ± 26 Nm, $p = 0.54$). Both groups improved isometric torque at 90-degree knee flexion (high volume: 64 ± 14 to 69 ± 13 Nm, $p = 0.03$, low volume: 63 ± 14 to 68 ± 15 Nm, $p = 0.014$), but not at 60-degree (high volume: 99 ± 12 to 100 ± 14 Nm, $p = 0.55$, low volume: 100 ± 13 to 104 ± 17 Nm, $p = 0.06$) or 30-degree knee flexion (high volume: 111 ± 13 to 113 ± 16 Nm, $p = 0.57$, low volume: 112 ± 15 to 115 ± 21 Nm, $p = 0.20$). We found no significant between-group differences in the change in maximal eccentric torque at 60 degrees/s ($p = 0.52$) or isometric torque at 90-degree ($p = 0.86$), 60-degree ($p = 0.31$), or 30-degree ($p = 0.20$) knee flexion (Figure 4).

3.4. Countermovement Jump and Sprint Performance. Countermovement jump height and 40 m sprint test results did not change from the pre- to the post-test in any of the groups, nor were there any differences between groups (Table 2).

3.5. Relationship between NordBord and Isokinetic Dynamometer Testing. We found a poor correlation ($r = 0.56$, $p > 0.001$) between maximal eccentric force in the NordBord test and maximal eccentric torque at 60 degrees/s tested in the isokinetic dynamometer at baseline, and the correlation ($r = 0.31$, $p = 0.01$) between the change from the pre- to the post-test for the two tests was even weaker (Figure 5).

3.6. Muscle Soreness. Hamstring muscle soreness was reported to be mild throughout the entire training intervention period for both groups (high volume: 2.2 ± 1.7, low volume: 2.3 ± 1.7), except after the pretest (Figure 6). Response rates for the high- and low-volume group were 68% and 86%, respectively.

4. Discussion

This is the first study to compare the effects of high versus low training volumes of the Nordic hamstring exercise during the preseason in female football players. The main finding was that the evidence-based high-volume programme did not perform better than the low-volume programme at improving eccentric hamstring strength. Players had to train for at least 6 weeks to improve their strength. No change was observed in jumping or sprint performance.

Our main finding is in line with two previous studies that have compared different volumes of the Nordic hamstring exercise. Both among recreationally active men (440 vs. 128 total reps over 6 weeks) [24] and male elite youth football players (1 vs. 4 sets per week for 6 weeks) [31], there were no differences in strength adaptations in the groups that were compared. A meta-analysis on Nordic hamstring exercise training volume has also concluded that performing lower training volumes of the Nordic hamstring exercise does not attenuate adaptations in eccentric strength [33]. Conversely, football players performing the Nordic hamstring exercise twice per week for eight weeks increased their strength, while those training once per week did not [34].

Few studies have investigated the response to using the Nordic hamstring exercise among female football players, and only one has measured strength with a device that resembles the NordBord. Seventeen female elite players performing a high-volume Nordic hamstring programme

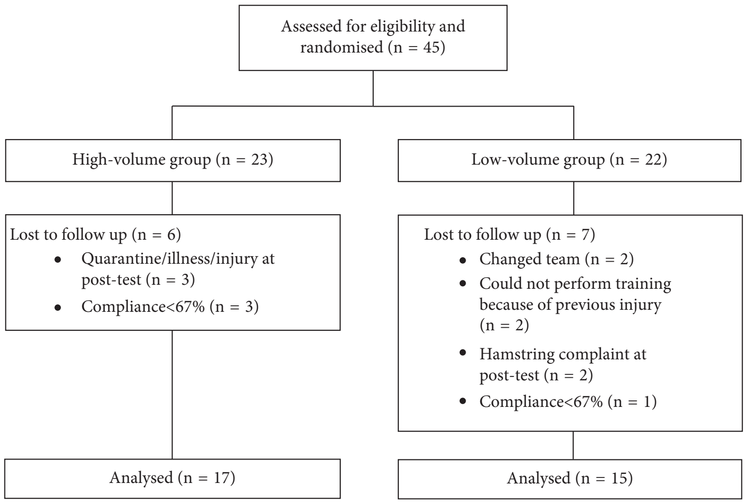

Figure 2: Chart showing flow of participants.

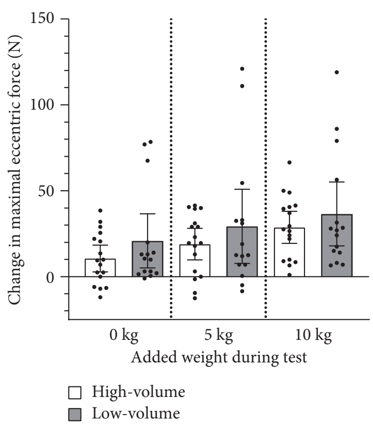

Figure 3: Change in maximal eccentric force for the high- ($N = 17$) and low-volume groups ($N = 15$) during NordBord testing with 0 kg, 5 kg, and 10 kg added weight. Results are presented as mean with 95% confidence intervals and individual values for change (•).

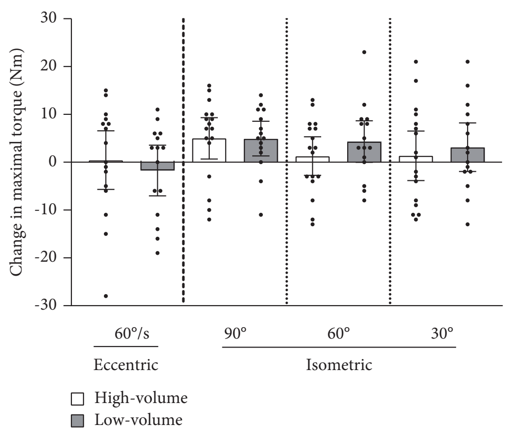

Figure 4: Changes in maximal eccentric torque at 60 degrees/s ($N = 31$) and maximal isometric torque at 90-degree, 60-degree, and 30-degree ($N = 32$) knee flexion from the pre- to the post-test for the high- and low-volume groups. Results are presented as mean of the right and left leg torque with 95% confidence intervals.

during the preseason (8 weeks, 472 total reps) increased their hamstring strength by 13% [19], which is similar to the 10% and 13% increase we observed in our high- and low-volume groups, respectively. Our results are lower than the ~20% increase found after Nordic hamstring interventions among male athletes [31, 35] and the ~30% increase seen among recreationally active men [24, 30]. Less concurrent training in the groups of recreationally active men can be one reason the latter studies observed greater strength gains, as concurrent training can attenuate improvements in strength [26]. Less experience with eccentric training, and therefore a greater potential for improvement, may be another reason.

Some players became strong enough to control the forward falling motion of the Nordic hamstring exercise throughout the range of motion. Without added weights, these may not have been able to reach their maximal eccentric force, since a prerequisite for the NordBord test is that players reach a critical point were the external gravitational force on the upper body exceeds their maximal eccentric hamstring strength [29]. This may explain that both groups had greater increase in maximal eccentric strength when the NordBord test was performed with added weights than without (Figure 3) and is the reason we emphasise the NordBord test results performed with 10 kg. We have only compared pre- and post-tests performed with the same weights.

Table 2: Pre- and post-test results in the countermovement jump test and 40 m sprint for the high- ($N = 16$) and low-volume groups ($N = 14$). Two participants are missing because they did not perform the test or there was a measurement error. Results are presented as mean ± standard deviation.

	High-volume group			Low-volume group			Between-groups p value
	Pre	Post	p value	Pre	Post	p value	
Countermovement jump							
Jump height (cm)	31.9 ± 5.7	31.1 ± 5.9	0.08	29.4 ± 5.0	29.6 ± 5.2	0.69	0.20
Sprint							
10 m (s)	2.01 ± 0.06	2.03 ± 0.08	0.31	2.05 ± 0.12	2.06 ± 0.14	0.71	0.66
20 m (s)	3.44 ± 0.11	3.45 ± 0.13	0.45	3.52 ± 0.21	3.54 ± 0.23	0.52	0.99
30 m (s)	4.79 ± 0.16	4.80 ± 0.18	0.85	4.93 ± 0.30	4.96 ± 0.33	0.46	0.67
40 m (s)	6.15 ± 0.22	6.15 ± 0.24	0.85	6.35 ± 0.41	6.37 ± 0.44	0.65	0.65

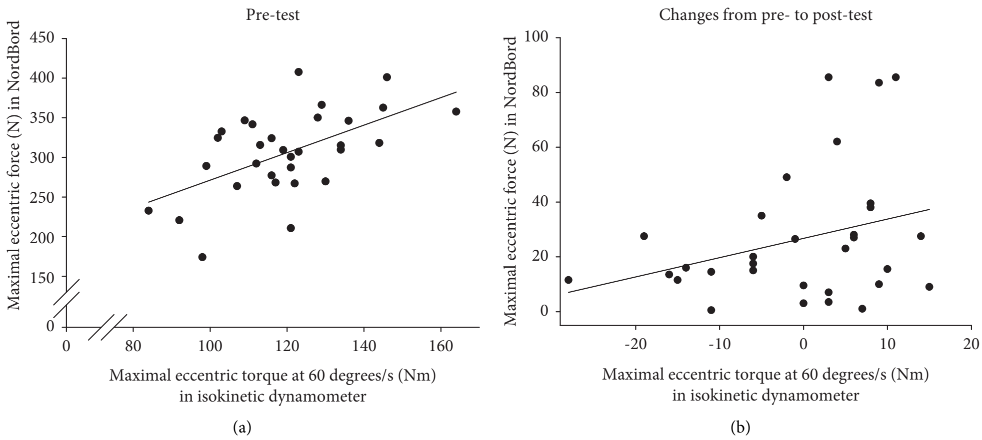

Figure 5: Scatter plot between maximal eccentric force in NordBord and maximal eccentric torque at 60 degrees/s tested in isokinetic dynamometer at pretest (a) and changes from pre- to post-test for the same tests (b). Results from both tests are average of right and left leg ($N = 31$).

