GROIN PROBLEMS IN MALE FOOTBALL: BEYOND THE TIME-LOSS APPROACH

Ernest Esteve Caupena

Universitat de Girona

Groin problems in male football

BEYOND THE TIME-LOSS APPROACH

Doctoral Thesis

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Thesis to obtain the degree of: “Doctor of the University of Girona”
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Supervisor
Kristian Thorborg, Professor, PT

Co-supervisors
Per Hölmich, Professor, MD

Michael Skovdal Rathleff, Professor, PT

Tutor:
Elisabeth Pinart Nadal, Professor, BI

“Look deep into nature, then you will understand everything better”

Albert Einstein

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Universitat de Girona

Thesis supervision certificate

Professor Kristian Thorborg, of University of Copenhagen (Denmark)
Professor Michael Skovdal Rathleff of Aalborg University (Denmark)
Professor Per Hölmich, of University of Copenhagen (Denmark)

WE DECLARE:

That the present thesis, entitled *Groin problems in male football*, and presented by Ernest Esteve Caupena to obtain a doctoral degree, is a compendium of publications, and has been completed under our supervision, and meets the requirements to opt for an International Doctorate.

For all intents and purposes, we hereby sign this document.

Prof. Kristian Thorborg Main supervisor	Prof. Michael S. Rathleff Co-supervisor	Prof. Per Hölmich Co-supervisor

Copenhagen, 31st of August 2020

List of publications

The present Doctoral Thesis is a based on the following scientific papers, which are detailed below and referred to in the text with their Roman numerals:

I. Prevalence and severity of groin problems in Spanish football: A prospective study beyond the time-loss approach.
Esteve E, Clausen MB, Rathleff MS, Vicens-Bordas J, Casals M, Palahí-Alcàcer A, Hölmich P, Thorborg K.
Scand J Med Sci Sports. December 2019. doi:10.1111/sms.13615
Journal Citation Reports (2019) Impact Factor: 3.255; Ranking: 14/85 (Sport Sciences); Quartile: 1

II. Groin problems from pre- to in-season: A prospective study on 386 male Spanish footballers.
Esteve E, Rathleff MS, Hölmich P, Casals M, Clausen MB, Vicens-Bordas J, Pizzari T, Thorborg K.
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III. Preseason adductor squeeze strength in 303 Spanish male soccer athletes: A cross-sectional study.
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IV. Past-, pre-, and in-season risk assessment of groin problems in male football: A prospective full-season study
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Submitted

List of abbreviations

B	beta
BMI	Body Mass Index
CG	control group
CI	Confidence Interval
cm	centimeters
DOI	Digital Object Identifier
ER	external rotation
et al.	et alia
FIFA	Fédération Internationale de Football Association
GP	groin pain
GrOS	Groin Outcome Score
HAGOS	The Copenhagen Hip And Groin Outcome Score questionnaire
HHD	Hand-Held Dynamometer
HR	Hazard ratio
hrs	hours
i.e.	id est
IBM	International Business Machines
ICr	Credibility Interval
IG	intervention group
INLA	Integrated Laplace Approximation
IR	internal rotation
IRR	Incidence rate ratio
kg	kilogram
lmerTest	Tests in Linear Effects Models
LMM	Linear Mixed Model
log	logarithm
m	meter
MDC	minimal detectable change
med	median
N	Newton
n	sample size
N·m	Newton-meter
N·m/kg	Newton-meter per kilogram

NA	not available
nlmer	Nonlinear Mixed-Effect Models
no.	number
º	degrees
OR	Odds Ratio
OSTRC	Oslo Sports Trauma Research Center
PD	Prevalence difference
PR	Prevalence ratio
Prob	probability
RA	rectus abdominis
RD	Rate difference
ROM	Range Of Movement
RR	Relative Risk
SD	Standard deviation
Sport	Sport and Recreation subscale from HAGOS questionnarei
SPSS	Statistical Package for the Social Sciences
VO2max	maximum rate of oxygen consumtion
wk	week
x2	Chi-square
yrs	years
z	z score
%	percentage

List of figures

List of tables

Table of contents

Abstract

This Thesis is aimed at investigating the extent of groin problems in male football, using the time-loss injury definition, together with self-reported measures to register groin pain, irrespective of time loss, and hip- and groin-related sporting function. It also aims to assess associations of risk factors with in-season groin problems, as well as, possible relationships among these risk factors.

The four papers, which form part of this Thesis, are based on the same research project investigating groin and hamstring injuries among a cohort of amateur players from 17 Spanish teams. Past-season groin pain information, pre-season short- and long-lever hip adductor squeeze strength, together with demographic and anthropometric data were registered at baseline (pre-season). Hip- and groin-related sporting function was registered at baseline, and every fourth week during the in-season, using the Sport and Recreation subscale from The Copenhagen Hip and Groin Outcome Score (HAGOS (Sport)) questionnaire. Time-loss groin injuries, registered by the team physiotherapist, in addition to self-reported groin pain, irrespective of time loss, were registered over 44 weeks to document all groin problems, and groin problems with and without time loss.

The average (range) weekly prevalence of groin problems in the competitive in-season (39 weeks) was 11.7% (7.2%-20.8%), with 1.3% (0.0%-3.2%) of groin problems with time loss, and 10.4% (6.3%-17.6%) without time loss. Players reporting groin problems showed lower HAGOS (Sport) subscale scores compared to players not reporting groin problems (mean difference: -19.5; 95% CI -20.7 to -18.4). There was no difference in HAGOS(Sport) scores, between players reporting groin problems with and without time loss. The average weekly prevalence of groin problems was higher during pre-season (3 weeks) (20.7%; 95% CI 18.4% to 23.3%) compared to the in-season (11.7%; 95% CI 11.2% to 12.3%). This was due to a higher prevalence of groin problems without time loss in the pre- (18.7%; 95% CI 16.4% to 21.2%) compared to the in-season (10.4%; 95% CI 9.9% to 10.9%), as there was no difference in the prevalence of groin problems with time loss.

No difference was found in hip adductor squeeze strength among players who suffered from past-season groin pain when adjusting for current groin pain and age. Players with a duration of past-season groin pain of longer than 6 weeks showed 11.5% and 15.3% lower values on the short- and long-lever adductor squeeze test, respectively, compared to players who did not suffer from past-season groin pain. Players who suffered from past-season groin pain had 2.4 times greater risk (2.4 RR; 95% ICr 1.52 to 3.74) of an in-season groin problem. Higher pre-season stregnth in the long-lever squeeze adductor test reduced the risk of in-season groin problems, with a 35% (0.65 RR; 95% ICr 0.42 to 0.99) risk reduction per unit (N·m/kg) increased in the test output. No effect was found on injury risk by age, short-lever squeeze test, or HAGOS (Sport) scores.

Groin problems go far beyond the scope of the time-loss definition of injury, as only one tenth result in time loss on a weekly basis. Players experience limitations in their hip/groin sporting function due to groin problems, although the degree of impairment is not only the cause for reducing participation. Groin problems are twice as common in pre-season compared to in-

season. This difference results from a greater weekly prevalence of groin problems without time loss in the pre-, compared to the in-season, as there is no difference in the prevalence of groin problems with time loss between the two season periods. Having had a duration of past-season groin pain of more than six weeks reduces pre-season hip adductor squeeze strength in the subsequent season, together with the player's increased age. Past-season groin pain, and pre-season lower long-lever adductor squeeze strength values were associated with an increased risk of in-season groin problems, whereas player's age, the short-lever squeeze test, and in-season HAGOS-Sport/Rec scores were not.

Resum

Aquesta Tesi va tenir com a objectiu investigar l'extensió dels problemes de l'engonal en futbolistes masculins, utilitzant la definició de lesió de *time-loss*, juntament amb mesures per registrar el dolor de l'engonal de manera autoreportada i independents de *time-loss*. També ha avaluat associacions de factors de risc per problemes de l'engonal durant la temporada, així com, possibles relacions entre aquests factors.

Els quatre articles científics, els quals formen part d'aquest tesi, estan basats en el mateix projecte de recerca que investiga lesions de l'engonal i dels isquiosurals en una cohort de jugadors amateurs de 17 equips espanyols. A l'inici de l'estudi (pretemporada) es va registrar informació sobre dolor de l'engonal en la temporada anterior, la força de compressió en adducció de maluc en palanca curta i llarga, juntament amb dades demogràfiques i antropomètriques (pretemporada). Cada quatre setmanes durant la temporada competitiva i també a l'inici de l'estudi, es va registrar la funció esportiva relacionada amb el maluc i la zona de l'engonal mitjançant la subescala *Sport and Recreation* del qüestionari *The Copenhagen Hip And Groin Outcome Score* (HAGOS (Sport). Les lesions de l'engonal amb *time loss*, registrades pels fisioterapeutes de cada equip, juntament amb el dolor de l'engonal autor-reportat i independent del *time loss*, es van registrar durant 44 setmanes per documentar els problemes de l'engonal, amb *time loss* i sense.

La prevalença setmanal mitjana (rang) de problemes de l'engonal durant les setmanes competitives (39 setmanes) va ser 11.7% (7.2%-20.8%), de les quals 1.3% (0.0%-3.2%), van ser problemes amb *time loss*, i 10.4% (6.3%-17.6%) problemes sense *time loss*. Els jugadors que van reportar problemes a l'engonal van mostrar valors més baixos en la subescala HAGOS(Sport), comparats amb els jugadors que no van reportar problemes (diferència mitjana: -19.5; 95% CI -20.7 to -18.4). No hi va haver diferència en els valors de HAGOS (Sport) entre jugadors que varen reportar problemes amb *time loss* i sense. La prevalença setmanal mitjana de problemes de l'engonal va ser més alta durant la pretemporada (3 setmanes) (20.7%; 95% CI 18.4 to 23.3%), comparat amb la temporada competitiva (11.7%; 95% CI 11.2 to 12.3%). Aquesta diferència va ser deguda a una major prevalença de problemes sense *time loss* durant la pretemporada (18.7%; 95% CI 16.4% to 21.2%), comparat amb la temporada competitiva (10.4%; 95% CI 9.9% to 10.9%), ja que no hi va haver diferència en la prevalença de problemes amb *time loss*.

No es van observar diferències en la força de compressió en adducció del maluc, entre jugadors que van patir de dolor a l'engonal la temporada anterior i els que no van fer-ho, quan es va ajustar per la presència actual de dolor a l'engonal i per l'edat. Els jugadors que van patir de dolor a l'engonal durant més de 6 setmanes, en la temporada anterior, respecte dels que no van partir-ne, van mostrar reduccions del 11.5% i del 15.3% en els valors de força de compressió d'adductors de palanca curta i llarga, respectivament. Els jugadors que van patir de dolor a l'engonal en la temporada anterior vam mostrar 2.4 vegades més risc (2.4 RR; 95% ICr 0.42 to 0.99) de patir problemes de l'engonal durant la nova temporada. Valors més alts de força en el test de compressió en adducció del maluc van reduir el risc de problemes a l'engonal un 35% per cada unitat incrementada (N·m/kg) en el resultat del test. No es va

observar efecte sobre el risc de lesió per l'edat, la força de compressió en adducció en palanca curta i o els valors de HAGOS (Sport).

Els problemes de l'engonal s'estenen més enllà de la definició de lesió de *time loss*, ja que setmanalment només una desena part d'aquests resulten en *time loss*. Els jugadors pateixen limitacions en la funció esportiva del maluc i de l'engonal, tot i que el grau d'aquestes limitacions sembla no és l'única causa per reduir la participació (i.e. *time loss*). Els problemes de l'engonal són el doble de freqüents durant la pretemporada comparat amb la temporada competitiva. Aquest diferència, rau en una major prevalença de problemes sense *time loss* durant la pretemporada, comparat amb la temporada competitiva, ja que no hi va haver diferència en els problemes amb *time loss* durant els dos períodes de la temporada. Haver patit de dolor a l'engonal durant més de sis setmanes redueix els valors de força en adducció del maluc a la següent pretemporada, juntament amb l'increment de l'edat del jugador. Dolor a l'engonal en la temporada anterior, i valors més baixos en força de compressió en adducció mitjançant palanca llarga estan associats a un increment del risc de problemes a l'engonal durant la temporada competitiva, mentre que l'edat, la força en palanca curta i els valors de HAGOS (Sport) no ho estan.

Resumen

Esta Tesis tuvo como objetivo investigar la extensión de los problemas inguinales en futbolistas masculinos, utilizando la definición de *time loss*, junto con medidas para registrar el dolor inguinal de manera auto-reportada, independientes de *time loss*. También ha evaluado asociaciones de factores de riesgo para problemas inguinales durante la temporada, así como, posibles relaciones entre estos factores.

Los cuatro artículos científicos, los cuales forman parte de esta tesis, están basados en el mismo proyecto de investigación que investiga lesiones inguinales e isquiosurales en una cohorte de jugadores amateurs de 17 equipos españoles. Al inicio del estudio (pre-temporada), se registró información sobre el dolor inguinal en la temporada anterior, fuerza de compresión en aducción de cadera en palanca corta y larga, juntamente con datos demográficos y antropométricos. Cada cuatro semanas durante la temporada competitiva, y también al inicio del estudio, se registró la función deportiva relacionada con la cadera y la ingle mediante la sub-escala *Sport and Recreation* del cuestionario *The Copenahgen Hip And Groin Outcome Score* (HAGOS (Sport). Las lesiones inguinales con *time loss*, registradas por los fisioterapeutas de los equipos, junto con el dolor inguinal autor-reportado e independiente de *time loss*, se registraron durante 44 semanas para documentar los problemas inguinales, con y sin *time loss*.

La prevalencia semanal promedio (rango) de problemas inguinales durante las semanas competitivas (39 semanas) fue del 11.7% (7.2%-20.8%), de los cuales 1.3% (0.0%-3.2) fueron problemas con *time loss* y 10.4% (6.3%-17.6%) fueron problemas sin *time loss*. Los jugadores que reportaron problemas inguinales mostraron valores de fuerza más bajos en la sub-escala HAGOS (Sport), comparado con los jugadores que no reportaron problema (diferencia media: -19.5; 95% CI -20.7 to -18.4). No hubo diferencia en los valores de HAGOS (Sport) entre jugadores que reportaron problemas con y sin *time loss*. La prevalencia semanal promedio de problemas inguinales fue mayor durante la pre-temporada (3 semanas) (20.7%; 95% CI 18.4% to 23.3%), comparado con la temporada competitiva (11.7% 95% CI 11.2% to 12.3%). Esto fue debido a una mayor prevalencia de problema sin *time loss* durante la pre-temporada (18.7%; 95% CI 16.4 to 21.2%), comparado con la temporada competitiva (10.4%: 95% CI 9.9% to 10.9%), ya que no hubo diferencia en la prevalencia de problemas con *time loss*.