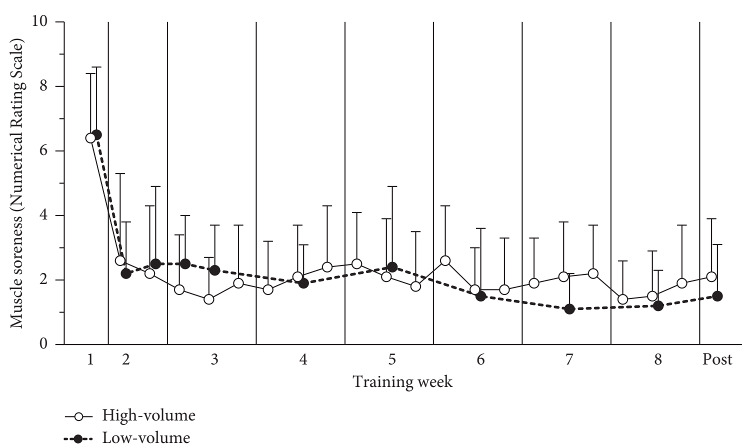

Figure 6: Hamstring muscle soreness reported on a numerical rating scale before all Nordic hamstring sessions during the intervention by the high- (○) and low-volume groups (•). Results are presented as mean and standard deviation.

Presland et al. [24] found muscular adaptations to happen early in the intervention with significant changes after only 14 days of training. We included mid-tests in training weeks 4 and 6 and found that strength did not increase significantly by week 4, but by week 6. In the systematic review by Cuthbert et al. [33], 4-week interventions found trivial to small differences in strength from pre to post, while 6–10 weeks saw moderate-to-very-large effect sizes.

Neither of our groups improved their isokinetic eccentric torque. This is in contrast to some previous studies [28, 36, 37], while other studies did not detect any change in isokinetic eccentric torque [38, 39]. The discrepancy between changes in strength measured with NordBord and isokinetic dynamometer may be explained by the low correlation we (Figure 5) and others find [40, 41]. Although both tests are designed to measure eccentric hamstring strength, they may measure different traits and be highly specific to the training mode chosen [42]. The NordBord test is very similar to the training exercise; this could be why we found improvements on the NordBord test but not on the dynamometer.

During isometric testing, it was surprising that we only detected an increase at 90-degree knee flexion, a knee angle where the lowest force is required when performing the Nordic hamstring exercise. We suspect this may be due to a lack of familiarisation to the test; isometric testing at 90-degree knee flexion was the first test performed. Therefore, it is possible that the increase is due to a learning effect. Another possibility is that players who were not able to control the forward falling motion through the full range of motion only trained in the first part of the movement. Including a version of the exercise that reduced the load for weaker player (e.g., using elastic bands) may have helped more players work at longer muscle lengths during the exercise.

One main challenge to facilitate player adherence with injury prevention is concerns over muscle soreness and "heavy legs" [43]. While unaccustomed eccentric exercise can cause muscle soreness, as we also observed after the initial pretesting session (Figure 6), a single session of eccentric training protects against muscle damage and soreness in subsequent sessions due to the repeated-bout-effect [44, 45]. We, like other studies using a careful, gradual increase in training load [28, 30], found the Nordic hamstring exercise to cause low levels of muscle soreness throughout the training intervention. Still, it should be noted that some players reported persistent soreness throughout the entire training period. Performance enhancing effects of an injury prevention programme may increase buy-in from players and coaches. Previous studies have indicated the Nordic hamstrings exercise can improve sprint, jump height, repeated sprint, and acceleration [46–48]. In our study, however, neither group had any changes in jump height or sprint times.

4.1. Limitations. We were unable to perform familiarisation sessions before the pretests. We have previously tested 21 female top-division players one week apart without familiarisation and found good test-retest reliability for NordBord (unpublished data: 95% limits of agreement: −8 N (−32 N; 17 N), intraclass correlation coefficient: 0.93 (0.80–0.97), standard error of the mean: 11 N (3%)), and isokinetic eccentric torque, jump height, and sprint speed did not change from pre- to post-testing. Therefore, we consider it unlikely that there was a learning effect. One of the teams was put in quarantine for a week because a player tested positive for COVID-19 (no one else was infected). During that week, these players performed the Nordic hamstring programme on their own and we followed up their training via phone. As players were randomised within teams, this should not cause any systematic error. As we do not have a control group, the improvements in strength can potentially be caused by football training and not the Nordic hamstrings training. We consider this unlikely, as amateur players tested 8 weeks apart did not change their eccentric hamstring force, when training football only [19]. However, football training may have contributed to some of the reported muscle soreness. We did not include a control group because we considered it unethical to deny football players from taking part in an evidence-based injury prevention programme, and it was not necessary to answer our primary research question. Because some players were lost to follow-up (Figure 2), the number of players completing the intervention in the low-volume group was slightly below our sample size calculations. This reduces our statistical power.

5. Conclusion

Female football players performing a high-volume Nordic hamstring programme during the preseason did not increase hamstring strength to a greater extent compared to players performing a low-volume programme. Both groups increased their maximal eccentric force measured with the NordBord, and we observed significant improvements after 6 weeks of training. Neither group improved their maximal eccentric torque measured by isokinetic dynamometer. The poor correlation between the two strength tests may explain this difference. None of the programmes improved jump height or sprint performance.

5.1. Perspectives. Our findings demonstrate that a low-volume Nordic hamstring exercise programme is equally effective as the evidence-based high-volume programme in increasing eccentric hamstring strength among female elite football players. Performing a low-volume programme is probably more feasible and likely to be adopted in a real-world context than a high-volume programme; as such, our findings have important implications for future implementation of the Nordic hamstring exercise among female elite football players.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request to roara@nih.no.

Conflicts of Interest

The authors declare that they have no conflicts of interest regarding the publication of this paper.

Acknowledgments

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References

[1] Fédération Internationale de Football Association, "Women's football strategy," 2022, https://digitalhub.fifa.com/m/baafcb84f1b54a8/original/z7w21ghir8jb9tguvbcq-pdf.pdf.

[2] Union of European Football Associations, "Women's Football across the National Associations," 2022, https://www.uefa.com/MultimediaFiles/Download/OfficialDocument/uefaorg/Women'sfootball/02/51/60/57/2516057_DOWNLOAD.pdf.

[3] Fédération Internationale des Associations de Footballeurs Professionnels, "Raising our game," *Women's Football Report*, https://fifpro.org/media/vd1pbtbj/fifpro-womens-report_eng-lowres.pdf, 2022.

[4] N. Datson, A. Hulton, H. Andersson et al., "Applied physiology of female soccer: an update," *Sports Medicine*, vol. 44, no. 9, pp. 1225–1240, 2014.

[5] P. Bradley and D. Scott, "Physical analysis of the fifa women's world cup France," 2019, https://digitalhub.fifa.com/m/4f40a98140d305e2/original/zijqly4oednqa5gffgaz-pdf.pdf.

[6] J. Ekstrand, M. Hägglund, and M. Waldén, "Injury incidence and injury patterns in professional football: the UEFA injury study," *British Journal of Sports Medicine*, vol. 45, no. 7, pp. 553–558, 2011.

[7] J. Ekstrand, M. Waldén, and M. Hägglund, "Hamstring injuries have increased by 4% annually in men's professional football, since 2001: a 13-year longitudinal analysis of the UEFA Elite Club injury study," *British Journal of Sports Medicine*, vol. 50, no. 12, pp. 731–737, 2016.

[8] M. Hägglund, M. Waldén, and J. Ekstrand, "Injuries among male and female elite football players," *Scandinavian Journal of Medicine & Science in Sports*, vol. 19, no. 6, pp. 819–827, 2009.

[9] D. Horan, C. Blake, M. Hagglund, S. Kelly, M. Roe, and E. Delahunt, "Injuries in elite-level women's football-a two-year prospective study in the Irish Women's National League," *Scandinavian Journal of Medicine & Science in Sports*, vol. 32, no. 1, pp. 177–190, 2022.

[10] M. Hägglund, M. Walden, H. Magnusson, K. Kristenson, H. Bengtsson, and J. Ekstrand, "Injuries affect team performance negatively in professional football: an 11-year follow-up of the UEFA Champions League injury study," *British Journal of Sports Medicine*, vol. 47, no. 12, pp. 738–742, 2013.

[11] C. Eirale, J. L. Tol, A. Farooq, F. Smiley, and H. Chalabi, "Low injury rate strongly correlates with team success in Qatari professional football," *British Journal of Sports Medicine*, vol. 47, no. 12, pp. 807-808, 2013.

[12] G. M. Verrall, Y. Kalairajah, J. Slavotinek, and A. Spriggins, "Assessment of player performance following return to sport after hamstring muscle strain injury," *Journal of Science and Medicine in Sport*, vol. 9, pp. 87–90, 2006.

[13] R. Whiteley, A. Massey, T. Gabbett et al., "Match high-speed running distances are often suppressed after return from hamstring strain injury in professional footballers," *Sport Health*, vol. 13, no. 3, pp. 290–295, 2021.

[14] J. Larruskain, J. A. Lekue, I. Martin-Garetxana, I. Barrio, A. McCall, and S. M. Gil, "Injuries are negatively associated with player progression in an elite football academy," *Science and Medicine in Football*, pp. 1–10, 2021.

[15] J. Petersen, K. Thorborg, M. B. Nielsen, E. Budtz-Jorgensen, and P. Holmich, "Preventive effect of eccentric training on acute hamstring injuries in men's soccer: a cluster-randomized controlled trial," *The American Journal of Sports Medicine*, vol. 39, no. 11, pp. 2296–2303, 2011.

[16] N. van der Horst, D. W. Smits, J. Petersen, E. A. Goedhart, and F. J. Backx, "The preventive effect of the nordic hamstring exercise on hamstring injuries in amateur soccer players: a randomized controlled trial," *The American Journal of Sports Medicine*, vol. 43, no. 6, pp. 1316–1323, 2015.

[17] M. N. Bourne, R. G. Timmins, D. A. Opar et al., "An evidence-based framework for strengthening exercises to prevent hamstring injury," *Sports Medicine*, vol. 48, no. 2, pp. 251–267, 2018.

[18] D. M. Medeiros, C. Marchiori, and B. M. Baroni, "Effect of nordic hamstring exercise training on knee flexors eccentric strength and fascicle length: a systematic review and meta-analysis," *Journal of Sport Rehabilitation*, vol. 30, no. 3, pp. 482–491, 2020.

[19] K. B. Vianna, L. G. Rodrigues, N. T. Oliveira, J. B. Ribeiro-Alvares, and B. M. Baroni, "A preseason training program with the nordic hamstring exercise increases eccentric knee flexor strength and fascicle length in professional female soccer players," *International Journal of Sports Physical Therapy*, vol. 16, no. 2, pp. 459–467, 2021.

[20] C. W. Fuller, "Assessing the return on investment of injury prevention procedures in professional football," *Sports Medicine*, vol. 49, no. 4, pp. 621–629, 2019.

[21] R. Bahr, K. Thorborg, and J. Ekstrand, "Evidence-based hamstring injury prevention is not adopted by the majority of Champions League or Norwegian Premier League football teams: the Nordic Hamstring survey," *British Journal of Sports Medicine*, vol. 49, no. 22, pp. 1466–1471, 2015.

[22] P. Chesterton, C. Tears, M. Wright, and M. Portas, "Hamstring injury prevention practices and compliance of the Nordic hamstring program in English professional football," *Translational Sports Medicine*, vol. 4, no. 2, pp. 214–222, 2021.

[23] G. W. Ralston, L. Kilgore, F. B. Wyatt, and J. S. Baker, "The effect of weekly set volume on strength gain: a meta-analysis," *Sports Medicine*, vol. 47, no. 12, pp. 2585–2601, 2017.

[24] J. D. Presland, R. G. Timmins, M. N. Bourne, M. D. Williams, and D. A. Opar, "The effect of Nordic hamstring exercise training volume on biceps femoris long head architectural adaptation," *Scandinavian Journal of Medicine & Science in Sports*, vol. 28, no. 7, pp. 1775–1783, 2018.

[25] T. J. Suchomel, S. Nimphius, C. R. Bellon, and M. H. Stone, "The importance of muscular strength: training considerations," *Sports Medicine*, vol. 48, no. 4, pp. 765–785, 2018.

[26] J. M. Wilson, P. J. Marin, M. R. Rhea, S. M. Wilson, J. P. Loenneke, and J. C. Anderson, "Concurrent training: a

meta-analysis examining interference of aerobic and resistance exercises," *The Journal of Strength & Conditioning Research*, vol. 26, no. 8, pp. 2293–2307, 2012.
[27] B. M. Roberts, G. Nuckols, and J. W. Krieger, "Sex differences in resistance training: a systematic review and meta-analysis," *The Journal of Strength & Conditioning Research*, vol. 34, no. 5, pp. 1448–1460, 2020.
[28] R. Mjølsnes, A. Arnason, T. osthagen, T. Raastad, and R. Bahr, "A 10-week randomized trial comparing eccentric vs. concentric hamstring strength training in well-trained soccer players," *Scandinavian Journal of Medicine & Science in Sports*, vol. 14, no. 5, pp. 311–317, 2004.
[29] D. A. Opar, T. Piatkowski, M. D. Williams, and A. J. Shield, "A novel device using the Nordic hamstring exercise to assess eccentric knee flexor strength: a reliability and retrospective injury study," *Journal of Orthopaedic & Sports Physical Therapy*, vol. 43, no. 9, pp. 636–640, 2013.
[30] M. N. Bourne, S. Duhig, R. Timmins et al., "Impact of the Nordic hamstring and hip extension exercises on hamstring architecture and morphology: implications for injury prevention," *British Journal of Sports Medicine*, vol. 51, no. 4, 2017.
[31] M. Lacome, S. Avrillon, Y. Cholley, B. M. Simpson, G. Guilhem, and M. Buchheit, "Hamstring eccentric strengthening program: does training volume matter?" *International Journal of Sports Physiology and Performance*, vol. 15, no. 1, pp. 81–90, 2020.
[32] B. W. Freeman, W. B. Young, S. W. Talpey, A. M. Smyth, C. L. Pane, and T. A. Carlon, "The effects of sprint training and the Nordic hamstring exercise on eccentric hamstring strength and sprint performance in adolescent athletes," *The Journal of Sports Medicine and Physical Fitness*, vol. 59, no. 7, pp. 1119–1125, 2019.
[33] M. Cuthbert, N. Ripley, J. J. McMahon, M. Evans, G. G. Haff, and P. Comfort, "The effect of nordic hamstring exercise intervention volume on eccentric strength and muscle architecture adaptations: a systematic review and meta-analyses," *Sports Medicine*, vol. 50, no. 1, pp. 83–99, 2019.
[34] T. M. Medeiros, J. B. Ribeiro-Alvares, C. G. Fritsch et al., "Effect of weekly training frequency with the nordic hamstring exercise on muscle-strain risk factors in football players: a randomized trial," *International Journal of Sports Physiology and Performance*, pp. 1–8, 2020.
[35] R. G. Timmins, D. Filopoulos, V. Nguyen et al., "Sprinting, strength, and architectural adaptations following hamstring training in Australian footballers," *Scandinavian Journal of Medicine & Science in Sports*, vol. 31, no. 6, pp. 1276–1289, 2021.
[36] J. Iga, C. Fruer, M. Deighan, M. Croix, and D. James, ""Nordic" hamstrings exercise—engagement characteristics and training responses," *International Journal of Sports Medicine*, vol. 33, no. 12, pp. 1000–1004, 2012.
[37] J. B. Ribeiro-Alvares, V. B. Marques, M. A. Vaz, and B. M. Baroni, "Four weeks of nordic hamstring exercise reduce muscle injury risk factors in young adults," *The Journal of Strength & Conditioning Research*, vol. 32, no. 5, pp. 1254–1262, 2018.
[38] K. D. Seymore, Z. J. Domire, P. DeVita, P. M. Rider, and A. S. Kulas, "The effect of Nordic hamstring strength training on muscle architecture, stiffness, and strength," *European Journal of Applied Physiology*, vol. 117, no. 5, pp. 943–953, 2017.
[39] R. Clark, A. Bryant, J. P. Culgan, and B. Hartley, "The effects of eccentric hamstring strength training on dynamic jumping performance and isokinetic strength parameters: a pilot study on the implications for the prevention of hamstring injuries," *Physical Therapy in Sport*, vol. 6, no. 2, pp. 67–73, 2005.
[40] H. P. Wiesinger, C. Gressenbauer, A. Kosters, M. Scharinger, and E. Muller, "Device and method matter: a critical evaluation of eccentric hamstring muscle strength assessments," *Scandinavian Journal of Medicine & Science in Sports*, vol. 30, no. 2, pp. 217–226, 2020.
[41] N. van Dyk, E. Witvrouw, and R. Bahr, "Interseason variability in isokinetic strength and poor correlation with Nordic hamstring eccentric strength in football players," *Scandinavian Journal of Medicine & Science in Sports*, vol. 28, no. 8, pp. 1878–1887, 2018.
[42] H. P. Wiesinger, M. Scharinger, A. Kosters, C. Gressenbauer, and E. Muller, "Specificity of eccentric hamstring training and the lack of consistency between strength assessments using conventional test devices," *Scientific Reports*, vol. 11, no. 1, Article ID 13417, 2021.
[43] A. McCall, G. Dupont, and J. Ekstrand, "Injury prevention strategies, coach compliance and player adherence of 33 of the UEFA Elite Club Injury Study teams: a survey of teams' head medical officers," *British Journal of Sports Medicine*, vol. 50, no. 12, pp. 725–730, 2016.
[44] M. P. McHugh, "Recent advances in the understanding of the repeated bout effect: the protective effect against muscle damage from a single bout of eccentric exercise," *Scandinavian Journal of Medicine & Science in Sports*, vol. 13, no. 2, pp. 88–97, 2003.
[45] R. D. Hyldahl, T. C. Chen, and K. Nosaka, "Mechanisms and mediators of the skeletal muscle repeated bout effect," *Exercise and Sport Sciences Reviews*, vol. 45, no. 1, pp. 24–33, 2017.
[46] H. Chaabene, Y. Negra, J. Moran et al., "Effects of an eccentric hamstrings training on components of physical performance in young female handball players," *International Journal of Sports Physiology and Performance*, vol. 15, no. 1, pp. 1–22, 2019.
[47] L. Ishøi, P. Holmich, P. Aagaard, K. Thorborg, T. Bandholm, and A. Serner, "Effects of the Nordic Hamstring exercise on sprint capacity in male football players: a randomized controlled trial," *Journal of Sports Sciences*, vol. 36, no. 14, pp. 1663–1672, 2018.
[48] K. Krommes, J. Petersen, M. B. Nielsen, P. Aagaard, P. Holmich, and K. Thorborg, "Sprint and jump performance in elite male soccer players following a 10-week Nordic Hamstring exercise Protocol: a randomised pilot study," *BMC Research Notes*, vol. 10, no. 1, p. 669, 2017.