No ser observaron diferencias en la fuerza de compresión en aducción de cadera entre jugadores que sufrieron dolor inguinal en la temporada anterior y los que no lo sufrieron, cuando se ajustó por la presencia actual de dolor inguinal y la edad. Los jugadores que sufrieron dolor inguinal en la temporada anterior por más de seis semanas, mostraron valores de fuerza en compresión en aducción en palanca corta y larga un 11.5% y un 15.5% más bajos respectivamente, comparado con jugadores que no sufrieron dolor. Los jugadores que sufrieron dolor inguinal en la temporada anterior mostraron un riesgo de sufrir problemas inguinales durante la nueva temporada 2.4 veces más alto (2.4 RR; 95% ICr 0.42 to 0.99). Valores más altos en el test de fuerza en compresión en aducción redujeron el riesgo de problemas inguinales un 35% por incremento en unidad (N·m/kg) en el resultado del test. No

ser observó efecto en el riesgo de lesión para la edad, la fuerza de compresión en aducción en palanca corta, ni en los valores de HAGOS (Sport).

Los problemas inguinales se extienden más allá de la definición de lesión de *time loss*, ya que semanalmente solo una décima parte de estos problemas resultan en *time loss*. Los jugadores sufren limitaciones en su función deportiva de la cadera y la ingle, aunque el grado de estas limitaciones parece no es la única causa para reducir la participación (i.e. *time loss*). Los problemas inguinales son dos veces más frecuentes durante la pre-temporada, comparado con la temporada competitiva. Esta diferencia radica en una mayor prevalencia de problemas inguinales sin *time loss* durante la pre-temporada, comparado con la temporada competitiva, ya que no hubo diferencia en la prevalencia de problemas con *time loss* durante los dos periodos de la temporada. Haber sufrido dolor inguinal en la temporada anterior durante más de seis semanas reduce los valores de fuerza de compresión en aducción de cadera, junto con un aumento de la edad del jugador. Dolor inguinal en la temporada anterior y valores reducidos de fuerza de compresión en aducción en palanca larga están asociados un incremento del riesgo de sufrir problemas inguinales durante la temporada competitiva, mientras que la edad la fuerza de aducción de cadera en palanca corta y los valores de HAGOS (Sport) no lo están.

Chapter 1
General introduction

Football provides benefits for cardiovascular health and reduces the risk of metabolic diseases,[1,2] although it implies an inherent risk of injury or harm on the musculoskeletal system.[3–14] The injury incidence in football is among the highest in team-based sports.[15,16] In male amateur football, which represents the vast majority of football players, the overall injury incidence is 5.1-9.6 injuries per 1000 hours of football, [8,13,17,18] with 2.4-7.6 injuries per 1000 training hours, and 12.3-32.2 injuries per 1000 match hours.[8,13,17–19] Nearly one in every two players sustain an injury during the season (33%-69%),[14,17,20,21] and recurrence rates are commonly high (10%-33%).[8,13,17,22] Football injuries result in underperformance,[19,23–25] and a significant number of days lost from participation,[8,9,23,26] which represent a great burden that extends to all playing levels of football.

The football game involves repeating high intensity and explosive actions, such as sprinting, accelerations and decelerations, changes of direction and kicking.[27,28] It is not surprising therefore that most football injuries occur in the lower extremities (83%-90%).[5,14,17,18,20,22,29] The groin area, usually defined as the junction between the lower abdomen and the anteromedial part of the thigh,[26,30] is among the most frequently injured.[5,14,17,20,29,31–35] Groin injuries are more common in male players, as they have a more than two-fold higher groin injury rate compared to female players.[3–5,30] Groin injuries are persistent and highly recurrent,[6,31,31,36–40] and a major contributor to the total injury burden in football,[8,26,41] which calls for implementing effective preventative measures for these injuries.

Prevention of groin injuries

In 1991 van Mechelen et al. described “the sequence of prevention”, providing a four- step framework on how to effectively prevent sports injuries (Figure 1).[42] The first step in the sequence is to determine the magnitude of the problem, by measures of frequency and severity of the target injuries. The second step is to identify risk factors, causes, and mechanisms of injuries. The third step is to introduce preventative measures based on the aetiological factors and mechanisms identified in the second step. Finally, the fourth step refers to assessing the effectiveness of the implemented measures, ideally in a randomized controlled trial.

According to this framework, sports injuries seem preventable, although the existing evidence that groin injuries can be effectively prevented in sports is inconclusive. In 2015, we published, a systematic review with meta-analyses of randomized controlled trials on prevention of groin injuries in sports, as a preliminary publication of this PhD project (Appendix I).[43] This systematic review included a total of seven studies, with six studies on football,[13,38,44,45] and one on female handball.[46] The six studies on football were from different levels of play across European countries; four studies were on male senior leagues,[13,38,44,45] and two on senior and youth female football,[47,48] respectively. Three of the four studies on senior male football tested active exercise-based interventions,[13,38,45] while the remaining one tested the effect of a video-based awareness intervention on soccer injuries.[44] The meta-analysis including all seven studies on different sports revealed a non-significant reduction in groin injury of 19%. Identical non-significant estimates were obtained in the subgroup analysis in male and female football players. Likewise, the subgroup meta-analysis, including only the three studies on

male football testing active exercise-based interventions, showed a reduction in groin injury of 16%, although this estimate was also non-significant. Even though in total more than 4000 players from football and handball were examined in the meta-analyses, the number of groin injuries in these studies was very low (157 groin injuries). In studies on male football, groin injury was a rare event, only affecting between 8% and 16% of the players.[13,38,45]

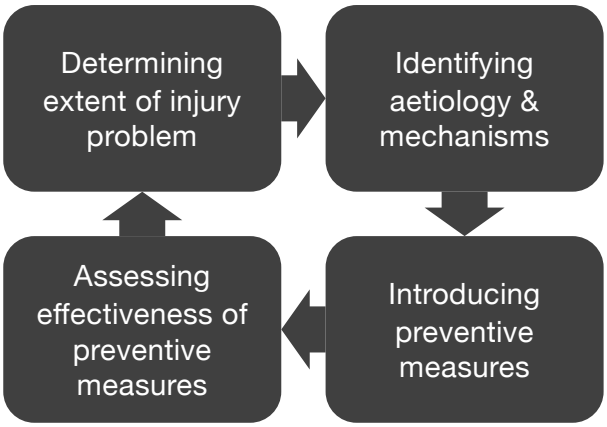

Figure 1 Four step sequence of injury prevention research. (adapted from van Mechelen 1992)[42]

An American study on male soccer players reporting on groin injuries was later identified in a systematic review on the effect of FIFA prevention programmes on overall injury rates in football.[49] This study included all injuries registered in a health-insurance database, which resulted in a higher event rate (71 groin injuries) compared to previous studies.[50] Results from this study showed that the FIFA11+, an active exercise-based intervention evolved from previous studies (the FIFA11), significantly reduced the number of groin injuries by 40%. This study, however, has not been pooled in a meta-analysis on groin injuries in isolation.

Recently, a Norwegian study has been identified in a systematic review on diagnosis, prevention and treatment of lower extremity muscle injuries in sport.[51] This study showed that a single-exercise approach on adductor muscles reduced the prevalence of groin problems by 41%.[52] In this study, the definition of groin problems included, apart from pain, aches and stiffness. All these complaints were self-reported and independent of player availability to participate in trainings and matches. Importantly, this study also showed an average weekly prevalence of groin problems of up to 21%, and that only one-third of these problems resulted in absences from football. Table 1 shows characteristics of prevention studies on male football reporting on groin injuries identified in systematic reviews.

The number of events (i.e. injuries) is a critical factor for estimating injury risk.[53] A low injury rate may limit the statistical power to detect differences in estimates, as well as requiring larger sample sizes.[53] Necessarily, the number of events, and therefore injury incidence, are influenced by injury definition.[54] In most studies to date, the definition of injury has been in relation to player availability to participate in training sessions and matches. However, studies have revealed that players continue playing with minor injuries or pain,[55,56] which may call

Table 1 Prevention studies on male football reporting on groin injuries identified in systematic reviews[43,49,51]

Study (year)	Population (years)	Preventive intervention	Follow-up	Completion (players)	Injury definition	Number of groin injuries	Conclusion (estimates)
Arnason *et al.* (2005)[44]	Elite (age not specified)	15-min presentation and vide-awareness + 2h workshop at respective clubs. One-time intervention.	1 season, 4 months	Intervention 127 Control 144	Time loss	Intervention 7 Control 6	No significant difference was observed in the number of groin injuries (χ^2: z=0.50)
Engebretsen *et al.*† (2008)[45]	Elite (age not specified)	15min training performed at home, including isometric adductor muscles and transverse abdominal exercises, sideways jumping, sliding and diagonal walking	1 season including 10-week pre-season	Intervention 62 Control 98	Time loss‡	Intervention 11 Control 16	No significant difference was observed in the number of groin injuries (RR=1.18; 95% CI, 0.55-2.54)
Harøy *et al.* (2019)[52]	Semi-pro	Adductor Strengthening Programme consisting of a single exercise: the Copenhagen Adduction exercise performed as part of the regular warm-up with different levels of difficulty	1season, 9 months	Intervention 122 Control 242	Any complaint	Total 2458[a]	The Adductor Strengthening Programme substantially reduced the prevalence and risk of groin problems (OR=0.59; 95% CI 0.40-0.86)
Hölmich *et al.* (2010)[32]	Amateur (18-42.4)	13min program integrated as part of regular warm up, consisting in isometric and eccentric hip adductors strengthening, abdominal and hip flexors training, one leg coordination and stretching of iliopsoas muscle.	1 season, 42 weeks	Intervention 477 Control 430	Time loss + Medical attention	Intervention 23 Control 30	No significant difference was observed in time to groin injury, 31% of risk reduction not significant (HR=0.69, P=0.18)
Silvers-Granelli *et al.* (2015)[50]	Collegiate, (18-25)	"The 11+": 20min warm -up with 15 exercises with progressions including running, strength, plyometric and balance for the lower limb and trunk	1 autumn season, 5 months	Intervention 675 Control 850	Time loss + Medical attention	Intervention 48 Control 23	Injury rates were significantly lower in the IG when stratified for type of injury. Groin injury Rate Ratio=0.60; 95% CI 0.37-0.98
van Beijsterveldt *et al.* (2012)[50]	Amateur (18-40)	"The 11": 10 exercises for core stability, eccentric training of the thigh muscles, proprioception, dynamic stabilization and plyometric with straight alignment. 10-15 min warm-up programme during regular practise	1 season, 9 months	Intervention 223 Control 233	Time loss	Intervention 20 Control 23	Not reported for groin injury

Data presented in the table is from randomized, or cluster randomized controlled trials; † Data from group of players at increased risk of groin injuries ‡Included small repetitive strains that did not lead to time loss registered by medical staff; Semi-pro: semi-professional; [a] Number of self-reported groin problems out of 13628 questionnaire responses

into question the use of injury definitions based upon player availability to participate. Not only may statistical support in detecting differences in the rate of injury, when it exists, have been limited, but the true extent of groin injuries may also have been underestimated.

Taken together, these findings reveal the need to revise the steps of "the sequence of prevention", starting with the true extent of groin injuries by including broader and clinically meaningful injury definitions, such as groin pain. Similarly, the knowledge of the causes and risk factors of these injuries should be broadened.

Groin-injury epidemiology in male football

Definitions in injury surveillance in football

In the last decades, epidemiological studies in football have used different definitions of injury. An injury was registered in some studies when it was reported for insurance company records.[57,58] In others, an injury was registered based on the need for first-aid or medical attention, and severity was classified by grading medical care and medically prescribed activity restriction.[59,60] These differences in injury definition have complicated comparisons between studies. To address this issue, a Consensus statement on injury definitions and data collection procedures was published in 2006 under the auspices of the Fédération Internationale de Football Association Medical Assessment and Research Centre.[61] This Consensus was aimed at providing definitions, methods for data collection, and recommendations on how data should be reported.

In the Consensus, a football injury is defined as "any physical complaint sustained by a player that results from a football match or football training, irrespective of the need for medical attention or time loss from football activities". An injury that results in a player receiving medical attention is referred to as a ''medical attention'' injury, and an injury that results in a player being unable to take part fully in future football training or match play as a ''time-loss'' injury.[61] Injury severity is measured as "the number of days that have elapsed from the date of injury to the date of the player's return to full participation in team training and availability for match selection". According to the number of missed days, injuries can be grouped in: slight (0 days); minimal (1-3 days), mild (4-7 days); moderate (8-28 days); severe (>28 days), and career-ending, when players do not get back to sport. Injuries can also be classified by injury mechanism as: traumatic injury ("an injury resulting from a specific, identifiable event"), or overuse injury ("one caused by repeated microtrauma without a single, identifiable event responsible for the injury"). A recurrent injury (i.e. re-injury) is classified as "an injury of the same type and at the same site as an index injury and which occurs after the player's return to full participation".

Although the Consensus statement provides a common basis for injury studies in football, it actually proposes three different definitions and therefore, the estimations of injury rate will vary according to the chosen definition.

Incidence, prevalence and severity of groin injuries in male football

In 2015, Walden and colleagues published a comprehensive systematic review on epidemiology of groin injuries in senior male and female football.[30] This review included original studies with a prospective design, which had studied at least one playing season or national team tournament, and reported data on groin injury in organized senior football. The inclusion criteria specified that studies had to be written in English, and injury had to be defined according to medical attention and/or time loss.

From the 34 prospective studies included on male and female football, 20 reported groin injury data in men's club football, covering at least one football season (see Table 2). In 12 of these 20 studies, the total number of groin injuries also included the hip.[5,14,20,29,31,32,34,35,40,62–64] The reported seasonal proportion of groin injuries was between 4% and 19% of all injuries. Using reported and re-calculated rates, seasonal groin injury rates ranged from 0.2 to 2.1/1000h. In seven of the nine studies reporting on injury mechanisms, more than half of groin injuries were classified as overuse (60–73%).[29,37,40,63–66] Re-injuries were reported in seven studies accounting for 10% to 42%.[3,12,14,17,37,40,64,66] Ten studies reported on injury severity as the duration of time loss from football.[10,29,32,36,37,40,62–64,66] In four studies most groin injuries were classified as moderate (8 to 28 days) or severe (>28 days),[36,40,62,64] while five studies described more injuries as being slight (< 3 days) or minor (3 to 7 days).[10,29,32,66] The one remaining study showed equal numbers in terms of groin injury severity.[37] The quantitative synthesis with aggregated data from all seasonal studies in male football showed a relative proportion of groin injuries of 12.8%, with a groin injury rate of 2.4/1000h.

In this review, most of the seasonal studies adopted, almost solely, the time-loss definition of injury. Only two studies used injury definitions that included the presence of symptoms and/or an altered function, irrespective of time loss. A study by Engebretsen and colleagues on amateur football,[37] included groin injuries that did not lead to time loss, but were registered by medical staff (i.e. medical attention), such as small repetitive strain injuries. Of the 61 registered groin injuries, there were 22 acute and 31 overuse injuries, but no time loss for only two overuse injuries. The time-loss and medical attention definitions were also combined in a Danish study in sub-elite male football.[40] This study showed that one-third of groin problems that sought medical attention did not result in time loss. Although a combination of "medical attention" and time-loss injury definitions is likely to capture more complaints than solely time loss, the registration of injuries would be highly dependent on the availability of medical support. This would result in important variations in injury rates, especially when comparing studies across different levels of football where differences in the availability of medical support are more likely to exist.

The true extent of the problem

Recent investigations have shown that when studies rely on the time-loss injury definition, complaints with a gradual development of symptoms or functional impairments are not recorded, as players seem to continue training and competing with pain or reduced function.[67,68] This seems highly relevant for groin injuries, in which a common gradual onset[26,69] may allow players to adapt their training and continue participating. Data from cross-sectional studies showed that the seasonal prevalence of groin pain can be up to 70% among

Table 2 Groin-injury epidemiology in seasonal prospective studies identified in the most recent systematic review[30]

Study	Publication year	Country	Football level	Seasons	Teams-season	Players	Injury definition	Number of groin injuries (%)	Groin-injury rate (95% CI)
Arnason *et al.*[36]	2004	Iceland	Divisions I and II	1	17	306	Time loss	32(13)	0.9 (0.7 to 1.3)*
Aus der Fünter *et al*.[62]	2014	Germany	Divisions I and II	2	14	254	Time loss	12 (4)†	0.2 (0.1 to 0.4)*
Bjørneboe *et al.*[63]	2014	Norway	I	6	73	-	Time loss	255 (11)†	0.5 (0.5 to 0.6)*
Ekstrand & Gillquist[10]	1983	Sweden	IV	1	12	180	Time loss	32 (13)	NA
Ekstrand & Hilding[66]	1999	Sweden	IV	2	21	326	Time loss	31 (8)	0.8 (0.6 to 1.1)
Engebretsen *et al.*[37]	2010	Norway	I to III	1	31	508	Combined*	61 (12)	0.6 (0.4 to 0.7)
Engström *et al.*[65]	1990	Sweden	I and II	1	3	64	Time loss	10 (12)	NA
Hawkins & Fuller[12]	1999	United Kingdom	Professional[a]	3	12	108	Time loss	62 (11)	NA
Hawkins *et al.*[3]	2001	United Kingdom	I to IV	2	182	2376	Time loss	596 (10)	NA
Hagglund *et al.*[5]	2005	Denmark	I	1	8	188	Time loss	58 (15)†	2.1 (1.6 to 2.7)*
Hagglund *et al.*[31]	2006	Sweden	I	2	24	525	Time loss	206 (17)†	S1: 1.1 (0.9 to 1.4) S2: 1.3 (1.0 to 1.6)
Hagglund *et al*.[14]	2007	Sweden	IV	1	10	241‡	Time loss	12 (9)†	0.5 (0.3 to 0.8)*
Hagglund *et al*[32].	2009	Sweden	I	1	11	239	Time loss	97 (18)†	1.0 (0.8 to 1.3)
Hölmich *et al.*[40]	2014	Denmark	V to VII	1	44	998	Combined[b]	58 (12)	0.4 (0.3 to 0.5)
Noya-Salces *et al*[35].	2014	Spain	I	1	16	427	Time loss	175 (14)†	0.8 (0.7 to 0.9)
Noya-Salces *et al.*[34]	2014	Spain	II	1	11	301	Time loss	144 (16)†	0.6 (0.5 to 0.7)
Sousa *et al.*[17]	2013	Portugal	Amateur[a]	1	11	231	Time loss	17 (8)†	0.4 (0.2 to 0.6)*
van Beijsterveldt *et al.*[20]	2015	Netherlands	I	1	8	217	Time loss	30 (10.5)†	0.6 (0.5 to 0.9)*
			Amateurs[a]		23	456		47 (11)†	1.1 (0.8 to 1.4)*
Walden *et al.*[29]	2005	Sweden	Division I	1	14	310	Time loss	114 (16)†	1.2 (1.0 to 1.5)*
Werner et al.[64]	2009	Europe	I	7	23	1065	Time loss	628 (14)†	1.1 (1.0 to 1.2)

† Reporting hip and groin injuries together; ‡ Control group in an RCT; * Recalculated (chi-squared test) from reported data in the study for the purpose of this Thesis; NA: data no available [a] Football level not specified; [b] Combination of time-loss and medical-attention injury definitions

male football players,[39,70] indicating that the extent of groin problems is at high risk of being underestimated when only the time-loss definition is adopted.

A Norwegian study investigated the prevalence of groin problems in male and female soccer, during a 6-week period of match congestion.[24] This study registered self-reported groin problems according to the "any physical complaint" injury definition using The Oslo Sports Trauma Research Center (OSTRC) Injury Questionnaire, distributed through smartphone application software. The study reported data on 195 male players from different levels of football including 44 players from under-19 teams. Of the 195 male players, 112 (59%) reported at least one episode of groin problems, and the average weekly prevalence of any groin problem was 29% (range, 23%-32%). The number of groin problems that led to time loss was only one-third of the number of groin problems registered with the "any physical complaint definition". Figure 2 shows the number of groin problems registered by the time-loss definition of injury and the new method. Lately, the same injury registration methods have been used in a randomized controlled trial evaluating the preventive effect of the Copenhagen Adduction Exercise on the prevalence of groin problems.[52] The average weekly prevalence of all groin problems during the 28-week competitive season in the control group was 21.3%, with again only one-third of groin problems leading to time loss.

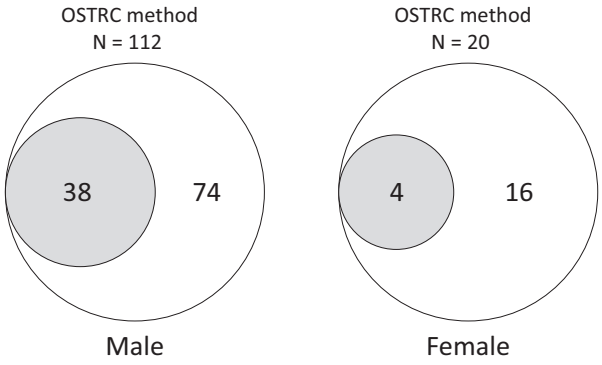

Figure 2 Venn diagram displaying the number of groin problems identified by standard injury registration, using a time-loss definition (grey circle), and the new OSTRC method. Harøy et al.[24] reproduced with permission.

These findings from Norwegian studies also indicate that the prevalence of groin problems seems phase-dependant throughout the season, with higher prevalence at times of higher football loads, such as a congested calendar (29%).[24] Previous studies found higher proportions of groin injuries during pre-season, with most of these injuries classified as overuse,[3,5,35] although all previous studies investigating football pre-season have been limited to time loss.

Likewise, measuring injury severity as the duration of time loss from football might be an inappropriate measure in the case of groin injuries. Instead, measuring limitations in sporting performance from the player's perspective is more likely to reflect the true impact of these injuries.[25,67] In previous studies, the weekly prevalence of substantial groin problems, resulting in moderate or severe reduction in training volume, sporting performance or a total inability

to participate, was 8% during the football season,[52] increasing up to 10% during a period of match congestion.[24] It is, however, at present unknown how the severity of groin problems, measured as limitations in sports-related sporting function, may be related to time loss from football.

Studies investigating the extent of groin problems beyond the time-loss approach with broader injury definitions are lacking in southern European football. Thus, in Paper I we wanted to investigate the prevalence and severity of groin problems in male amateur Spanish footballers, using novel registration methods, which included groin pain and not only time loss. In addition, in Paper II, we examined the prevalence and severity of groin problems during a football pre-season, and compared them with in-season data.

Risk factors for groin problems

The identification of factors and mechanisms whereby a particular athlete may be at higher risk of sustaining an injury is a fundamental step for effectively preventing sports injuries.[42] The identification of these factors, allows us to introduce targeted measures aimed at reducing the risk and/or severity of future injuries in a determined population. Risk factors are commonly grouped in two main categories. Characteristics inherent to the athlete (intrinsic factors), and factors related to the environment (extrinsic factors). Risk factors can also be grouped into non-modifiable, such as gender or age, and modifiable, such as muscle strength or balance, which arouse the most interest, as they are potentially modifiable through specific interventions,

However, sports injuries result from a complex interaction of multiple intrinsic and extrinsic factors and mechanisms, rather than a consequence of one isolated factor.[42,71,72] Meeuwisse proposed a multifactorial model for examining the aetiology of the athletic injury (see Figure 3).[71] In this model, a combination of intrinsic (i.e. physical condition, previous history, or age) and extrinsic (i.e. sporting activity, field condition, or game rules) risk factors may lead an athlete to be more susceptible to injury, although they are insufficient for developing an injury on their own without an inciting event (i.e. injury mechanism). The identification of an inciting event seems obvious for acute injuries, in which the event is commonly related visually to the injury, such as kicking a ball or receiving a tackle. In the case of overuse injuries, which seems the case of most groin injuries, the identification of the inciting event might be less obvious. In overuse injuries, injury onset is believed to be gradual, as the result of repetitive bouts of exercise rather than a unique event.

Risk factors may interact producing higher or lower associations with a specific outcome than either of the factors independently. It might also be that the association between a potential risk factor and the outcome (i.e. injury) is mediated by a third (observed or unobserved) factor, which is also related to the potential risk factor and the outcome, respectively (confounding).[71,72] Due to this complexity and the multifactorial nature of sports injury, studies aimed at risk factor identification are advised to assess multiple factors simultaneously in prospective studies where a group of healthy participants is followed over time.[53,71–73] Although the identification of isolated factors using univariate analyses might be valuable at

some stages, this approach hampers research into how the combination of different factors may relate to injury. It seems obvious, therefore, that risk factor studies cannot determine *per se* the causes of injury, although they can identify potential modifiable risk factors of a specific injury to reduce the risk of injury.[42,73]

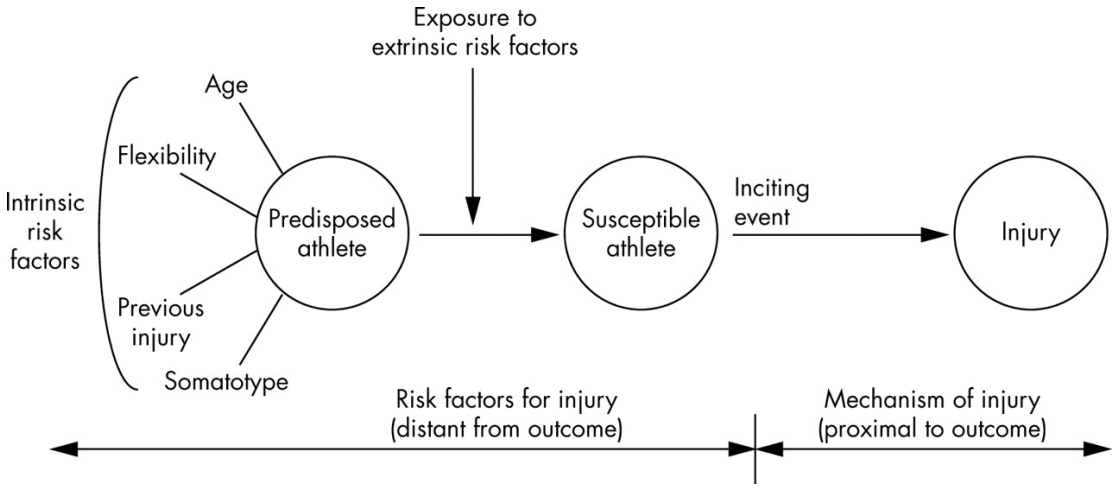

Figure 3 Multifactorial model of athletic injury epidemiology. (Reprinted with permission from Clinical Journal of Sports Medicine. Lippincott Williams & Wilkins, Meeuwisse)[67]

Two systematic reviews have summarised the existing evidence on risk factors for groin injuries in sporting populations. Whittaker and colleagues published an updated version of a previous review from the same group, investigating risk factors for groin injury in sport.[74] Compared to the previous review, which focused on groin strain injury,[75] in the updated version, the authors modified the definition of injury in the included studies in order to match current consensus on groin injury terminology. This modification increased the number of studies included from 11 to 29. A systematic review from Ryan and colleagues,[76] investigated risk factors for hip and groin injuries including seven studies on field-based sports with common kicking and sprinting mechanics, such as European football, Australian football, and rugby. In total, these two reviews included 30 studies from different sports on this topic. In male senior football, a number of modifiable and non-modifiable risk factors have been investigated in nine prospective studies. Table 3 shows characteristics of prospective risk-factor studies on male senior football, reporting data on groin injuries.