Appendices

Appendix I

Decision letters from the Norwegian School of Sports Sciences Ethical committee and the Norwegian Centre for Research Data. Informed consent forms for women's premier league players. Hamstring injury form and MRI scoring form used in *Paper II*.

Papers I, II and III

Thor Einar Andersen
Seksjon for idrettsmedisin

OSLO 06. januar 2020

Endringsmelding 129-051219 - 86-131218 – Sammenhengen mellom treningsbelastning, skader og fysisk prestasjonsevne i norsk elite kvinnefotball

Vi viser til endringsmelding med vedlegg mottatt 20.12.19.

I henhold til retningslinjer for behandling av søknad til etisk komite for idrettsvitenskapelig forskning på mennesker, har leder av komiteen på fullmakt konkludert med følgende:

Vedtak

På bakgrunn av forelagte dokumentasjon finner komiteen at endringene er forsvarlig og at det kan gjennomføres innenfor rammene av anerkjente etiske forskningsetiske normer nedfelt i NIHs retningslinjer. Til vedtaket har komiteen lagt følgende forutsetning til grunn:

- *Vilkår fra NSD følges*

Komiteen gjør oppmerksom på at vedtaket er avgrenset i tråd med fremlagte dokumentasjon.

Dersom det gjøres vesentlige endringer i prosjektet som kan ha betydning for deltakernes helse og sikkerhet, skal dette legges fram for komiteen før eventuelle endringer kan iverksettes.

Med vennlig hilsen

Professor Sigmund Loland
Leder, Etisk komite, Norges idrettshøgskole

Sikt

Meldeskjema / Sammenheng mellom treningsbelastning, skader og fysisk prestasjons... / Vurdering

Vurdering av behandling av personopplysninger

Referansenummer	Vurderingstype	Dato
662612	Standard	23.03.2023

Prosjekttittel
Sammenheng mellom treningsbelastning, skader og fysisk prestasjonsevne i norsk elite kvinnefotball

Behandlingsansvarlig institusjon
Norges idrettshøgskole / Institutt for idrettsmedisinske fag

Prosjektansvarlig
Thor Einar Gjerstad Andersen

Prosjektperiode
01.01.2020 - 31.12.2029

Kategorier personopplysninger
Alminnelige
Særlige

Lovlig grunnlag
Samtykke (Personvernforordningen art. 6 nr. 1 bokstav a)
Uttrykkelig samtykke (Personvernforordningen art. 9 nr. 2 bokstav a)

Behandlingen av personopplysningene er lovlig så fremt den gjennomføres som oppgitt i meldeskjemaet. Det lovlige grunnlaget gjelder til 31.12.2029.

Meldeskjema

Kommentar
Personverntjenester har vurdert endringen registrert i meldeskjemaet.

Det er vår vurdering at behandlingen av personopplysninger i prosjektet vil være i samsvar med personvernlovgivningen så fremt den gjennomføres i tråd med det som er dokumentert i meldeskjemaet med vedlegg. Behandlingen kan fortsette.

OPPFØLGING AV PROSJEKTET
Vi vil følge opp underveis (hvert annet år) og ved planlagt avslutning for å avklare om behandlingen av personopplysningene er avsluttet/pågår i tråd med den behandlingen som er dokumentert.

Lykke til videre med prosjektet!

Vil du delta i forskningsprosjektet

«ReadyToPlay:

Protecting the health of Norwegian elite football players»

Dette er et spørsmål til deg om å delta i et forskningsprosjekt hvor formålet er å *beskrive forekomsten av skader og sykdom i Toppserien, og undersøke risikofaktorer for skader i sammenheng med belastning og fysisk form*. I dette skrivet gir vi deg informasjon om målene for prosjektet og hva deltakelse vil innebære for deg.

Formål
Kvinnefotball er i rask utvikling, og nivået og kravene som stilles på trening og i kamp er høyere enn noen gang. Dette kan påvirke risikoen for skader og sykdom, noe som er viktig å kartlegge siden det vil påvirke prestasjon og utvikling for både lag og spiller. Informasjon om faktorer som gjør at spillere har økt risiko for skader er viktig for å kunne forebygge skader, men dette er lite kartlagt i kvinnefotball. Hensikten med denne studien er derfor *å kartlegge alle helseproblemer i Toppserien og undersøke risikofaktorer for skader og sammenheng med treningsbelastning og fysisk form*. Dette vil være med å danne grunnlaget for hvordan vi kan forebygge skader og bedre prestasjon i fremtiden.

Prosjektet er del av flere doktorgradsprosjekter og involverer etablerte forskere og medisinere innen fotball. Anonymiserte resultater fra studien vil bli presentert på nasjonale og internasjonale konferanser, og bli brukt i undervisningsformål, inkludert i trenerutdanningen.

Hvem er ansvarlig for forskningsprosjektet?
Norges idrettshøgskole og Senter for idrettsskadeforskning er ansvarlig for prosjektet. *Norges fotballforbund* og *Toppfotball Kvinner* er også med som samarbeidspartnere for prosjektet.

Hvorfor får du spørsmål om å delta?
Vi ønsker å kartlegge samtlige lag og spillere i Toppserien, derfor får du som spiller på et toppserielag forespørselen om å delta.

Hva innebærer det for deg å delta?
Metoden som brukes i prosjektet er en prospektiv kohortstudie. Dette innebærer at vi ønsker å følge en spesifikk gruppe over tid, i dette tilfellet alle spillerne i Toppserien. Du vil trene som normalt med ditt lag hele sesongen, men vi vil samle data om din fysiske prestasjonsevne, sykdom og skader du blir utsatt for, samt intensiteten og varigheten av både trening og kamp du deltar i.

Hvis du velger å delta i prosjektet:

- Vil du i løpet av uken få påminnelser om å rapportere sykdom/skader, intensitet og varighet via mobilappen «AthleteMonitoring». Daglig for treningsbelastning og ukentlig for sykdom/skade registrering. Her må du svare på et kort spørreskjema, «OSTRC Questionnaire on Health Problems», og registrere treningsmengden for uken som har gått. Dette tar fra 30 sekunder til 4 minutter å svare på, avhengig av om du har hatt skade/sykdom eller ikke.
- Ditt lags fysioterapeut vil varsles umiddelbart om du rapporterer noe nytt, for å raskt kunne undersøke deg og sette i gang tiltak. Fysioterapeuten vil registre hvilken skade/sykdom som har oppstått og hvor mange dager du er borte fra trening/kamp.
- Toppfotball Kvinner gjennomfører i samarbeid med lagene i Toppserien testing av fysisk prestasjonsevne ved Idrettens Helsesenter. Her testes muskelstyrken i beina i tillegg til

prestasjonstester i spenst, agility og hurtighet. Du vil også svare på et spørreskjema hvor andre potensielle risikofaktorer for skader blir undersøkt. Vi vil lagre data fra disse testene og bruke resultatene til å se etter sammenhenger med skader.

- Vi vil samle inn data fra din Polar Team Pro bruker. Vi vil samle inn informasjon som total distanse, antall sprinter, antall meter i høy hastighet, og hjertefrekvens knyttet til trening og kamp.
- Anonyme data om skader og sykdom vil også knyttes opp mot data på trenings- og kampbelastning for å undersøke sammenhengen mellom belastning, skader og fysisk prestasjonsevne.
- TV-opptak vil brukes for å undersøke skader som oppstår i kamp nærmere.

Prosjektet vil starte etter at laget ditt har gjennomført testing på Idrettens Helsesenter (i februar/mars) og vare hele sesongen.

Det er frivillig å delta

Det er frivillig å delta i prosjektet. Hvis du velger å delta, kan du når som helst trekke ditt samtykke tilbake, uten å måtte oppgi noen grunn. Alle opplysninger om deg vil da bli anonymisert. Det vil ikke ha noen negative konsekvenser for deg hvis du ikke vil delta eller senere velger å trekke deg.

Det vil ikke få noen konsekvenser for deg eller dit lag dersom du ønsker å trekke deg i fra studien.