Previous groin injury

Previous groin injury is the most consistent risk factor for groin injury in male football.[6,31,36–38] In large prospective studies across different levels of football, previous groin injury increased by two to three-fold the risk of a new groin injury. A study by Arnason and colleagues reported an even higher risk for acute groin injury, with a seven-time risk increase when players reported a previous groin strain.[36] Changes in the structural or scar tissue after a prior injury, as well as inadequate rehabilitation and early return to play, have been pinpointed as possible explanations to support this factor.[6,36,37]

Table 3 Prospective risk factor studies on senior male football reporting on groin injuries identified in systematic reviews[74,76]

Study (year)	Participants, level, age, follow-up	Risk factor examined	Injury definition (no. injuries)	Reported as significant risk factors	Statistical figures
Witvrouw *et al.* (2003)[77]	Professional (n=146), age: not reported, 1 season	Hamstring flexibility, quadriceps flexibility, hip adductor flexibility, calf flexibility	Time loss (13)	No risk factor(s) identified	No difference in hip adductor ROM in injured vs uninjured (p=0.44)
Arnason *et al.* (2004)[36]	Elite and 1st division (n=306), mean (range) age: 24 years (16-38), 4-month competitive season	Age, BMI, body fat (skinfolds), hip ROM, power (Squat), jump height, VO2max, knee stability, ankle stability, previous history, player exposure	Time loss (32)	1. Previous Injury 2. Reduced hip abduction ROM	1. OR 7.3 (95%CI 2.3,23.2) p<0.001 2. OR 0.9 (95%CI 0.8,1.0) p=0.05
Hagglund *et al.* (2006)[31]	Elite (n=197), mean (SD) age: 25 years (5) s, 2 seasons	Age, height, weight, BMI, previous groin injury	Time loss (104)	1. Previous groin/hip injury	1. HR=2.4 (1.2 to 4.6)
Ibrahim *et al.* (2007)[78]	Professional (n=101), age: not reported, 1 season	Total hip IR and ER ROM	Time loss (9)	1. Total hip IR and ER ROM	1. Between group comparison of dominate leg (t=?, p=0.03) and non- dominate leg (t=?, p=0.04)
Hölmich *et al.* (2010)[†38]	Amateur (n=977), age (years) med: IG 24.5, CG 24.6, 33-week competitive season and a 9-week break	Intervention (injury prevention program), previous groin injury, higher level of play, occupational demands, age, player position, geography, urban vs non- urban	Time loss + medical attention (not reported)	1. Previous groin injury 2. Higher level of play	1. HR 2.0 (95%CI 1.1,3.4) p=0.02 2. HR 2.6 (95%CI 1.5,4.5) p<0.001
Engebretsen *et al.* (2010).[37]	Sub-elite (n = 508), age: not reported, 1 season (10 weeks)	Age, height, BMI, max. jump height, 40m sprint time, adductor strength, hip flexibility, adductor length, adductor or RA insertion or muscle TOP, pain with resisted adduction, RA function, GrOS (5 sub-scales), player position, matches played, level of play, previous groin injury	Time loss (61)	1. Previous groin injury 2. Weak adductor muscles (clinical exam) 3. Faster 40m sprint time 4. RA TOP	1. Adjusted OR 2.6 (95%CI 1.1,6.1) p=0.03 2. Adjusted OR 4.3 (95%CI 1.3,14.0) p=0.02 3. Adjusted OR 2.3 (95%CI 1.1,3.9) p=0.03 4. Adjusted OR 15.5 (95%CI 1.1,2.2) p=0.04
Ekstrand *et al.* (2011)[79]	Professional (n= 2299), mean age (SD) 23.4 years (4.6), 1 to 9 seasons	Age category (16- 21, 22-30, and > 30 years of age), match play vs training	Time loss + Chronic tendinopathies (672)	1. Age 22-30 yrs. 2. Match play	1. Incidence of groin strains was highest in the 22-30 yrs age group (2.71/1000 player hours) 2. IRR 6.25 (0.32 injuries /1000 training hrs (95%CI 0.29,0.36) and 2.0 /1000 match hrs (95%CI 1.8, 2.2)
Hagglund *et al.* (2013)[6]	Professional (n = 1401), mean (SD) age; 25.8 (4.5), 9 seasons	Age, stature, weight, playing position, previous injury, match type, match venue, time of season, climate region	Time loss (523)	1. Goalie position 2. Previous injury 3. Other cup match 4. Away match 5. Competitive, season	1. HR 0.51 95%CI 0.29,0.91) p=0.22 2. HR 1.40 (95%CI 1.00-1.96) p=0.47 3. OR 0.56 (95%CI 0.43,0.73) p<0.001 4. OR 0.66 (95%CI 0.37,0.97) p=0.35 5. RR 0.78 (95%CI 0.61,0.98) p=0.03

All studies in the table are prospective cohorts, unless other indicated; No.: number; [†]Cluster Randomized Controlled Trial; no.: number; IG: Intervention Group; CG: Control Group; RA: Rectus Abdominis; ROM: Range of Movement; BMI: Body Mass Index; GrOS

However, most previous studies did not include the presence of groin symptoms, such as pain, when asking about previous injury. This is very relevant, as groin pain is a common complaint among male footballers, with a reported seasonal prevalence between 50% and 70%.[39,69] Additionally, a Danish study in sub-elite male football showed that among players who suffered groin pain in the previous season, nearly one-third experienced the same groin problem at the beginning of the new season.[39] This finding indicated that players who had suffered groin pain in the previous season may have been at higher risk of suffering the same groin problem at the beginning of a new season, carrying their groin problem from one season to the next.

Age

Several studies have shown that the player's age may play a role in injury risk in male football.[6,31,36,79] This seems to be the case for acute hamstring injuries, in which the risk of injury increases with age.[31,79] However, existing evidence does not support increasing age as a risk factor for groin injuries in male adult footballers.[6,31,36,37]

Nevertheless, an optimal assessment of age as a risk factor requires a high number of injuries.[53,79] This seems difficult to achieve at this point, as most risk factor studies have registered groin injuries according to the time-loss definition, which is likely to result in a low number of events.[43] Although age has been assessed in large cohorts, the number of registered events in some studies may not have been sufficient for detecting small associations, especially in multivariate approaches.[53] Including broader injury definitions than only time loss in future risk factor studies may not only reflect a clearer picture of the actual problem, but also allow for powerful analyses to assess the age factor.

Hip adduction strength

Current evidence supports that low hip adduction strength is associated with a higher risk of groin injury in sports, [74,76] although in football we found conflicting results. Hip adduction strength was assessed in a study by Engebretsen and colleagues, in which football players clinically diagnosed as having weak hip adductor muscles were shown to have a four times higher risk of new groin injury compared to players without this weakness.[37] Recently, Bourne and colleagues, found that players with higher levels of hip adductor strength showed a reduced likelihood of future hip and/or groin injury in professional soccer players.[80] However, Mosler and colleagues found no significant association between hip adduction strength and subsequent hip and/or groin injury in professional Qatari footballers.[81]

Hip adduction strength is typically measured with a hand-held dynamometer and values are commonly expressed as a torque. A unilateral and/or bilateral hip adduction test can be performed using different muscle activation modes and lever lengths,[82–85] At present, it is unknown whether different testing procedures may result in different risk estimates, which warrants further investigation.

Additionally, hip adduction strength is associated with both the presence of groin pain but also increasing age.[82,85] Players suffering from current groin pain, and also players at an older

age showed lower values of hip adduction strength compared to players free of pain or players at a younger age. It is at present unknown if hip adduction strength may be influenced by past-season groin pain and its duration, together with age. This would be valuable information when screening players to assess injury risk. Therefore, in Paper III, we wanted to investigate if pre-season hip adductor squeeze strength may be influenced by past-season groin pain and its duration and player's age.

Sporting function

In groin problems, symptoms fluctuate over time, and cases commonly present with a gradual onset. Previous studies indicated that hip- and groin-related sporting function might deteriorate even before players themselves recognize they are suffering a groin problem.[86] This highlights the need for close monitoring of players over time as early detection of players at risk of future groin problems might be facilitated. For this purpose, The Copenhagen Hip And Groin Outcome Score (HAGOS) is a patient-reported outcome measure specifically designed to assess hip and groin pain and function in physically active individuals.[87]

Bourne and colleagues found that players with high pre-season HAGOS values were 23% less likely to suffer a hip and /or groin injury in the subsequent season.[80] Similarly, in a study on Gaelic footballers, players who scored lower (<87.5 points) in the Physical Function in Sports and Recreation HAGOS subscale, were 9-fold more likely to suffer a groin injury compared to players with higher scores.[88] Nevertheless, HAGOS has never been registered continuously over the season for risk factor assessment.

In Paper IV, we investigated associations of potential risk factors with in-season groin problems in male football players. Potential risk factors included: past-season groin pain, age, hip adductor short- and long-lever squeeze strength and hip and/or groin sporting function. In addition, we investigated whether these potential associations could differ between groin problems with and without time loss.

Aims of this Thesis as a whole

The overall aim of this Ph.D. project was to broaden knowledge to prevent groin problems on amateur male football players. The specific objectives were to investigate:

- the extent of groin problems over a 39-week football season, using the traditional time-loss injury definition together with novel measures for estimating both the prevalence of groin pain, irrespective of time loss, and hip- and groin-related sporting function (Paper I).

- the weekly prevalence of groin problems over three weeks in a football pre-season, compared to a 39-week competitive in-season; and to compare hip- and groin-related sporting function between pre- and in-season. (Paper II).

- whether football players with past-season groin pain, and with different durations of past-season groin pain had lower pre-season hip adductor squeeze strength compared with those without past-season groin pain; and whether possible differences in pre-season hip adductor squeeze strength, in relation to past-season groin pain and its duration, could be influenced by current groin pain and age (Paper III).

- whether past-season groin pain, player's age, pre-season short- or long-lever adductor squeeze strength, and in-season hip and groin sporting function measures, were associated with an in-season groin problem in male football players; and whether potential associations of these factors may differ between groin problems with and without time loss. (Paper IV).

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Chapter 2
Paper I

Prevalence and severity of groin problems in Spanish football: A prospective study beyond the time-loss approach

Ernest Esteve
Mikkel Bek Clausen
Michael Skovdal Rathleff
Jordi Vicens-Bordas
Martí Casals
Albert Palahí-Alcàcer
Per Hölmich
Kristian Thorborg

Esteve E, Clausen MB, Rathleff MS, Vicens-Bordas J, Casals M, Palahí-Alcàcer A, Hölmich P, Thorborg K. Prevalence and severity of groin problems in Spanish football: A prospective study beyond the time-loss approach. Scand J Med Sci Sports. December 2019, 30(5):914–921.

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Abstract

The time-loss definition of injury is commonly adopted in epidemiological groin-injury studies in football, with a significant risk of underestimating the impact of these injuries. This study investigated the extent of groin problems, beyond the time-loss approach, over a full Spanish football season. Players from 17 amateur male teams were followed over 39 consecutive weeks. Groin-injury time loss and self-reported groin pain, irrespective of time loss, were combined to calculate the average weekly prevalence of all groin problems with or without time loss. A subscale measuring hip- and groin-related sporting function from the Copenhagen Hip and Groin Outcome Score questionnaire (HAGOS, Sport/Rec) was registered every 4 weeks. In total, 407 players participated in the study. The average (range) weekly prevalence of all groin problems was 11.7% (7.2%-20.8%); 1.3% with time loss (0.0%-3.2%) and 10.4% without time loss (6.3%-17.6%). Players with groin problems reported lower scores (mean difference) on the HAGOS, Sport/Rec subscale compared with players without (−19.5 [95% CI: −20.7 to −18.4]), while there was no difference between players reporting groin problems with and without time loss (4.0 [95% CI: −1.1 to 9.1]). The traditional time-loss measure only captured 10% of all groin problems. Hip- and groin-related sporting function was not different between players reporting groin problems with or without time loss, suggesting the reason for continuing to play is not only related to the severity of symptoms. These findings question the judicious use of the time-loss approach in overuse conditions, such as groin pain in footballers.

Keywords

Football; groin injury; groin pain; groin problems; sporting function; time-loss

Chapter 3
Paper II

Groin problems from pre- to in-season: A prospective study on 386 male Spanish footballers

Ernest Esteve
Michael Skovdal Rathleff
Jordi Vicens-Bordas
Mikkel Bek Clausen
Per Hölmich
Lluís Sala
Kristian Thorborg

Paper II has been submitted to the Reseach in Sports Medicine journal, and is presented in its last submitted version.

Submission acceptance letter:

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Dear Mr Esteve:

Your manuscript entitled "Groin problems from pre- to in-season: A prospective study on 386 male Spanish footballers" has been successfully submitted online and is presently being given full consideration for publication in Research in Sports Medicine.

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Groin problems from pre- to in-season: A prospective study on 386 male Spanish footballers

Abstract

This study investigated the weekly prevalence of groin problems over a 3-week football pre-season, compared to a 39-week competitive in-season. We registered time-loss groin injuries, and self-reported weekly groin-pain in 17 amateur male football teams (386 players). The average weekly prevalence of groin problems (prevalence ratio (PR)) was 1.8 times higher (95% CI 1.6 to 2.0) during pre-season (21%) compared to in-season (12%). We found a higher weekly prevalence (PR 1.8; 95% CI 1.6 to 2.1) of groin problems without time loss, during the pre-season (19%) compared to the in-season (10%), but no significant difference in the weekly prevalence of groin problems with time loss (PR 1.5; 95% CI 1.0 to 2.4). Attention should be given to optimal load progression, and early implementation of preventive measures during the football pre-season to reduce the prevalence of groin problems in both pre- and in-season.

Keywords: groin pain, groin injuries, injury prevention, injury epidemiology, HAGOS
Word count (including abstract, captions, and endnotes): 1500 words

Introduction

In men's football, the highest weekly prevalence of groin problems is at the beginning of the in-season (20%) (Esteve et al., 2019), and during periods of increased match frequency (29%) (Harøy et al., 2017). Rapid changes in football loads have been shown to increase the risk of injury in professional football players (Malone et al., 2017), with low levels of off-season sport-specific training increasing the risk of a new groin injury when training loads resume (Emery & Meeuwisse, 2001).

Few prospective epidemiological studies investigate the prevalence of groin problems using groin symptoms and self-reported functional impairment in addition to time loss (Esteve et al., 2019; Harøy et al., 2017), with none investigating pre-season. The present study compared the extent of groin problems between the pre- and the in-season in amateur Spanish male players. We also investigated if limitations in hip- and groin-related sporting function due to groin problems were different between pre- and in-season.

Methods

The in-season data and methodological details for the present prospective cohort study have been published previously (Esteve et al., 2019). Over a 3-week pre-season period a convenience sample of amateur Spanish players from 17 teams (tiers IV to VI) completed a weekly survey asking about groin pain, irrespective of time loss, during the preceding week. Players also completed the Sports/Recreation subscale from the Hip And Groin Outcome Score (HAGOS) questionnaire measuring hip and groin sporting function (Thorborg et al., 2011) each week. Football staff registered the number and characteristics of time-loss groin injuries and team exposure as minutes of participation in physical activity under the supervision of the coaching staff.

Groin problems with and without time loss were determined using information from time-loss injury records and groin-pain surveys. A player was considered as having a groin problem with time loss when, in a given week, he missed at least one training session or was not available for match selection due to groin injury (i.e., time-loss groin injury). A player was considered as having a groin problem without time loss, when he answered "yes" to the question "Did you suffer from groin pain (inguinal region including adductor, lower abdomen, and pubic region) in the past week?", but no time loss due to a groin problem was reported in that week.

Individual HAGOS, Sport/Rec subscale scores were calculated per player at every time point (3 pre-season time points) regardless of whether players reported groin pain or not in the preceding week.

Ethics approval was obtained from a regional committee. All participants provided written informed consent according to the Helsinki Declaration prior to participating.

Data analyses

Weekly prevalence of groin problems, was calculated by dividing the number of players reporting groin problems with or without time loss, respectively, by the number of players who were part of a team in each week (Esteve et al., 2019). We calculated injury incidence (Hägglund et al., 2009), and injury burden of time-loss groin injuries (Ekstrand et al., 2016) using team exposure to football in hours.

We calculated a prevalence ratio (PR) and prevalence difference (PD) to compare pre- with in-season prevalence; and incidence rate ratio (IRR) and rate difference (RD) to compare injury incidence and burden. For comparisons of HAGOS-Sport/Rec scores from players reporting groin problems between pre-season and in-season, we performed a linear mixed model. Season period (pre-/in-season) was included as fixed effect, while player was considered as a random effect.

Data were analysed in IBM SPSS statistics 25.0, and R version 3.3.2 (R Core Team, 2016). Alpha level was set at 5%.

Results

On average, 74.3% of the players responded to the weekly groin-pain survey (Week 1: 82% (n=309); week 2: 68% (n=372); week 3: 72% (n=379)). Figure 1 shows weekly prevalence of groin problems during pre- and in-season. The average weekly prevalence of all groin problems and groin problems without time loss was higher during the pre-season compared to the in-season. For groin problems with time loss, there was no significant difference between pre- and in-season. Neither time-loss groin-injury incidence or injury burden were different in the pre- compared to the in-season (Table 1).

[Insert Figure 1 near here]

[Insert Table 1 near here]

In pre-season compared to in-season, there were minor mean differences in HAGOS-Sport/Rec scores among players reporting “any groin problem” (mean difference: 2.7; 95% CI -0.2 to 5.6; *P* = .06), players reporting time-loss groin problems (mean difference: -2.3; 95% CI -21.0 to 16.4; *P* = .80); and players reporting groin problems without time loss (mean difference: 3.1; 95% CI 0.3 to 6.0; *P* = .03), of which only the latter was statistically significant (Figure 2).

[Insert Figure 1near here]

Discussion

We found a high (21%) pre-season weekly prevalence of groin problems. Previous studies show similarly high pre-season point-prevalence of groin symptoms (20% to 35%) (Harøy et al., 2019; Langhout et al., 2019; Thorborg, Rathleff, et al., 2017). This highlights the need for a greater focus on prevention strategies during pre-season considering the recurrent and persistent nature of groin problems (Thorborg, Rathleff, et al., 2017). Asking two simple questions at pre-season about past-season groin pain and its duration is sufficient to detect players at higher risk of experiencing severe reductions in their hip and groin function at the beginning of the new season (Esteve et al., 2018; Thorborg, Rathleff, et al., 2017).

Although the substantial reduction in weekly prevalence of groin problems from pre- to in-season occurred without the initiation of any controlled prevention strategies, the implementation of a hip adductor strengthening exercise during pre-season could further reduce the prevalence of groin problem in the in-season (Harøy et al., 2019). This reflects the importance of pre-season training for developing sport-specific adaptations to protect against in-season groin problems, in addition to improving player performance.

The highest weekly prevalence of groin problems (28%) was registered in the first week of pre-season. This could indicate that prevalence of groin problems may peak as football pre-season starts, emphasising the importance of balancing and progressing training loads from the off-season to the pre-season (Malone et al., 2017). The off-season period could also provide an opportunity to implement novel measures outside team-training routines aimed at building hip adductor muscle capacity and resolving existing groin problems (Thorborg, Rathleff, et al., 2017).

We found minimal mean differences (3 points) on HAGOS-Sport/Rec scores between pre- and in-season and their clinical relevance is debatable. However, worse pre-season hip and groin health has been linked to an increased risk of groin injury in the subsequent in-season in male football players (Bourne et al., 2019). Early detection and close monitoring is advisable to facilitate optimal management and to prevent recurrence and/or aggravation. This could be achieved using specific alerts on hip adductor strength test (>15% reduction), HAGOS questionnaire (score <70 out of 100) (Wollin et al., 2018). The "five-second squeeze test" is an excellent surrogate measure of HAGOS and could be also useful to reflect hip and groin health trough the full season (Thorborg, Branci, et al., 2017).

Exposure could only be registered successfully at the team level, leading to slightly underestimated injury rates (Kristenson et al., 2016). Response rate to the groin pain survey (75%) was lower compared to our previously reported in-season rate (93%), but our method of prevalence calculation negates any overestimation. We captured 3 weeks of pre-season, despite varying pre-season lengths: 12 teams had a 4-week pre-season, 2 teams had a 5-week pre-season and 2 teams were included in their last pre-season week. We consider present estimates representative of most European amateur male football levels, although generalizations to extended pre-season and/or higher football levels must be made with caution.

Conclusion

Groin problems were twice as prevalent during pre-season compared to the in-season. This difference was due to a greater weekly prevalence of groin problems without time loss during the pre-season. This highlights the importance of optimal progression of pre-season loading and early implementation of preventive measures to reduce the prevalence of groin problems in both pre- and in-season.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

This study was not funded.

Figure 1 Weekly prevalence proportions of groin problems during pre- and in-season periods

Figure 2 HAGOS – Sport/Rec subscale scores from player reporting any groin problem, and groin problems with and without time loss, from pre- and in-season periods

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Table 1 Pre- and in-season data overview and measures compared

	Pre-season (n = 386)	In-season (n = 407)	Ratios †	Difference ‡
Data overview (SD)				
Follow-up	3 weeks	39 weeks		
Total number of participants	386	407		
Age, years	23 (4)	23 (4)		
Weight, Kg	74 (8)	74 (7)		
Height, cm	178 (6)	178 (6)		
Number of players reporting a groin-pain episode[a]	125	216		
Number of time-loss groin injuries	10	63		
Days lost due time-loss groin injury	72	617		
Total exposure, hours	8576	71908		
Average exposure team/week	6.9 h (2)	6 h (1)		
Measures compared (95% CI)				
Weekly prevalence of groin problems	21% (18% to 23%)	12% (11% to 12%)	1.8 (1.6 to 2.0)	9.0% (6.4% to 11.6%)
Groin problems with time loss	2.0% (1.3% to 3.1%)	1.3% (1.1% to 1.5%)	1.5 (1.0 to 2.4)	0.7% (-0.2% to 1.6%)
Groin problems without time loss	19% (16% to 21%)	10% (10% to 11%)	1.8 (1.6 to 2.1)	8.3% (5.9% to 10.8%)
Time-loss groin-injury incidence[b]	1.2 (0.6 to 2.2)	0.9 (0.8 to 1.0)	1.3 (0.7 to 2.6)	0.03 (-0.05 to 0.10)
Time-loss groin-injury burden[c]	8.4 (6.6 to 10.6)	8.6 (7.9 to 9.3)	1.0 (0.8 to 1.3)	0.01 (-0.21 to 0.19)

† Prevalence ratios for prevalence measures, and incidence rate ratios for incidence and burden measures; ‡ Prevalence difference for prevalence measures and rate difference for incidence and burden measures (pre-season group as reference) [a] Number of players reporting at least one episode of groin pain; [b] Number of injuries per 1000 hours of football; [c] Number of days lost per 1000 hours of football.

Figure 1 Weekly prevalence proportions of groin problems during pre- and in-season periods

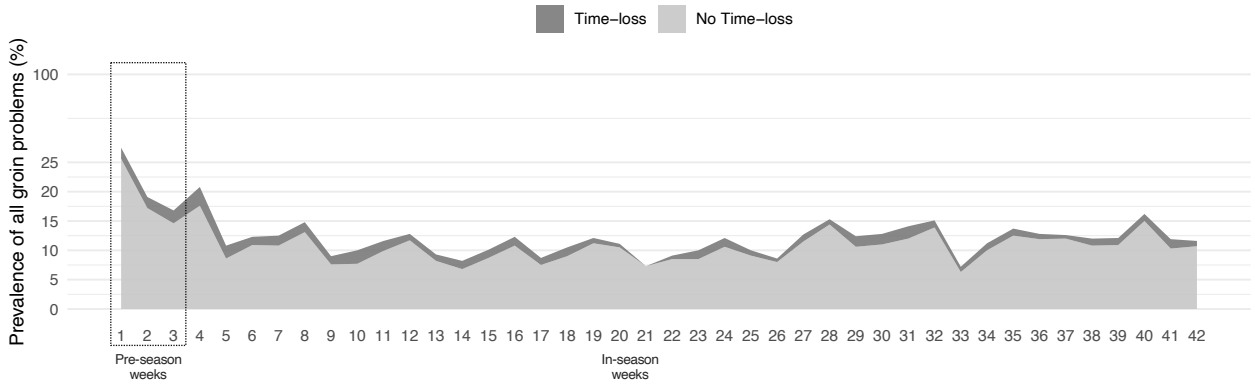
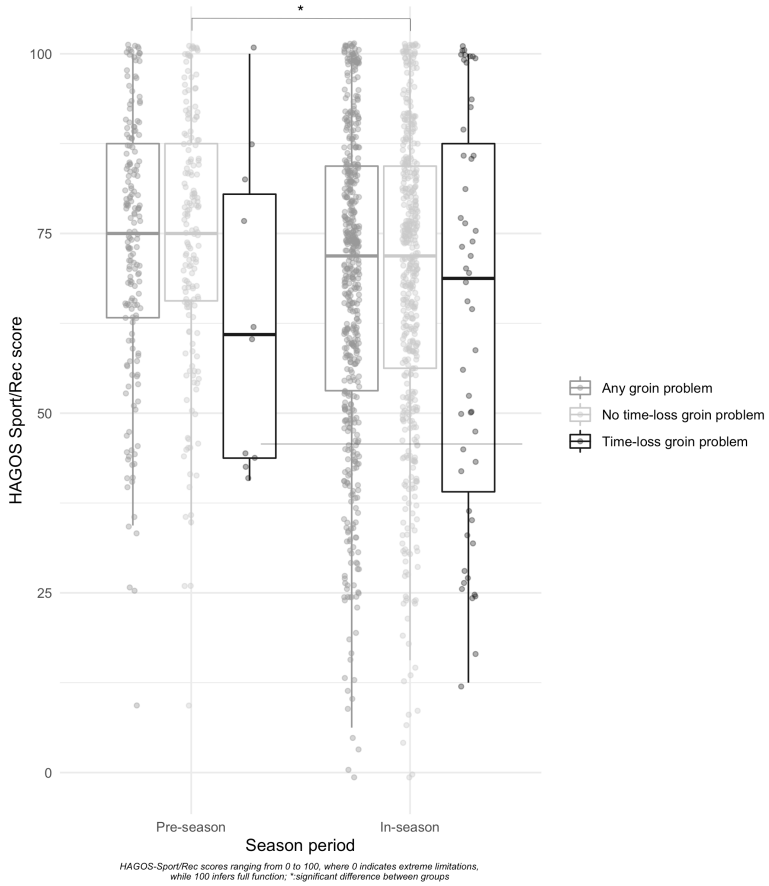


Figure 2 HAGOS – Sport/Rec subscale scores from player reporting any groin problem, and groin problems with and without time loss, from pre- and in-season periods



Chapter 4
Paper III

Preseason adductor squeeze strength in 303 Spanish male soccer athletes

Ernest Esteve
Michael Skovdal Rathleff
Jordi Vicens-Bordas
Mikkel Bek Clausen
Per Hölmich
Lluís Sala
Kristian Thorborg

Original Research

Preseason Adductor Squeeze Strength in 303 Spanish Male Soccer Athletes

A Cross-sectional Study

Ernest Esteve,*†‡ PT, MSc, Michael Skovdal Rathleff,§‖ PT, PhD, Jordi Vicens-Bordas,†‡ MSc, Mikkel Bek Clausen,¶# PT, MSc, Per Hölmich,¶ MD, DMSc, Lluís Sala,† MSc, and Kristian Thorborg,¶** PT, PhD

Investigation performed at Sportclínic, Physiotherapy and Sports Training Centre, Girona, Spain

Background: Hip adductor muscle weakness and a history of groin injury both have been identified as strong risk factors for sustaining a new groin injury. Current groin pain and age have been associated with hip adductor strength. These factors could be related, but this has never been investigated.

Purpose: To investigate whether soccer athletes with past-season groin pain and with different durations of past-season groin pain had lower preseason hip adductor squeeze strength compared with those without past-season groin pain. We also investigated whether differences in preseason hip adductor squeeze strength in relation to past-season groin pain and duration were influenced by current groin pain and age.

Study Design: Cross-sectional study; Level of evidence, 3.

Methods: In total, 303 male soccer athletes (mean age, 23 ± 4 years; mean weight, 74.0 ± 7.9 kg; mean height, 178.1 ± 6.3 cm) were included in this study. Self-reported data regarding current groin pain, past-season groin pain, and duration were collected. Hip adductor squeeze strength was obtained using 2 different reliable testing procedures: (1) the short-lever (resistance placed between the knees, feet at the examination bed, and 45° of hip flexion) and (2) the long-lever (resistance placed between the ankles and 0° of hip flexion) squeeze tests.

Results: There was no difference between those with (n = 123) and without (n = 180) past-season groin pain for hip adductor squeeze strength when adjusting for current groin pain and age. However, athletes with past-season groin pain lasting longer than 6 weeks (n = 27) showed 11.5% and 15.3% lower values on the short-lever ($P = .006$) and long-lever ($P < .001$) hip adductor squeeze strength tests, respectively, compared with those without past-season groin pain.

Conclusion: Male soccer athletes with past-season groin pain lasting longer than 6 weeks are likely to begin the next season with a high-risk groin injury profile, including a history of groin pain and hip adduction weakness.

Keywords: groin pain; soccer; injury prevention; epidemiology; muscle strength; sports

Nearly 1 in every 2 players is affected by groin pain during a single soccer season, and 1 in 3 will start the new soccer season with groin pain.[15,26] Importantly, among players starting the new soccer season with groin pain, one-third suffer from the same groin pain problem as they did in the previous season.[26] This suggests that the interseason break is not sufficient for a full recovery from a past-season groin pain episode.

A history of groin injury is the strongest risk factor for sustaining a new groin injury among male soccer athletes.[30] Male soccer athletes with a previous groin injury have a 2.4 to 7.3 times higher risk of a new groin injury.[1,5,8] However, previous studies investigating risk factors for groin pain have failed to take into account the duration of pain and symptoms of the previous groin injury.[1,5,8] This hampers any firm conclusion about how the duration of groin pain in the previous season affects the current season. Specific information about past-season hip and/or groin pain and its duration has recently been related to sports function in the beginning of a new soccer season.[26] Soccer athletes with different past-season hip and/or groin pain durations (1-2, 3-6, and >6 weeks) showed an almost dose-response relationship with hip- and/or groin-related sports function and pain,[26] with preseason HAGOS (Copenhagen Hip and Groin Outcome Score) values being lower when the duration of pain in the past season was longer. This indicates that not only a history of groin injury but also the duration of a previous groin injury could be related to future hip and/or groin injury events in soccer[26] and also

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highlights the importance of obtaining specific information on duration in relation to past-season groin pain at the beginning of a new preseason.

There is consistent evidence that low hip adductor strength is a strong risk factor for a new groin injury in soccer.[24] In European soccer, players with weak hip adductors were found to have a more than 4 times higher risk of sustaining a new groin injury compared with players without weak hip adductors.[5] However, when investigating hip adductor strength as a risk factor for a new groin injury in soccer, various types of hip adductor strength measurements of unknown precision and reliability have been used,[5,22] which makes it difficult to compare across studies. Additionally, current groin pain and age have been associated with hip adductor strength in soccer, in which both the presence of groin pain[18,21,25] and older player age[20] have a negative effect on hip adductor strength and consequently need consideration when screening soccer athletes using strength measurements to detect high-risk groin injury profiles. Furthermore, it is at present unknown how past-season groin pain and its duration may affect preseason hip adductor squeeze strength and if these 2 risk factors are related. This is important, as soccer athletes who suffered from past-season groin pain could be prone to start the new soccer preseason with a high-risk profile that includes both a history of groin pain and hip adductor squeeze strength weakness.