Ditt personvern – hvordan vi oppbevarer og bruker dine opplysninger

Vi vil bare bruke opplysningene om deg til formålene vi har fortalt om i dette skrivet. Vi behandler opplysningene konfidensielt og i samsvar med personvernregelverket.

- Alle som får innsyn i dine data vil ha taushetsplikt. Kun forskere som deltar i prosjektgruppen vil ha tilgang til dine data. I tillegg vil klubbens fysioterapeut og lege ha innsyn i dine data.
- Når dine data benyttes til forskningsformål, vil de avidentifiseres ved at navn og personnummer fjernes. Dataene vil bli behandlet konfidensielt.
- Applikasjonen som brukes heter «Athlete Monitoring» og er utviklet av et kanadisk selskap ved samme navn. Applikasjonen er godkjent etter de nye personvernreglene, GDPR.

Alle resultater som omtales i publikasjonene etter prosjektet vil være anonymiserte og det vil ikke være mulig å gjenkjenne deg i resultatene som publiseres.

Hva skjer med opplysningene dine når vi avslutter forskningsprosjektet?

Prosjektet skal etter planen avsluttes 31.12.2029. Alle opplysninger som kan knytte deg til materialet vil bli anonymisert og opplysninger vi har lagret om deg vil slettes.

Alle data om skader og fysisk prestasjonsevne som hentes ut for forskningsformål vil bli lagret, i anonymisert form, i en database for å kunne kartlegge hvordan omfang og utvikling endrer seg i Toppserien over tid. Materialet vil være viktig kunnskap for å forstå hvordan vi skal arbeide med forebygging av skader og sykdom, samt tilrettelegging av belastning med tanke på forebygging og utvikling av fysisk prestasjonsevne. Dataene vil kunne danne et viktig grunnlag for utarbeidelse av blant annet arbeidskrav i Toppserien.

Styret ved Norges idrettshøgskole har bestemt at forskningsdata skal lagres i fem år etter prosjektslutt for etterprøvbarhet og kontroll. Dette innebærer at alle data, utenom personopplysninger, vil bli lagret i sin helhet i fem år hos Norges idrettshøgskole. Dette er meldt til Norsk senter for forskningsdata (NSD).

Dine rettigheter
Så lenge du kan identifiseres i datamaterialet, har du rett til:

- innsyn i hvilke personopplysninger som er registrert om deg,
- å få rettet personopplysninger om deg,
- få slettet personopplysninger om deg,
- få utlevert en kopi av dine personopplysninger (dataportabilitet), og
- å sende klage til personvernombudet eller Datatilsynet om behandlingen av dine personopplysninger.

Hva gir oss rett til å behandle personopplysninger om deg?
Vi behandler opplysninger om deg basert på ditt samtykke.

På oppdrag fra *Norges idrettshøgskole* har NSD – Norsk senter for forskningsdata AS vurdert at behandlingen av personopplysninger i dette prosjektet er i samsvar med personvernregelverket.

Hvor kan jeg finne ut mer?
Hvis du har spørsmål til studien, eller ønsker å benytte deg av dine rettigheter, ta kontakt med:

- *Norges idrettshøgskole* ved *Solveig Thorarinsdottir*, *solveig.thorarinsdottir@nih.no*, *tlf. 405 22 930*, *Roar Amundsen*, *roar.amundsen@nih.no*, *tlf. 482 97 832,* eller *Markus Vagle*, *markus.vagle@nih.no*, *tlf. 992 74 982.*
- Vårt personvernombud: *Rolf Haavik*, *rolf.haavik@habberstad.no*, tlf. 90 73 37 60.
- NSD – Norsk senter for forskningsdata AS, *personverntjenester@nsd.no) eller tlf. 555 82 117*.

Med vennlig hilsen

Roar Amundsen (PhD-stipendiat)

Solveig Thorarinsdottir (PhD-stipendiat)

Markus Vagle (PhD-stipendiat)

Professor dr. med. Roald Bahr (Prosjektleder og leder for Senter for idrettsskadeforskning)

Samtykkeerklæring

Dersom du ønsker å delta i forskningsprosjektet vil du kunne gi ditt samtykke elektronisk ved å godkjenne informasjonen når du logger inn i appen som brukes for å registrere skader, sykdom og treningsmengde. Informasjonen er også gjengitt i dette skrivet. Du og ditt lag vil få tilgang til appen uavhengig av om du gir ditt samtykke til at dataene dine brukes i forskningsprosjektet.

#ReadyToPlay

Protecting the health of Norwegian elite football players

Skjema for registrering av hamstringsskader

Generell informasjon			
Fysioterapeut:		**Dato for første undersøkelse:**	
Spiller:		**Klubb:**	

Skadehistorie	
Hvilket bein er skadet?	☐ Høyre ☐ Venstre
Oppstod skaden akutt eller gradvis?	☐ Akutt ☐ Gradvis ☐ Akutt forverring av symptomer som kom gradvis
Hvilken dato oppstod skaden/ forverring av symptomer?	
Har spilleren hatt symptomer i forkant av skaden?	☐ Ja ☐ Nei Hvis ja, hvor lenge? ______________________
Hvor oppstod skaden?	☐ Kamp ☐ Fotballtrening ☐ Annen aktivitet Hvis kamp: Motstander: _________________ Minutt av kampen: __________
Hva gjorde spilleren da hun ble skadet?	☐ Sprint ☐ Løp ☐ Retningsforandring ☐ Hopp ☐ Landing ☐ Fall ☐ Skudd/pasning ☐ Dribling ☐ Takling ☐ Utfallsbevegelse ☐ Strekte ut beinet ☐ Passiv tøying ☐ Annet
Kort beskrivelse av hvordan skaden/forverring av symptomer oppstod:	
Har spilleren hatt skade i hamstrings tidligere?	☐ Ja ☐ Nei Hvis ja, hvilket bein: ☐ Høyre ☐ Venstre Startdato: _____________________________ Hvor lenge ute av spill: __________________

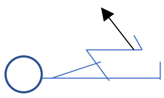
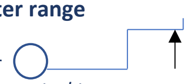
Registrering av smerte:
*Sett **1** hvis testen reproduserer smerten spilleren kjenner pga. skaden.*
*Sett **0+** hvis testen gir smerter, men ikke den samme som skaden.*
*Sett **0** hvis testen ikke gir smerter.*

Undersøkelse

Observasjon	
Synlig subcutant hematom/suggilasjoner?	☐ Ja ☐ Nei

Palpasjon: *Palpasjon av hamstringsskader gjøres med spilleren liggende på magen med utstrakt bein. Palper først utspringet til hamstringsmusklene på sittebensknuten (tuber ischiadicum). Få pasienten til å aktivere hamstringsmusklene ved å gjøre en isometrisk kontraksjon mens du holder igjen hælen og hindrer knefleksjon. Palper langs hele muskelen, fra utspringet til muskelens feste, først ned og så opp igjen. Gjør dette både lateralt (m. biceps femoris) og medialt (m. semimembranosus og m. semitendinosus). Det punktet hvor pasienten rapporterer høyest smerte ved palpsjon markeres på huden med en penn, og avstanden fra sittebensknuten til punktet som er markert på huden måles med målebånd. Mål også lengden (cranial-caudal) og bredden (medial-lateral) på området hvor palpasjon gir smerte.*

Smerte ved palpasjon lateralt? **(m. biceps femoris)**	☐ 1 ☐ 0+ ☐ 0
Smerte ved palpasjon medialt? **(m. semitendinosus/m. semimembranosus)**	☐ 1 ☐ 0+ ☐ 0
Smertefullt område ved palpasjon	Lengde: __________ cm Bredde: __________ cm
Avstand (cm) fra sittebensknuten (tuber ischiadicum) til punkt med høyest rapportert smerte ved palpasjon?	_________________ cm

Kliniske tester	**Høyre bein**	**Venstre bein**
Smerte ved MHFAKE test? *Ryggliggende med maksimal hoftefleksjon (spilleren presser låret mot brystet med armene). Spilleren gjør så maksimalt utslag med aktiv kneekstensjon. Beinet som ikke testes ligger strakt (uten bøy i kne).* 	☐ 1 ☐ 0+ ☐ 0	☐ 1 ☐ 0+ ☐ 0
Smerte ved isometrisk kontraksjon, outer range *Ryggliggende, 90 grader hoftefleksjon, 90 grader knefleksjon. Fysio presser oppover fra under ankelen. Beinet som ikke testes ligger strakt.* 	☐ 1 ☐ 0+ ☐ 0	☐ 1 ☐ 0+ ☐ 0
Smerte ved isometrisk kontraksjon, mid range *Mageliggende med 30 grader knefleksjon. Fysio presser nedover på ankelen. Beinet som ikke testes ligger strakt.* 	☐ 1 ☐ 0+ ☐ 0	☐ 1 ☐ 0+ ☐ 0

Diagnose/kommentar

#ReadyToPlay

Protecting the health of Norwegian elite football players

Undersøkelse av hamstringsskader

Hensikten med denne undersøkelsen er å analysere skademekanismer og risikofaktorer for hamstringsskader blant kvinnelige fotballspillere, noe som ikke er gjort tidligere. Ved å fylle ut og sende inn det vedlagte skjemaet når du undersøker hamstringsskadene til spillerne på ditt lag bidrar du til at vi får informasjonen som vil være viktig i arbeidet med å forebygge hamstringsskader i kvinnefotball.

På forhånd takk for at du tar deg tid til å fylle ut dette skjemaet og bidrar til økt kunnskap om hamstringsskader hos kvinnelige fotballspillere. Om du har spørsmål, ta kontakt med Roar Amundsen, roar.amundsen@nih.no, tlf. 48 29 78 32.

Rapportering

For å rapportere dine funn og diagnosen har du to muligheter:

1. Sende dette skjemaet i posten til:
   Roar Amundsen, Norges idrettshøgskole, Sognsveien 220, 0863 Oslo

2. Stryk over navnet til spilleren, scann/ta bilde av utfylt skjema (alle sider) og send på mail til roar.amundsen@nih.no eller til tlf. 48 29 78 32. Jeg ringer deg for informasjon om spilleren.

Jeg setter stor pris på om du kan sende skjemaet til meg samme dag som du gjennomfører undersøkelsen.

MR-UNDERSØKELSE

Som en del av prosjektet ønsker vi MR-undersøkelse av hamstrings- og lyskeskader dersom:

- Spilleren ikke kan delta på trening og kamp i **3 dager eller mer** på grunn av hamstrings-, hofte- eller lyskeplager

  ELLER
- Spilleren har rapportert hamstrings-, hofte- eller lyskeplager i **2 uker eller mer** (uansett om hun fortsatt har klart å trene og spille tross plager).

Dette gjelder også de spillerne som allerede har plager når de inngår i prosjektet.

Prosessen:

- Meld skaden inn til Skadetelefonen i appen «Skadetelefon» eller på nettsiden: https://www.idrettshelse.no/article/idrettens-skadetelefon
- Når dere melder skaden inn anbefales det å legge inn informasjon om at dere deltar i prosjektet. Da blir det lettere å følge dere opp så raskt som mulig.
- Hvis du har spørsmål eller problemer, ring skadetelefonen og de hjelper deg videre
  - Åpen alle dager 09:00 – 21:00
  - Telefon: 987 02 033 (fra utlandet +4702033 / 91 50 20 33)

Dekking av kostnad:

- Spillere som er med i prosjektet «ReadyToPlay», betaler **IKKE** egenandel ved MR undersøkelse. Fakturen for egenandelen vil bli sendt direkte til Senter for idrettsskadeforskning.

Videoer av kliniske tester

Trykk på linkene under for å se video av de tre kliniske testene. I ReadyToPlay er vi kun ute etter om testene gir smerte, så vi måler ikke med dynamometer og det er ikke nødvendig å feste spillerne til undersøkelsesbenken med stropper slik det blir gjort på videoen.

MHFAKE: https://www.youtube.com/watch?v=KEMj1oYGFEg

Outer-range: https://www.youtube.com/watch?v=ly7DzZkgba4

Mid-range: https://www.youtube.com/watch?v=U9ZvQMAB-EQ

ReadyToPlay

HAMSTRING MRI SCORING FORM

PLAYER'S NAME: ____ **DOCTOR'S NAME:** __________________________

DATE FOR MRI: ____ **DATE FOR SCORING MRI**_____________________

Total number of lesions:

1	2	3

Sett ring for å markere hvor mange lesjoner spilleren har.

Lesion no.: ____________________ *Hver lesjon scores på hvert sitt skjema. Marker om det er lesjon nr. 1, 2 eller 3 som scores her.*

1.

	LOCATION *(Askling, 2007):*						**Additional**	**Presence of tendon disruption** *(Comin et al. 2013)*	
MUSCLE	PT	PMTJ	PMB	DMB	DMTJ	DT	Myofascial	Focal defect	Waviness
B F Long Head								☐	☐
B F Short Head								☐	☐
SM								☐	☐
ST								☐	☐

2.

	MUSCLE			
LOCATION	BF	SM	ST	**CRITERIA** *(Pollock et al., 2014)*
Proximal third	☐	☐	☐	Proximal third is above the lower margin of the gluteus maximus
Middle third	☐	☐	☐	
Distal third	☐	☐	☐	Distal third is below the origin of the short head of biceps femoris

DISTANCE FROM ISCHIAL TUBEROSITY (cm) _____________ *(fra ishial tuberosity til øverste punkt med ødem)*

(Measured from most cranial pole of the injury to most caudal part of ischial tuberosity, Askling 2007)

(*) : Mention Not Applicable (NA) if not measurable

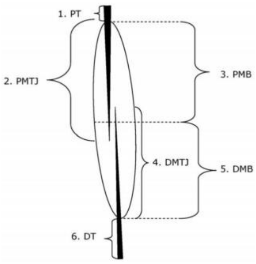
3.

OVERALL GRADING (modified Peetrons')		**CRITERIA** *(Ekstrand et al., 2012)*
Grade 0	☐	*Negative MRI;*
Grade 1	☐	*Oedema but nor architectural distortion;*
Grade 2	☐	*Architectural disruption indicating partial tear;*
Grade 3	☐	*Total muscle or tendon rupture*

ReadyToPlay

HAMSTRING MRI SCORING FORM

Comments:

LOCATION *(Askling, 2007)*	**TENDON DISRUPTION** *(Comin, 2013)*
Askling, 2007: Marking several locations is possible. Wangensteen, 2017: Choose one (?) 	Each radiologist identified the central tendon of the injured muscle as being either intact or disrupted. Disruption was determined by the presence of findings that suggested structural damage to the central tendon: a focal defect separating proximal and distal parts of the tendon, or waviness of the tendon (in place of the normal straight margins) suggesting loss of structural tension (Figures 3, 4, and 5 in Comin, 2013).

Wangensteen, 2017	Pollock, 2014
The involved muscle(s) were described and the anatomical location within the muscle was scored (proximal tendon, proximal musculotendinous junction, proximal muscle belly, distal muscle belly, distal musculotendinous junction, distal tendon) and within the same third (proximal, middle, distal) of this anatomical location. Conjoint tendon injury was scored if the common tendon of the biceps femoris and semitendinosus was injured.	Site of injury (proximal, central or distal third) relative to the muscle origin. With respect to hamstring injuries, it is proposed that the proximal third is above the lower margin of the gluteus maximus and the distal third is below the origin of the short head of biceps femoris.

Appendix II

Decision letters from the Norwegian School of Sports Sciences Ethical committee and the Norwegian Centre for Research Data for the inclusion of male participants in *Paper III*.
Informed consent forms for the male 1st division players.

Paper III

Thor Einar Andersen
Institutt for idrettsmedisinske fag

OSLO 01. februar 2021

Endringsmelding 179-180321-129-051219 - 86-131218 – Sammenhengen mellom treningsbelastning, skader og fysisk prestasjonsevne i norsk elite kvinnefotball

Vi viser til endringsmelding med vedlegg mottatt 27.01.21.

I henhold til retningslinjer for behandling av søknad til etisk komite for idrettsvitenskapelig forskning på mennesker, har leder av komiteen på fullmakt konkludert med følgende:

Vedtak

På bakgrunn av forelagte dokumentasjon finner komiteen at endringene er forsvarlig og at det kan gjennomføres innenfor rammene av anerkjente etiske forskningsetiske normer nedfelt i NIHs retningslinjer. Til vedtaket har komiteen lagt følgende forutsetning til grunn:

- *Vilkår fra NSD følges*

Komiteen gjør oppmerksom på at vedtaket er avgrenset i tråd med fremlagte dokumentasjon. Dersom det gjøres vesentlige endringer i prosjektet som kan ha betydning for deltakernes helse og sikkerhet, skal dette legges fram for komiteen før eventuelle endringer kan iverksettes.

Komiteen forutsetter videre at prosjektet gjennomføres på en forsvarlig måte i tråd med de til enhver tid gjeldende tiltak ifbm Covid-19 pandemien.

Med vennlig hilsen

Anne Marte Pensgaard

Professor Anne Marte Pensgaard
Leder, Etisk komite, Norges idrettshøgskole

Sikt

Meldeskjema / Sammenheng mellom treningsbelastning, skader og fysisk prestasjons... / Vurdering

Vurdering av behandling av personopplysninger

Referansenummer	Vurderingstype	Dato
662612	Standard	23.03.2023

Prosjekttittel
Sammenheng mellom treningsbelastning, skader og fysisk prestasjonsevne i norsk elite kvinnefotball

Behandlingsansvarlig institusjon
Norges idrettshøgskole / Institutt for idrettsmedisinske fag

Prosjektansvarlig
Thor Einar Gjerstad Andersen

Prosjektperiode
01.01.2020 - 31.12.2029

Kategorier personopplysninger
Alminnelige
Særlige

Lovlig grunnlag
Samtykke (Personvernforordningen art. 6 nr. 1 bokstav a)
Uttrykkelig samtykke (Personvernforordningen art. 9 nr. 2 bokstav a)

Behandlingen av personopplysningene er lovlig så fremt den gjennomføres som oppgitt i meldeskjemaet. Det lovlige grunnlaget gjelder til 31.12.2029.

Meldeskjema

Kommentar
Personverntjenester har vurdert endringen registrert i meldeskjemaet.

Det er vår vurdering at behandlingen av personopplysninger i prosjektet vil være i samsvar med personvernlovgivningen så fremt den gjennomføres i tråd med det som er dokumentert i meldeskjemaet med vedlegg. Behandlingen kan fortsette.