In this study, we aimed to investigate if soccer athletes with past-season groin pain had lower preseason hip adductor squeeze strength compared with soccer athletes without past-season groin pain. Secondly we also investigated if soccer athletes with different durations of past-season groin pain had lower preseason hip adductor squeeze strength compared with soccer athletes without past-season groin pain. Additionally, we investigated if the possible differences in preseason hip adductor squeeze strength, in relation to past-season groin pain and its duration, could be influenced by current groin pain and age, as these are factors associated with hip adductor squeeze strength.

METHODS

Design and Participants

The reporting of the present cross-sectional study follows the STROBE (Strengthening the Reporting of Observational studies in Epidemiology) statement.[29] This study is based on data from a large cohort study investigating the incidence, prevalence, and risk factors of groin pain in Spanish male soccer athletes. Under the corresponding approval of a local ethics committee, 17 male amateur soccer teams from the northeastern region of Spain, competing in the third national and the first and second regional divisions, were invited to participate. All 17 teams accepted the invitation, and none of their respective players refused to be recruited. In total, 363 players from these teams were screened for eligibility and were tested during the preseason (July-August 2015). To be included in the study, soccer athletes had to be present at baseline testing and available to fully participate in the following training session. Athletes not able to perform the test because of an injury, sickness, or any physical complaint were excluded. Also, soccer athletes not able to understand the Catalan, Spanish, or English language and players younger than 18 years were not included. Before entering the study, all soccer athletes were informed verbally about the purpose of the study and gave written informed consent to participate.

Testing Procedure

Baseline measurements were performed at the respective team facilities by 3 members of the research team: 1 physical therapist and 2 physical trainers with a sports science background. All players were asked to arrive 90 minutes before the start of a preseason regular training session to complete the test battery. Team physical therapists, physical trainers, and members of the technical staff of the respective teams collaborated in the assessments, providing questionnaires and forms and conducting the standardized warm-up, which consisted of low-intensity shuttle runs and active lower limb mobility exercises.

Using a standardized form, soccer athletes were asked about personal information (identification number, date of birth, and telephone number) and history of groin pain. Data on current groin pain (yes or no), past-season groin pain (yes or no), and duration of past-season groin pain (0 weeks, $\leq$3 weeks, >3 to $\leq$6 weeks, or >6 weeks) were collected for each athlete.

Hip adductor squeeze strength values were obtained using a handheld dynamometer (MicroFet2; Hoggan Health Industries) with 2 different testing procedures: (1) the short-lever (resistance placed between the knees, feet at the examination bed, and 45° of hip flexion) and (2) the

*Address correspondence to Ernest Esteve, PT, MSc, Sportclínic, Physiotherapy and Sports Training Centre, St. Joan Roca i Pinet, Num. 1, Local 5, 17003 Girona, Spain (email: ernestesteve@hotmail.com).
†Sportclínic, Physiotherapy and Sports Training Centre, Girona, Spain.
‡School of Health and Sport Sciences (EUSES), University of Girona, Salt, Spain.
§Center for Sensory-Motor Interaction, Department of Health Science and Technology, Faculty of Medicine, Aalborg University, Aalborg, Denmark.
||Department of Occupational Therapy and Physiotherapy, Aalborg University Hospital, Aalborg, Denmark.
¶Sports Orthopedic Research Center–Copenhagen, Department of Orthopedic Surgery, Amager-Hvidovre Hospital, Copenhagen University Hospital, Hvidovre, Denmark.
#Department of Physiotherapy and Occupational Therapy, Faculty of Health and Technology, Metropolitan University College, Copenhagen, Denmark.
**Physical Medicine and Rehabilitation Research–Copenhagen, Amager-Hvidovre Hospital, Copenhagen University Hospital, Hvidovre, Denmark.
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long-lever (resistance placed between the ankles and 0° of hip flexion) squeeze tests. Isometric peak force (N) was obtained from 1 maximal repetition for both tests, as this method has shown to be reliable for both tests in soccer athletes (minimal detectable change: long-lever test = 13.6%-13.7%, short-lever test = 15.2%-18.6%).[17] Body weight, as well as short- and long-lever lengths, was measured in each athlete, and all strength values were normalized to body weight and lever and reported as N·m/kg. A single physical therapist collected all hip adductor strength values, and the dynamometer was calibrated before each testing session to ensure valid data.

Statistical Analysis

All statistical analyses and assumption testing were performed using SPSS version 22.0.0.1 (IBM). For descriptive statistics, means ± SDs were used for continuous variables, while numbers (percentages) were used for categorical variables. Differences in preseason hip adductor squeeze strength between soccer athletes without past-season groin pain compared with (1) all soccer athletes with past-season groin pain (model 1) and (2) soccer athletes with ≤3 weeks, >3 to ≤6 weeks, and >6 weeks of past-season groin pain (model 2) were obtained using linear regression models. Preseason hip adductor squeeze strength values (short lever and long lever) were included as the dependent variables, while past-season groin pain (model 1) and duration of past-season groin pain (model 2) were included as the independent variables of interest. Furthermore, adjusted estimates were obtained using linear multiple regression models by including current groin pain and age as covariates into the respective models. Corresponding 95% CIs were also obtained for all estimates derived from these models. All assumptions for all regression models were tested. A significance level of .05 was used. Estimates of differences in hip adductor squeeze strength values were presented as absolute mean differences (N·m/kg) and as a percentage, by dividing the absolute mean difference by the estimated mean of the reference group, for each variable.

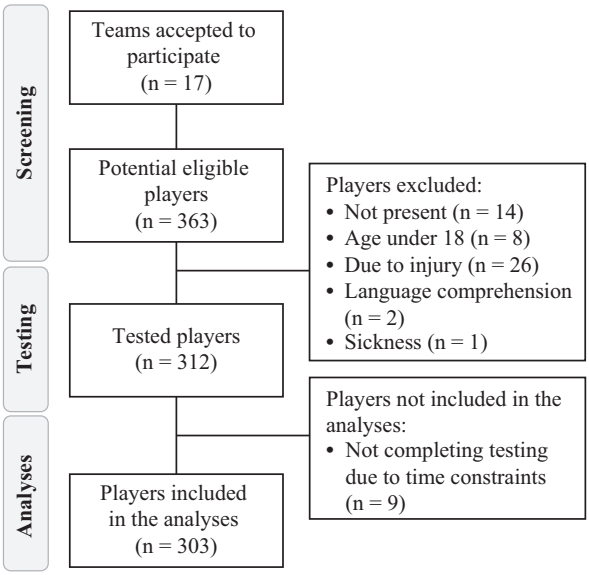

Figure 1. Flow chart of participants.

RESULTS

In total, 303 soccer athletes were included in the analyses (mean age, 23 ± 4 years; mean weight, 74.0 ± 7.9 kg; mean height, 178.1 ± 6.3 cm). From the 363 potentially eligible athletes, 51 did not meet the inclusion criteria and were excluded. Nine athletes did not complete all relevant tests and were therefore not included in the analyses (Figure 1). Preseason hip adductor strength values are shown in Table 1.

Past-Season Groin Pain

Soccer athletes with past-season groin pain showed 5.4% lower strength on the long-lever squeeze test compared with soccer athletes without past-season groin pain (P =

TABLE 1
Hip Adductor Strength Values[a]

	n (%)	Short-Lever Squeeze Test, N·m/kg	Long-Lever Squeeze Test, N·m/kg
Past-season GP			
No	180 (59.4)	1.818 ± 0.346 (0.98-2.77)	2.816 ± 0.482 (1.67-3.87)
Yes	123 (40.6)	1.770 ± 0.400 (0.67-2.55)	2.664 ± 0.572 (1.31-4.30)
Duration of past-season GP			
≤3 wk	74 (24.4)	1.856 ± 0.351 (1.18-2.55)	2.768 ± 0.493 (1.56-3.82)
>3 to ≤6 wk	22 (7.3)	1.713 ± 0.458 (0.67-2.37)	2.783 ± 0.654 (1.38-4.30)
>6 wk	27 (8.9)	1.580 ± 0.416 (0.71-2.26)	2.280 ± 0.556 (1.31-3.31)
Current GP			
No	257 (84.8)	1.814 ± 0.359 (0.67-2.77)	2.797 ± 0.505 (1.38-4.30)
Yes	46 (15.2)	1.713 ± 0.412 (0.71-2.60)	2.515 ± 0.576 (1.31-3.70)
Overall	303 (100.0)	1.798 ± 0.369 (0.67-2.77)	2.754 ± 0.525 (1.31-4.30)

[a]Values are shown as mean ± SD (range) unless otherwise indicated. GP, groin pain.

TABLE 2
Unadjusted Estimates From Linear Regression[a]

	Short-Lever Squeeze Test, N·m/kg		Long-Lever Squeeze Test, N·m/kg	
	Estimated Mean (95% CI)	Mean Difference (95% CI)	Estimated Mean (95% CI)	Mean Difference (95% CI)
Past-season GP				
No	1.818 (1.764 to 1.872)[b]	Reference	2.816 (2.739 to 2.892)[b]	Reference
Yes		–0.048 (–0.133 to 0.037)		–0.152 (–0.272 to –0.032)[c]
Duration of past-season GP				
≤3 wk		0.039 (–0.060 to 0.137)		–0.048 (–0.185 to 0.090)
>3 to ≤6 wk		–0.105 (–0.266 to 0.057)		–0.033 (–0.257 to 0.192)
>6 wk		–0.237 (–0.385 to –0.090)[c]		–0.536 (–0.741 to –0.331)[b]
Current GP				
No	1.814 (1.769 to 1.859)[b]	Reference	2.797 (2.733 to 2.860)[b]	Reference
Yes		–0.100 (–0.216 to 0.015)		–0.282 (–0.445 to –0.119)[c]
Age				
Current	2.058 (1.813 to 2.304)[b]	Reference	2.956 (2.605 to 3.307)[b]	Reference
Per-year increase in player's age		–0.011 (–0.022 to –0.001)[c]		–0.009 (–0.024 to 0.006)

[a]N = 303. GP, groin pain.
[b]$P < .001$.
[c]$P < .05$.

TABLE 3
Adjusted Estimates From Multiple Regression Models 1 and 2[a]

	Short-Lever Squeeze Test, N·m/kg		Long-Lever Squeeze Test, N·m/kg	
	Estimated Mean (95% CI)	Mean Difference (95% CI)	Estimated Mean (95% CI)	Mean Difference (95% CI)
Model 1				
Past-season GP				
No	2.067 (1.819 to 2.315)[b]	Reference	2.987 (2.638 to 3.336)[b]	Reference
Yes		–0.024 (–0.117 to 0.069)		–0.082 (–0.213 to 0.049)
Current GP (yes)		–0.078 (–0.205 to 0.050)		–0.229 (–0.408 to –0.049)[c]
Per-year increase in player's age		–0.011 (–0.021 to 0.000)[c]		–0.007 (–0.022 to 0.008)
Model 2				
Past-season GP (no)	2.062 (1.817 to 2.307)[b]	Reference	3.001 (2.658 to 3.343)[b]	Reference
Duration of past-season GP				
≤3 wk		0.035 (–0.065 to 0.136)		–0.030 (–0.170 to 0.111)
>3 to ≤6 wk		–0.096 (–0.266 to 0.075)		0.028 (–0.210 to 0.266)
>6 wk		–0.237 (–0.404 to –0.069)[c]		–0.459 (–0.694 to –0.225)[b]
Current GP (yes)		0.001 (–0.134 to 0.136)		–0.126 (–0.314 to 0.062)
Per-year increase in player's age		–0.011 (–0.021 to 0.000)[c]		–0.008 (–0.022 to 0.007)

[a]N = 303. GP, groin pain.
[b]$P < .001$.
[c]$P < .05$.

.013), whereas there was no difference on the short-lever test (Table 2). When adjusted for current groin pain and age, no significant differences were seen in squeeze strength between soccer athletes with and without past-season groin pain (Table 3).

Duration of Past-Season Groin Pain

Soccer athletes with a duration of past-season groin pain of more than 6 weeks showed 13% and 19% lower strength, respectively, on the short-lever ($P = .002$) and long-lever ($P < .001$) squeeze tests compared with players without past-season groin pain. When adjusting for current groin pain and age, differences remained significant, and soccer athletes with a duration of past-season groin pain of more than 6 weeks showed 11.5% and 15.3% lower strength on the short-lever ($P = .006$) and long-lever ($P < .001$) squeeze tests, respectively, compared with soccer athletes without past-season groin pain. There were no differences between soccer athletes without past-season groin pain and the 2 other subgroups of athletes with past-season groin pain durations of ≤3 weeks or >3 to ≤6 weeks.

Current Groin Pain and Age

Soccer athletes with current groin pain showed 10.1% lower strength on the long-lever squeeze test ($P = .001$) compared with soccer athletes without current groin pain. There was no difference between athletes with and without current groin pain on the short-lever test. Current groin pain also negatively influenced the difference on the long-lever test between athletes with and without past-season groin pain ($P = .013$). Soccer athletes with current groin pain showed a 7.7% mean reduction in squeeze strength, irrespective of having had past-season groin pain. No influence was detected for current groin pain in relation to the different durations of past-season groin pain and preseason hip adductor squeeze strength values.

Age had a negative effect on the short-lever test ($P = .035$), with a mean reduction in squeeze strength of 0.5% per 1-year increase in player's age. Age was also shown to negatively influence the differences on the short-lever test in relation to past-season groin pain and its duration, with identical estimates in both models (Table 3), with a mean reduction in squeeze strength of 0.5% per 1-year increase in player's age ($P = .046$). The results of the long-lever squeeze test were not significantly related to player age.

Details on multiple regression models 1 and 2 can be found in Appendix Tables A1 and A2.

DISCUSSION

This study investigated if soccer athletes with past-season groin pain, and with different durations of past-season groin pain, had lower preseason hip adductor squeeze strength compared with soccer athletes without past-season groin pain. The most important finding of the present study was that soccer athletes with past-season groin pain of longer than 6 weeks showed 12% and 15% lower preseason hip adductor strength on the short- and long-lever squeeze tests, respectively, compared with soccer athletes without past-season groin pain, independently of current groin pain and player age.

This finding is in line with a previous study in subelite Danish male soccer in which players who suffered from past-season groin pain for more than 6 weeks showed the lowest scores in sports function and participation compared with groups of players with a shorter duration of groin pain symptoms.[26] This supports the finding of the present study, indicating that having had past-season groin pain for more than 6 weeks seems to induce objective muscle impairment in addition to self-reported hip and groin–related sporting limitations.[26] The present study also found that, compared with soccer athletes without past-season groin pain, athletes who reported suffering from past-season groin pain but who were free of groin pain at the time of testing did not show lower values on preseason hip adductor squeeze tests. Similarly, a recent study conducted on male professional soccer athletes playing in the Qatar Stars League found that past-season hip and/or groin time-loss injuries had no effect on hip strength profiles at the beginning of a new season.[20] Although these 2 studies are not completely comparable because of the differences in injury definitions, it seems that the negative effect of previous groin injury on preseason hip adductor strength is more related to the duration of pain and symptoms during the past season than to a history of groin injuries alone.