OPPFØLGING AV PROSJEKTET
Vi vil følge opp underveis (hvert annet år) og ved planlagt avslutning for å avklare om behandlingen av personopplysningene er avsluttet/pågår i tråd med den behandlingen som er dokumentert.

Lykke til videre med prosjektet!

Vil du delta i forskningsprosjektet

«ReadyToPlay: Undersøkelse av NordBord-test»

Dette er et spørsmål til deg om å delta i et forskningsprosjekt hvor formålet er å *undersøke hvordan å gjennomføre NordBord-test med ekstra vekt påvirker testresultatene.* I dette skrivet gir vi deg informasjon om målene for prosjektet og hva deltakelse vil innebære for deg.

Formål

NordBord er en test som er utviklet for å teste maksimal styrke i hamstringsmusklene under utførelse av øvelsen Nordic hamstrings. Testen brukes mye i forskning på fotballspillere for å undersøke hamstringsstyrke, men metoden som brukes varierer mye mellom studier, blant annet om testen kjøres kun med kroppsvekt eller om det legges på ekstra vekt når testen gjennomføres. Formålet med denne studien er å *undersøke hvordan å gjennomføre NordBord-test med ekstra vekt påvirker testresultatene.*

Prosjektet er del et doktorgradsprosjekt og involverer etablerte forskere og medisinere innen fotball. Anonymiserte resultater fra studien vil bli presentert på nasjonale og internasjonale konferanser, brukt i undervisningsformål, inkludert i trenerutdanningen.

Hvem er ansvarlig for forskningsprosjektet?

Norges idrettshøgskole og Senter for idrettsskadeforskning er ansvarlig for prosjektet.

Hvorfor får du spørsmål om å delta?

Som deltagere ønsker vi mannlige fotballspiller på toppnivå, og har derfor kontaktet fotballklubber på toppnivå i Oslo-området. Vi kontakter deg med denne forespørselen fordi ditt lag har sagt seg villig til å delta i prosjektet.

Hva innebærer det for deg å delta?

Hvis du velger å delta i prosjektet;

- Vil vi ta med testapparatet (Nordbord) til treningsanlegget til din fotballklubb og du vil gjennomføre en test av styrke i hamstrings i forbindelse med en fotballtrening.
- Testen gjennomføres ved at du gjennomfører øvelsen Nordic hamstrings i testapparatet (NordBord). Du vil først ta tre repetisjoner med kroppsvekt, deretter en repetisjon med 5 kg ekstra i en vektvest, en repetisjon med 10 kg ekstra i en vektvest, og en repetisjon med 15 kg ekstra i en vektvest. Denne testen tar ca. 10 minutter å gjennomføre. I tillegg vil vi måle høyde, legglengde og vekt.

Testingen vil gjennomføres på treningsfeltet deres på en dag som avtales med treneren deres ut i fra deres treningsplan.

Det er frivillig å delta

Det er frivillig å delta i prosjektet. Hvis du velger å delta, kan du når som helst trekke ditt samtykke tilbake, uten å måtte oppgi noen grunn. Alle opplysninger om deg vil da bli anonymisert. Det vil ikke ha noen negative konsekvenser for deg hvis du ikke vil delta eller senere velger å trekke deg.

Det vil ikke få noen konsekvenser for deg eller dit lag dersom du ønsker å trekke deg i fra studien.

Ditt personvern – hvordan vi oppbevarer og bruker dine opplysninger
Vi vil bare bruke opplysningene om deg til formålene vi har fortalt om i dette skrivet. Vi behandler opplysningene konfidensielt og i samsvar med personvernregelverket.

- Alle som får innsyn i dine data vil ha taushetsplikt. Kun forskere som deltar i prosjektgruppen vil ha tilgang til dine data.
- Når dine data benyttes til forskningsformål, vil de avidentifiseres ved at navn og personnummer fjernes. Dataene vil bli behandlet konfidensielt.

Alle resultater som omtales i publikasjonene etter prosjektet vil være anonymiserte og det vil ikke være mulig å gjenkjenne deg i resultatene som publiseres.

Hva skjer med opplysningene dine når vi avslutter forskningsprosjektet?
Prosjektet skal etter planen avsluttes 31.03.2022. Alle opplysninger som kan knytte deg til materialet vil bli anonymisert og opplysninger vi har lagret om deg vil slettes.

Styret ved Norges idrettshøgskole har bestemt at forskningsdata skal lagres i fem år etter prosjektslutt for etterprøvbarhet og kontroll. Dette innebærer at alle data, utenom personopplysninger, vil bli lagret i sin helhet i fem år hos Norges idrettshøgskole. Dette er meldt til Norsk senter for forskningsdata (NSD).

Dine rettigheter
Så lenge du kan identifiseres i datamaterialet, har du rett til:

- innsyn i hvilke personopplysninger som er registrert om deg,
- å få rettet personopplysninger om deg,
- få slettet personopplysninger om deg,
- få utlevert en kopi av dine personopplysninger (dataportabilitet), og
- å sende klage til personvernombudet eller Datatilsynet om behandlingen av dine personopplysninger.

Hva gir oss rett til å behandle personopplysninger om deg?
Vi behandler opplysninger om deg basert på ditt samtykke.

På oppdrag fra *Norges idrettshøgskole* har NSD – Norsk senter for forskningsdata AS vurdert at behandlingen av personopplysninger i dette prosjektet er i samsvar med personvernregelverket.

Hvor kan jeg finne ut mer?
Hvis du har spørsmål til studien, eller ønsker å benytte deg av dine rettigheter, ta kontakt med:

- *Norges idrettshøgskole* ved *Roar Amundsen, roar.amundsen@nih.no, tlf. 482 97 832.*
- Vårt personvernombud: *Rolf Haavik, rolf.haavik@habberstad.no*, tlf. 90 73 37 60.
- NSD – Norsk senter for forskningsdata AS, *personverntjenester@nsd.no) eller tlf. 555 82 117*.

Med vennlig hilsen

Roar Amundsen (PhD-stipendiat)

Professor dr. med. Roald Bahr (Veileder og leder for Senter for idrettsskadeforskning)

Samtykkeerklæring

Jeg har mottatt og forstått informasjon om prosjektet «*ReadyToPlay: Undersøkelse av NordBord-test*», og har fått anledning til å stille spørsmål. Jeg samtykker til:

- å gjennomføre testing av styrke i hamstrings med NordBord

Jeg samtykker til at mine opplysninger behandles frem til prosjektet er avsluttet

----

(Signert av prosjektdeltaker, dato)

Appendix III

Decision letters from the Norwegian School of Sports Sciences Ethical committee and the Norwegian Centre for Research Data and informed consent form.

Paper IV

Roald Bahr
Institutt for idrettsmedisinske fag

OSLO 08. oktober 2020

Endringsmelding 164-291020- 124-051219 - Effekten av to ulike protokoller med Nordic Hamstring på styrke og muskelvekst hos kvinnelige fotballspillere – en randomisert studie

Vi viser til endringsmelding med vedlegg mottatt 6.10.2020.

I henhold til retningslinjer for behandling av søknad til etisk komite for idrettsvitenskapelig forskning på mennesker, har leder av komiteen på fullmakt konkludert med følgende:

Vedtak

På bakgrunn av forelagte dokumentasjon finner komiteen at endringene er forsvarlig og at det kan gjennomføres innenfor rammene av anerkjente etiske forskningsetiske normer nedfelt i NIHs retningslinjer. Til vedtaket har komiteen lagt følgende forutsetning til grunn:

- *Vilkår fra NSD følges*

Komiteen forutsetter videre at prosjektet gjennomføres på en forsvarlig måte i tråd med de til enhver tid gjeldende tiltak ifbm Covid-19 pandemien.

Komiteen gjør oppmerksom på at vedtaket er avgrenset i tråd med fremlagte dokumentasjon. Dersom det gjøres vesentlige endringer i prosjektet som kan ha betydning for deltakernes helse og sikkerhet, skal dette legges fram for komiteen før eventuelle endringer kan iverksettes.

Med vennlig hilsen

Sigmund Loland
Professor Sigmund Loland
Leder, Etisk komite, Norges idrettshøgskole

NORGES IDRETTSHØGSKOLE

Besøksadresse: Sognsveien 220, Oslo
Postadresse: Pb 4014 Ullevål Stadion, 0806 Oslo
Telefon: +47 23 26 20 00, postmottak@nih.no
www.nih.no

Sikt

Meldeskjema / Effekten av ulike protokoller med Nordic Hamstring på styrke og musk... / Vurdering

Vurdering av behandling av personopplysninger

Referansenummer	Vurderingstype	Dato
485861	Standard	07.10.2020

Prosjekttittel
Effekten av ulike protokoller med Nordic Hamstring på styrke og muskelvekst hos kvinnelige fotballspillere – en randomisert kontrollert studie

Behandlingsansvarlig institusjon
Norges idrettshøgskole / Institutt for idrettsmedisinske fag

Prosjektansvarlig
Roar Amundsen

Prosjektperiode
01.01.2021 - 01.04.2022

Kategorier personopplysninger
Alminnelige
Særlige

Lovlig grunnlag
Samtykke (Personvernforordningen art. 6 nr. 1 bokstav a)
Uttrykkelig samtykke (Personvernforordningen art. 9 nr. 2 bokstav a)

Behandlingen av personopplysningene er lovlig så fremt den gjennomføres som oppgitt i meldeskjemaet. Det lovlige grunnlaget gjelder til 01.04.2022.

Meldeskjema

Kommentar
NSD har vurdert endringen registrert 06.10.2020. Det er vår vurdering at behandlingen av personopplysninger i prosjektet vil være i samsvar med personvernlovgivningen så fremt den gjennomføres i tråd med det som er dokumentert i meldeskjemaet med vedlegg den 07.10.2020. Behandlingen kan fortsette.

Endring: Prosjektperioden er utsatt et år. Prosjektet vil behandler personopplysninger fra 01.01.2021 til 01.04.2022.

OPPFØLGING AV PROSJEKTET
NSD vil følge opp ved planlagt avslutning for å avklare om behandlingen av personopplysningene er avsluttet.

Lykke til med prosjektet!

Kontaktperson hos NSD: Kajsa Amundsen
Tlf. Personverntjenester: 55 58 21 17 (tast 1)

Vil du delta i forskningsprosjektet

«Effekten av ulike protokoller med Nordic Hamstring på styrke hos kvinnelige fotballspillere – en randomisert studie»?

Dette er et spørsmål til deg om å delta i et forskningsprosjekt hvor formålet er å undersøke ulike måter å gjennomføre Nordic Hamstring program på hos kvinnelige fotballspillere og finne ut hvilken måte som er mest effektiv i å øke hamstringsstyrke. I dette skrivet gir vi deg informasjon om målene for prosjektet og hva deltakelse vil innebære for deg.

Formål
Hamstringskader er svært vanlig i fotball, og når du først har fått en hamstringsskade øker risikoen for å få en ny. Fravær i forbindelse med skade vil være negativt for lag og spiller, både når det gjelder utvikling og prestasjon. Tidligere studier har vist at et treningsprogram med Nordic Hamstring i forbindelse med fotballtreninger kan øke styrke i hamstring og redusere risikoen for hamstringskader hos menn, men ingen slike studier er gjort på kvinner. Hensikten med studien er å undersøke ulike måter å gjennomføre Nordic Hamstring program på hos kvinnelige fotballspillere og finne ut hvilken måte som er mest effektiv i å øke hamstringsstyrke. Vi ønsker å sammenligne fremgangen i styrke mellom de som trener med høyt eller lavt treningsvolum. Vi vil også observere tidsforløpet på hvordan styrken i hamstring utvikler seg gjennom intervensjonen.

Prosjektet er del av et doktorgradsprosjekt ved Norges Idrettshøgskole/Senter for idrettsskadeforskning og involverer flere etablerte forskere og medisinere innen fotball. Senter for idrettsskadeforskning sin hovedmålsetting er å forebygge skader i norsk idrett, med spesiell satsning på håndball, fotball, ski og snowboard. Anonymiserte resultater fra studien vil bli presentert på nasjonale og internasjonale konferanser, og muligens brukt i undervisningsformål og trenerutdanning.

Hvem er ansvarlig for forskningsprosjektet?
Norges Idrettshøgskole (NIH) og Senter for Idrettsskadeforskning er ansvarlig for prosjektet.

Hvorfor får du spørsmål om å delta?
Vi kontakter deg med denne forespørselen fordi ditt lag har sagt seg villig til å delta i prosjektet. Vi ønsker å kartlegge kvinnelige fotballspillere på høyt nivå, derfor får du som spiller på et lag i 1.divisjon forespørselen om å delta. Spillerne på to lag som spiller i 1.divisjon og holder til i Oslo-regionen vil få forespørsel om å delta i prosjektet.

Hva innebærer det for deg å delta?
Du vil trene som normalt med ditt lag, og styrkeøvelsen Nordic Hamstring vil bli gjennomført på slutten av treningene. Hvilket treningsvolum du skal gjøre kommer an på hvilken gruppe du får utdelt. Treningen tar ca. 10 minutter og gjennomføres 1-3 ganger i uken i forbindelse med fotballtrening. Prosjektet vil starte i sesongoppkjøringen. Treningsintervensjonen varer i 8 uker, i tillegg vil testing bli gjennomført uken før og uken etter treningsintervensjonen.

Hvis du velger å delta i prosjektet;

- Trener du et Nordic Hamstring program som du får utdelt av oss på slutten av fotballtrening 1-3 ganger i uken. Treningen tar ca. 10 minutter og styres av en person tilknyttet prosjektet fra NIH.
- Blir du testet før og etter treningsintervensjonen. Testingen gjennomføres på NIH, tar ca. 1,5 time og testbatteriet består av testing av styrke, spenst og hurtighet.
- Styrke i Nordic Hamstring øvelsen vil også bli testet to ganger (etter 4 og 6 uker av programmet) på treningsfeltet til laget ditt i forbindelse med fotballtrening. Denne testingen tar ca. 5 minutter.

Det er frivillig å delta
Det er frivillig å delta i prosjektet. Hvis du velger å delta, kan du når som helst trekke samtykke tilbake uten å oppgi noen grunn. Alle opplysninger om deg vil da bli anonymisert. Det vil ikke ha noen negative konsekvenser for deg eller ditt lag hvis du ikke vil delta eller senere velger å trekke deg.

Ditt personvern – hvordan vi oppbevarer og bruker dine opplysninger
Vi vil bare bruke opplysningene om deg til formålene vi har fortalt om i dette skrivet. Vi behandler opplysningene konfidensielt og i samsvar med personvernregelverket.

- Alle som får innsyn i dine data vil ha taushetsplikt. De som deltar i prosjektgruppen og som vil ha tilgang til dine data er *PhD-stipendiat Roar Amundsen, masterstudent Janita Sæther Heimland, prosjektleder Roald Bahr, samt Thor Einar Gjerstad Andersen, Merete Møller, Solveig Thorarinsdottir og Morten Wang Fagerland*. I tillegg vil du og din trener, og eventuelt andre personer i din klubb som får ditt samtykke, kunne få innsyn i dine data.
- All data vil i etterkant av prosjektet anonymiseres ved at all gjenkjennende informasjon om deg som f. eks. navn, alder, o.l. vil slettes. Dataene vil bli behandlet konfidensielt. Navnet og kontaktopplysningene dine vil erstattes med en kode som lagres på egen navneliste adskilt fra øvrige data, og datamaterialet vil lagres på forskningsserver.

Alle resultater som omtales i publikasjonene etter prosjektet vil være anonymiserte og det vil ikke være mulig å gjenkjenne deg i resultatene som publiseres.

Hva skjer med opplysningene dine når vi avslutter forskningsprosjektet?
Prosjektet skal etter planen avsluttes 01.04.2022. Styret ved Norges Idrettshøgskole har bestemt at forskningsdata skal lagres i fem år etter prosjektslutt for etterprøvbarhet og kontroll. Dette innebærer at data uten navn eller andre direkte kjennetegn vil bli oppbevart til 1.04.2027. Kodenøkkelen som kobler deltakerne til opplysningene og vil være fysisk innelåst. Kun *Roar Amundsen* vil ha tilgang til denne. Etter 1.04.2027 vil alle opplysninger som kan knytte deg til materialet anonymiseres (kodenøkkelen slettes) og opplysninger for øvrig vi har lagret om deg slettes.

Dine rettigheter
Så lenge du kan identifiseres i datamaterialet, har du rett til:

- innsyn i hvilke personopplysninger som er registrert om deg,
- å få rettet personopplysninger om deg,
- få slettet personopplysninger om deg,
- få utlevert en kopi av dine personopplysninger (dataportabilitet), og
- å sende klage til personvernombudet eller Datatilsynet om behandlingen av dine personopplysninger.

Hva gir oss rett til å behandle personopplysninger om deg?
Vi behandler opplysninger om deg basert på ditt samtykke.

På oppdrag fra *Norges Idrettshøgskole* har NSD – Norsk senter for forskningsdata AS vurdert at behandlingen av personopplysninger i dette prosjektet er i samsvar med personvernregelverket.

Hvor kan jeg finne ut mer?
Hvis du har spørsmål til studien, eller ønsker å benytte deg av dine rettigheter, ta kontakt med:

- *Norges Idrettshøgskole og Senter for idrettsskadeforskning* ved *Roar Amundsen, roar.amundsen@nih.no, tlf. 48 29 78 32*
- Vårt personvernombud: *Tove Riise, Norges Idrettshøgskole, personvernombud@nih.no*.
- NSD – Norsk senter for forskningsdata AS, *personverntjenester@nsd.no eller tlf. 55 58 21 17.*

Med vennlig hilsen

Professor Dr. Med. Roald Bahr (Veileder)	Roar Amundsen (PhD-stipendiat)

Samtykkeerklæring

Jeg har mottatt og forstått informasjon om prosjektet *«Effekten av ulike protokoller med Nordic Hamstring på styrke hos kvinnelige fotballspillere – en randomisert kontrollert studie»*, og har fått anledning til å stille spørsmål. Jeg samtykker til:

- å delta i trening og testing i forbindelse med prosjektet

Jeg samtykker til at mine opplysninger behandles frem til prosjektet er avsluttet, ca. *01.04.2020.*

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(Signert av prosjektdeltaker, dato)	(Signert av foresatte (for spillere under 18 år), dato)

Roar Amundsen // Hamstring injuries in women's football