The findings of the study suggest that players who suffered from past-season groin pain for more than 6 weeks are likely to start the new soccer season with a high-risk groin injury profile. This high-risk profile includes both a history of groin pain and hip adductor weakness,[1,5] which place these soccer athletes at a higher risk for sustaining a new groin injury in the new season. Thus, to intervene in this subgroup of soccer athletes at the beginning of a new season, with secondary preventative measures, focusing on hip adductor weakness, seems important, as hip adductor strength is an intrinsic and modifiable risk factor.[24] However, the efficacy of groin injury preventative programs that include hip adductor strengthening exercises in soccer remains uncertain.[6] It has been suggested that one of the explanations for the lack of certainty from this approach could be compliance and the insufficient intensity related to these exercises.[10] A progression from static isometric to high-intensity dynamic exercises, especially those with eccentric muscle contractions, has been recommended when aiming at strength gains for injury prevention and athletic performance.[3] Full-range hip adduction exercises using elastic bands or the Copenhagen adduction exercise have both led to significant increases in eccentric hip adduction strength after 8 weeks of progressive training.[12,13] Both hip adduction with an elastic band and the Copenhagen adduction exercise require no or minimal equipment, which make them easy to implement during soccer training routines and which could provide an effective, supervised strengthening program.

The results from the present study also indicate that, in Spanish subelite male soccer athletes with past-season groin pain lasting longer than 6 weeks, the current activity regimen during the interseason break may not be sufficient to restore normal values in hip adductor strength. It has been outlined that the lack of sufficient sport-specific training during the interseason break increases the risk of a new groin injury.[30] Additionally, soccer athletes traditionally face high training loads with rapidly increasing spikes during the preseason,[14] which could be particularly challenging for athletes with a history of groin injury and hip adductor weakness. Improving hip adductor muscle strength requires repeated sessions and relatively large time frames that would inevitably require several weeks.[12,13] Thus, starting a hip adductor strengthening exercise program at the beginning of the preseason could be too late for soccer athletes with large strength deficits, and consequently, these athletes may still remain at a high risk until hip adduction strength values have been increased. The interseason break would be a better opportunity to provide such athletes with a more substantial strengthening program, including more exercises and higher loads, than what would normally be feasible during the soccer preseason, although it seems difficult to implement at this time point. However, implementing a more comprehensive strengthening program than a single exercise has been shown possible in a prospective

study in elite ice hockey players.[28] In this study, a 6-week preseason preventative program, including up to 7 strengthening exercises targeting hip adductor muscles, decreased the risk for adductor injuries during the season in a group of players identified as having weak hip adductors and thus at a high risk for sustaining a groin injury.[28]

Soccer athletes with past-season groin pain lasting longer than 6 weeks showed lower preseason hip adductor strength on both the short- and long-lever squeeze tests compared with athletes without past-season groin pain. Both the short- and long-lever (45° and 0° of hip flexion, respectively) squeeze tests used in this study are the most common bilateral examinations used in the literature.[16,18,20,21] The differences were largest on the long-lever squeeze test, which also provides a larger hip adductor moment and consequently is more demanding on the hip adductor muscle group.[4,23] It is important to note that adductor-related groin pain is the primary clinical entity in groin pain cases among male soccer athletes,[9,11] and it therefore seems reasonable to expect larger differences when testing hip adductor muscles using long levers. It is also important to note that in a bilateral adduction squeeze test, the output will be determined by the weaker side.[27] Although a bilateral test provides a quick and precise assessment to determine weaker players,[17] to determine the weaker side using a unilateral test could be highly relevant in a secondary assessment. A unilateral test should also include testing in different muscle activation modalities, which would have been unfeasible when testing full soccer squads in this primary assessment, when time efficiency was important.

In the present study, soccer athletes with current groin pain showed 10% lower strength on the long-lever squeeze test compared with players without current groin pain, whereas there was no difference on the short-lever test. A recent systematic review has shown that the presence of hip/groin pain is associated with lower hip adductor strength in the sporting population.[19] Studies in soccer have shown that players with current groin pain have lower hip adductor strength compared with asymptomatic players.[18,21,25] In the present study, having current groin pain also influenced the differences between soccer athletes with and without past-season groin pain on the preseason hip adductor long-lever squeeze test. Soccer athletes with current groin pain showed almost 8% lower values on the preseason hip adductor long-lever test compared with soccer athletes with no current groin pain, independent of past-season groin pain. Thus, the differences in preseason hip adductor squeeze strength between soccer athletes with and without past-season groin pain seem to be a consequence of having current groin pain symptoms and are not related to past-season groin pain as such. Conversely, having current groin pain did not influence the differences on preseason hip adductor squeeze strength values between soccer athletes with different durations of past-season groin pain compared with athletes without past-season groin pain.

Finally, this study also identified that age had a negative effect on the short-lever squeeze test. Estimates revealed that per 1-year increase in player's age, a 0.5% decrease could be expected in short-lever hip adductor squeeze strength. This is a small but important effect, considering that in 10 years, strength values could be reduced by 5%. A similar small but statistically significant negative influence of age on short-lever hip adductor squeeze strength (9% decrease per 10-year increase in player's age) was also found in a previous study looking at normative values on muscles around the hip in professional Qatari soccer athletes.[20] Thus, it seems relevant to address specific attention to older soccer athletes with a duration of past-season groin pain for more than 6 weeks, as they are likely to show even lower short-lever hip adductor strength compared with younger soccer athletes with past-season groin pain.

A potential limitation of the present study is recall bias, concerning the use of a self-reported past-season injury form. To minimize recall bias, the past-season injury form contained a small number of simple questions and included a clear definition of injury and details in relation to anatomic regions, which has shown to result in better recall.[2] Importantly, we also limited the extent of time over which participants were asked to recall to a 12-month time frame, as this has been shown to reduce the impact of recall bias.[7] Another potential limitation of this study is selection bias. This study was conducted in a convenience sample, and consequently, generalization of the results must always be taken with caution. Nevertheless, we were able to include a relatively large cohort of soccer athletes from similar levels of play, equally exposed to soccer, in which none refused to participate, and therefore, we have little reason to believe that using a random sample of the same population would have yielded different results.

CONCLUSION

Preseason hip adductor squeeze strength is lower in male soccer athletes who have had past-season groin pain for more than 6 weeks compared with soccer athletes without past-season groin pain, independent of current groin pain status and age. Differences in preseason hip adductor squeeze strength previously observed between soccer athletes with and without past-season groin pain seem to be associated with current groin pain and not to a history of groin pain alone. Age negatively influenced short-lever hip adductor squeeze strength and should be considered when using the short-lever squeeze test in soccer athletes with wide age ranges.

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APPENDIX

TABLE A1
Estimates From Linear Multiple Regression Model 1[a]

	Unstandardized Coefficients			
	B	Standard Error	95% CI for B	*P* Value
Short-lever squeeze test				
Constant	2.067	0.126	1.819 to 2.315	<.001
Current GP	–0.078	0.065	–0.205 to 0.050	.231
Age	–0.011	0.005	–0.021 to 0.000	.046
Past-season GP	–0.024	0.047	–0.117 to 0.069	.615
Long-lever squeeze test				
Constant	2.987	0.177	2.638 to 3.336	<.001
Current GP	–0.229	0.091	–0.408 to –0.049	.013
Age	–0.007	0.008	–0.022 to 0.008	.343
Past-season GP	–0.082	0.066	–0.213 to 0.049	.217

[a]N = 303. GP values are reported as N·m/kg. GP, groin pain.

TABLE A2
Estimates From Linear Multiple Regression Model 2[a]

	Unstandardized Coefficients			
	B	Standard Error	95% CI for B	*P* Value
Short-lever squeeze test				
Constant	2.062	0.125	1.817 to 2.307	<.001
Current GP	0.001	0.069	–0.134 to 0.136	.992
Age	–0.011	0.005	–0.021 to 0.000	.046
Duration of past-season GP				
≤3 wk	0.035	0.051	–0.065 to 0.136	.489
>3 to ≤6 wk	–0.096	0.087	–0.266 to 0.075	.271
>6 wk	–0.237	0.085	–0.404 to –0.069	.006
Long-lever squeeze test				
Constant	3.001	0.174	2.658 to 3.343	<.001
Current GP	–0.126	0.096	–0.314 to 0.062	.189
Age	–0.008	0.007	–0.022 to 0.007	.287
Duration of past-season GP				
≤3 wk	–0.030	0.071	–0.170 to 0.111	.680
>3 to ≤6 wk	0.028	0.121	–0.210 to 0.266	.817
>6 wk	–0.459	0.119	–0.694 to –0.225	<.001

[a]N = 303. GP values are reported as N·m/kg. GP, groin pain.

Chapter 5
Paper IV

Past-, pre-, and in-season risk assessment of groin problems in male football: A prospective full-season study

Ernest Esteve
Martí Casals
Marc Saez
Michael Skovdal Rathleff
Mikkel Bek Clausen
Jordi Vicens-Bordas
Per Hölmich
Tania PIzzari
Kristian Thorborg

Paper IV has been submitted to the British Journal of Sports Medicine journal, and is presented in its last submitted version.

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Dear Mr. Esteve:

Your manuscript entitled "PAST-, PRE- AND IN-SEASON RISK ASSESSMENT OF GROIN PROBLEMS IN MALE FOOTBALL: A PROSPECTIVE FULL-SEASON STUDY" has been successfully submitted online and is presently being given full consideration for publication in British Journal of Sports Medicine.

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PAST-, PRE- AND IN-SEASON RISK ASSESSMENT OF GROIN PROBLEMS IN MALE FOOTBALL: A PROSPECTIVE FULL-SEASON STUDY

Ernest Esteve[1 2], Martí Casals[3 4], Marc Saez[5 6], Michael Skovdal Rathleff[7 8], Mikkel Bek Clausen[9 10], Jordi Vicens-Bordas[2 11], Per Hölmich[9], Tania Pizzari[12], Kristian Thorborg[9 13]

(1) Sportclínic. Physiotherapy and Sports Training Centre. Girona, Spain.

(2) School of Health and Sport Sciences (EUSES), Universitat de Girona, Carrer de Francesc Macià 65, Salt, Spain.

(3) Sport and Physical Activity Studies Centre (CEEAF), Faculty of Medicine. University of Vic – Central University of Catalonia, Barcelona, Spain.

(4) Medical Department, Futbol Club Barcelona, Barça Innovation Hub, Barcelona, Spain.

(5) Research Group on Statistics, Econometrics and Health, GRECS, University of Girona, Spain.

(6) CIBER of Epidemiology and Public Health, CIBERESP, Madrid, Spain.

(7) SMI, Department of Health Science and Technology, Faculty of Medicine, Aalborg University, Aalborg, Denmark.

(8) Department of Occupational Therapy and Physiotherapy, Aalborg University Hospital, Soendre Skovvej 15, 9000 Aalborg, Denmark.

(9) Sports Orthopedic Research Center (SORC-C), Department of Orthopedic Surgery, Copenhagen University Hospital, Amager-Hvidovre, Denmark.

(10) Department of Midwifery, Physiotherapy, Occupational Therapy and Psychomotor Therapy, Faculty of Health, University College Copenhagen, Copenhagen, Denmark.

(11) NEOMA Research group, Department of Medical Sciences, Universitat de Girona (UdG), Girona, Catalonia, Spain.

(12) La Trobe Sport and Exercise Medicine Research Centre, La Trobe University, Bundoora, Victoria, Australia.

(13) Physical Medicine and Rehabilitation – Copenhagen (PMR-C), Amager-Hvidovre Hospital, Copenhagen University, Hvidovre, Denmark.

Corresponding Author:

Ernest Esteve

St. Joan Roca i Pinet, 1, local 5,

17003 Girona, Spain

E-Mail: ernestesteve@hotmail.com

Mobile phone: +34 660640518

ABSTRACT

Objective: We assessed past-, pre- and in-season risk factors to investigate their association with an in-season groin problem in male amateur football players.

Methods: Past-season groin-pain information and pre-season short- and long-lever adductor squeeze strength were obtained at baseline, together with anthropometrics (weight, lower limb lever length) and player age. In-season hip- and groin-related sporting function was monitored every four weeks using the Sport and Recreation subscale from the Hip And Groin Outcome Score questionnaire (HAGOS (Sport)). Groin problems, including time-loss groin injuries and groin pain irrespective of time loss, were collected over a 39-week competitive in-season. We estimated relative risk (RR), and 95% credibility intervals (ICr) from Bayesian logistic regressions.

Results: Players (n=245) suffering from groin pain during the past-season had 2.4 times higher risk of experiencing a groin problem in the new season (2.40 RR; 95% ICr 1.5–3.7). This risk was reduced by 35% (0.65 RR; 95% ICr 0.42–0.99) per unit (N·m/kg) increase in the long-lever adductor squeeze test. Player age, short-lever squeeze test and the HAGOS (Sport) scores were not associated with risk of a groin problem.

Conclusions: Past-season groin pain increased the risk of a groin problem in the new in-season. Importantly, this risk was reduced by higher preseason long-lever adductor squeeze strength. Past-season groin pain information and long-lever adductor squeeze strength can be quickly obtained during pre-season to identify players with an elevated risk of in-season groin problem, which may be key to reduce these problems in the new season.

Keywords: groin injuries, groin pain, hip strength, Bayesian inference

Word count: 2991 words

INTRODUCTION

Groin problems represent a significant health burden in male football, with a reported seasonal prevalence above 50%.[1–4] In an average week, 3−8 players in every 25-player squad will experience pain and reduced sporting function due to a groin problem.[1,2] If groin problems are only defined as time loss from football, many groin problems will not be no recorded since at least one-third of these players continue to participate despite symptoms.[1,2] This potentially impacts conclusions from previous studies investigating risk factors for groin injury as the time-loss definition has been used almost exclusively.[5,6]

Previous time-loss groin injury,[5–7] and reduced hip adductor strength,[7,8] are both established risk factors for a new groin injury. These findings, however, are limited to the time-loss definition and do not account for the presence of groin pain in the previous season, irrespective of time loss. Likewise, hip adductor strength has commonly been measured using either short- or long-lever tests, but it is unknown whether risk estimates differ between these two tests. In addition, hip adductor strength is influenced by groin pain in the previous season and player age, [9] and thus, both need to be considered when assessing adductor strength.[10]

Groin symptoms commonly develop gradually and fluctuate over time.[2,4,11] The Copenhagen Hip And Groin Outcome Score questionnaire (HAGOS), a patient-reported outcome for physically active people,[12] has been proposed for monitoring hip and groin function and symptoms in football players.[11] Better pre-season HAGOS scores have been shown to reduce the likelihood of subsequent hip and/or groin injury in professional football players.[13] However, HAGOS scores have never been used continuously during the in-season to assess groin-injury risk.

The aim of this study was to investigate whether past-season groin pain, player age, pre-season short- or long-lever adductor squeeze strength, and in-season hip and groin sporting function measures were associated with an in-season groin problem in male amateur football players. Secondly, we investigated if

any of these associations differed between groin problems with and without time loss.

METHODS

Design and participants

This study used data from a cohort investigating groin and hamstring injuries in male amateur Spanish football players.[1,9,14] A convenience sample of 17 male amateur football teams (tiers IV, V and VI) were invited to participate. Players (n = 363) from these teams were screened for potential risk factors during the 2015 pre-season (July-August). To be included in the study, players had to be present at baseline test and available to fully participate in the following training session (free of injury). Football players who were not able to perform the test due to an injury, sickness or any physical complaint were excluded. Football players not able to understand the Spanish or English language and players under 18 years were not included. Exposure to football, groin problems and hip- and groin-related sporting function were collected prospectively over a full competitive in-season (39 weeks). All players were informed verbally about the purpose and procedures of the study and signed a written consent form. Local ethics approval was obtained from a regional committee (reference number 08/2015/CEICEGC). The reporting of this prospective cohort study adhered to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines.[15]

Risk factors assessed

Past-season groin pain and age

During pre-season, we collected demographic (age) and anthropometric (body mass and lower-limb lever-lengths) data in addition to retrospective information about past-season groin pain from all included players. A player was considered to have had past-season groin pain when they answered “yes” to the question: Did you suffer from groin pain in the past-season?

Pre-season hip adduction squeeze strength

During the pre-season, we measured players' hip adduction squeeze strength using a hand-held dynamometer (HHD) (MicroFet2, Hogan Health Industries, Inc. Salt Lake City, USA) in two different testing procedures: 1) a short-lever (resistance placed between knees, feet at the examination bed, and 45 degrees of hip flexion), and 2) a long-lever (resistance placed between the ankles, and 0 degrees of hip flexion). The isometric peak force (N) was obtained from one maximal repetition for both test.[16] All squeeze tests were performed by the same researcher (EE). Absolute values (N) from the respective squeeze test (short- and long-lever tests) from each player were normalized (N*m/kg) for body mass (kg) and lever length (m) and used as torque values (N·m/kg).

In-season hip- and groin-related sporting function

At baseline (pre-season), and every four weeks in-season (overall, 11 time points), players completed the Sports and Recreation (Sport) subscale from the HAGOS questionnaire (HAGOS (Sport).[12] Every four weeks scores were calculated and assigned to each player for the subsequent four weeks. For the first in-season week, baseline scores were assigned. In this study, we used the translated and transcultural-adapted Spanish version of the HAGOS questionnaire (available at: www.koos.nu). The HAGOS (Sport) subscale (8 items) score ranges from 0 to 100 with a score of 100 representing full function and no limitations.

Individual football exposure

Exposure to football was registered by coaching staff, using a specifically designed computer-based spreadsheet. Individual exposure to football was defined as the number of minutes each player was involved in physical activity under the supervision of the coaching staff (training exposure) or participated in a match (match exposure).[17]

Study outcomes: Groin problems

A new onset of any in-season groin problem was the main outcome of interest. A groin problem was a compound outcome and included groin problems either with or without time loss, registered during the 39-week competitive period. See Box 1 for details on registration of groin problems with and without time

loss. A new onset of any groin problem was determined using information from time-loss injury records and groin-pain surveys. A player was considered as having a new onset of a groin problem with time loss when, according to time-loss injury records, he missed at least one training session or a match due to a groin problem (i.e., “time-loss groin injury”) in a given week. A player was considered as having a new onset of a groin problem without time loss when he reported in the groin-pain survey to suffer from groin pain (yes) in a given week, but reported to be free of groin pain in the previous week and no time loss due to a groin problem was registered during the week in question.

Box Registration of groin problems - with and without time loss

Groin problems with time loss

Team physiotherapists prospectively registered groin problems with time loss over the 39-week competitive in-season, as "any complaint located in the groin leading to a player being unable to fully participate in a future training or match play" (i.e. time-loss groin injury). Registration details included date of injury, and date of return to full participation. A groin problem with time loss was considered resolved when a player returned to full training participation or was available for selection for a match.

Groin problems without time loss

Groin problems without time loss were self-reported using a written groin-pain survey administered every four weeks, which asked whether players had suffered (yes/no) from groin pain in any of the past 4 weeks, each week recorded separately. The groin-pain survey included the question: "Did you have groin pain (inguinal region including adductors, lower abdomen and pubic region) during that week?". This question was repeated for each of the last 4 weeks as part of structured chart, including specific information regarding the dates and match opponent in each of the required weeks. An example template of the written groin-pain survey have been published previously.[1] A groin problem without time loss (i.e. groin-pain episode) was considered resolved when a player reported being free of groin pain in a subsequent week.

Statistical analyses

Baseline characteristics of the included players were summarized by measures of central tendency and dispersion when the variables were quantitative, and by proportions when variables were categorical. Players were included in analyses until they were no longer part of the participating teams. Differences between players who dropped out and players who remained in the study were assessed using independent samples t-test (age, short- and long-lever hip adductor strength), and chi-squared (past-season groin pain prevalence) and Mann-Whitney U (HAGOS (Sport) test. Data normality was assessed using the Kolmogorov-Smirnov test and Q-Q plots, and the homogeneity of the variance was verified using Levene's test. All assumptions were meet for all test. Players reporting incomplete information and/or current groin pain at baseline were not included in the analyses.

We estimated relative risk (RR) for groin problems using two multivariate models that included i) the short-lever and ii) the long-lever squeeze test, respectively, together with past-season groin pain, age, and HAGOS (Sport), all as explanatory variables. An in-season groin problem was set as the dependent variable as a mixture of its two components (i.e. dependent variables): groin problems with time loss, and groin problems without time loss. Since these two components were not independent, both were modelled together in a 'two-part' model,[18,19] within a Bayesian framework using the integrated nested Laplace approximation (INLA) approach.[20] In both parts of the model, a binomial family and a logit link (equivalent to logistic regression) were assumed. Both the short- and the long-lever models were run again estimating separate RRs to evaluate possible differences in estimates between groin problems with and without time loss.

All models were adjusted for individual exposure to football. Team and player variables were included as random effects. All random effects were unstructured (i.e. independent and identically distributed) and assumed to be normally distributed. For the random effects we used priors that penalize complexity (called PC priors). These priors are robust in the sense that they do not have an impact on the results and, [20] in addition, they have an epidemiological interpretation.[21] The fixed effects β (log-relative-risk per unit increase in the covariate) were reported as posterior median of relative risks (RRs), i.e.

exp$\{\beta i\}$, and 95% credibility intervals (95% ICr). Note that in the Bayesian approach the reported 95% credible intervals are distributions of the sampled values, including 2.5th to 97.5th percentiles.

Apart from the RRs and their 95% ICr, the probability of the parameter estimator (the log (RR)) as an absolute value being different from 0 (Prob) was also calculated (note that this is unilateral and so does not necessarily have to coincide with the credibility interval in all the cases). Unlike the p value in a usual environment, this probability allowed us to make inferences about the possible association, based upon a level of significance (i.e. alpha) set at 5%.

Short- and long-lever models were compared using the Watanabe-Akaike information criterion (WAIC).[22] Smaller values of WAIC indicated a higher performance. All analyses were performed using the free software R (version 3.4.0) (R Core Team, 2016), with the INLA package.[20]

RESULTS

Analyses included 245 players with complete baseline data (Figure 1; Table 1). The average response rate to the groin-pain survey and HAGOS questionnaire was 93.3% (range: 89.2%-95.4%). All teams provided full time-loss injury records. Two teams provided incomplete individual exposure. During the 39-week season, 99 players (40.4%) suffered a groin problem and 146 players (59.6%) remained free of any groin problem. The risk factor analyses included 233 in-season groin problems, of which 35 (15%) were groin problems with time loss and 198 (85%) without time loss.

Figure 1 Flow chart of participants

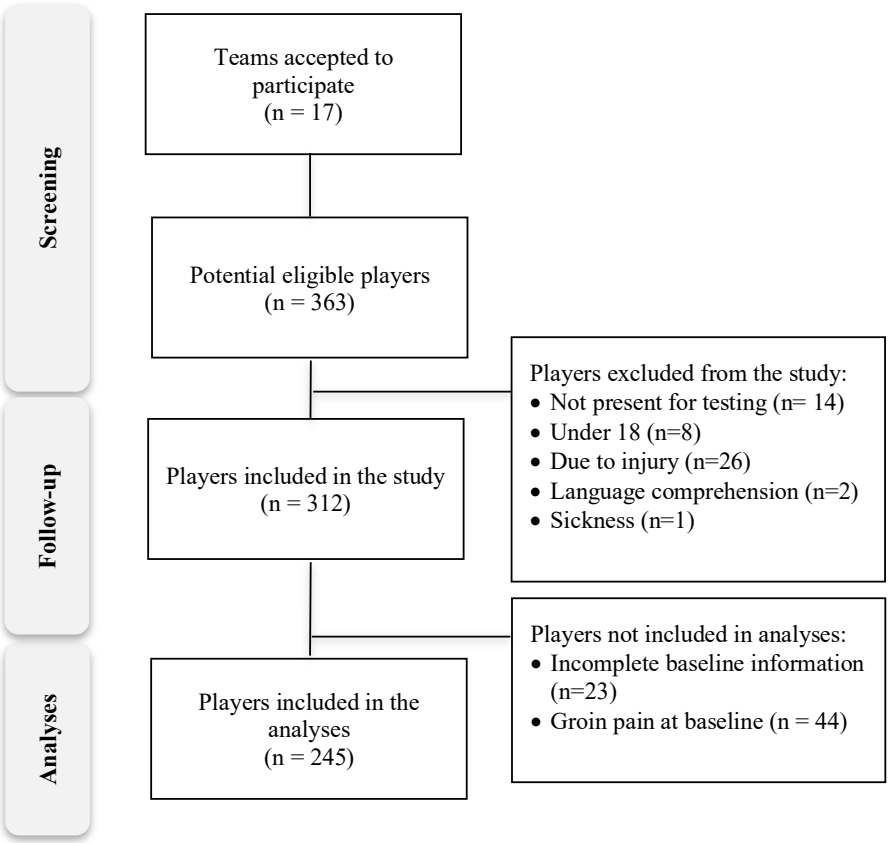

Table 1 Baseline characteristics and exposure data of the 245 included players, grouped by players that remained free of groin problems and players that reported an in-season groin problem.

Variables	Overall (n = 245)	Free of groin problems (n = 146)	Reporting groin problems (n = 99)
Age (years)	22.9 (18-38)	22.5 (SD 3.8)	23.5 (SD 3.9)
Weight (kg)	73.7 (57-98)	74.0 (SD 7.6)	73.1(SD 8.2)
Height (m)	1.78 (1.64-1.95)	1.78 (SD 0.6)	1.77 (SD 0.7)
Past-season groin pain†			
Yes	77 (31.4%)	37 (25.3%)	40 (40.4%)
No	168 (68.6%)	109 (74.7%)	59 (59.6%)
Short-lever squeeze strength (N·m/kg)	1.80 (SD 0.4)	1.83 (SD 0.4)	1.77 (SD 0.4)
Long-lever squeeze strength (N·m/kg)	2.79 (SD 0.5)	2.84 (SD 0.5)	2.72 (SD 0.5)
HAGOS (Sport) at baseline‡	93.8 (84.4-100)	93.8 (84.4-100)	93.8 (78.1-100)
Exposure (h)	30290	13797	16494
Training	24239	11122	13117
Match	6050	2674	3376

Values are mean (range), unless other indicated; † Number of players, and proportions (%) calculated in relation to the number of players in the group indicated at column top; ‡ Median and inter-quartile range (25th - 75th)

Risk factors for groin problems

Estimates from multivariate models can be found in Table 2. The long-lever model showed a higher performance (WAIC) compared with the short-lever model (see full models supplementary file). Players reporting past-season groin pain had a 2.4 times higher risk of an in-season groin problem (2.40 RR; 95% ICr 1.52–3.54; Prob 99%). Every unit (N·m/kg) increase in pre-season long-lever squeeze adduction strength reduced the risk of a groin problems by 35% (0.65 RR; 95% ICr 0.42–0.99; Prob 97%). We found no association of player age or in-season HAGOS (Sport) subscale scores with risk of groin problems. Estimates from the short-lever model (Table 2) showed that the short-lever squeeze test was not associated with the risk of a groin problem (0.72 RR; 95% ICr 0.39–1.30; Prob 86%).

Table 2 Short- and Long-lever squeeze strength multivariate models for groin problems

Variables	RR (95% ICr)	Prob.
Short-lever Model		
Past-season groin pain (yes)	2.50 (1.60–3.40)	0.99
Age (years)	1.05 (0.99–1.11)	0.96
Short-lever squeeze strength (N·m/kg)	0.72 (0.39–1.30)	0.86
HAGOS (Sport) (0-100)	1.00 (0.99–1.00)	0.65
Long-lever Model		
Past-season groin pain (yes)	2.40 (1.52–3.74)	0.99
Age (years)	1.05 (0.99–1.11)	0.94
Long-lever squeeze strength (N·m/kg)	0.65 (0.42–0.99)	0.97
HAGOS (Sport) (0-100)	1.00 (0.99–1.01)	0.66

RR: Relative Risk; ICr: Credibility Interval; Prob.: Probability of the parameter estimator (log(RR)) being different from 0

Risk factors for groin problem with and without time loss

Table 3 shows separate estimates for groin problems with and without time loss. The long-lever model showed a higher performance (WAIC) compared to the short-lever model (see full models in supplementary file). Reporting past-season groin pain was associated with a 2.6 times higher risk of experiencing a groin problem without time loss (2.60 RR 95% ICr 1.64–4.20; Prob 99%). Older age was associated with the risk

of groin problems without time loss, with a 5% higher risk per year increase in age (1.05 RR; 95% ICr 1.00–1.12; Prob 96%). We found no association for past-season groin pain and older age with groin problems with time loss. Similar estimates were obtained for the long-lever squeeze test for groin problems either with or without time loss. We found no associations for the short-lever squeeze test, or HAGOS (Sport) with the two different groin problem definitions.

Table 3 Short-lever and long-lever squeeze strength models with separate estimates for groin problems with and without time loss

Variables	RR (95% ICr)	Prob.
Short-lever Model		
Past-season groin pain (yes)		
Time-loss groin problem	1.60 (0.75–3.40)	0.89
No time-loss groin problem	2.76 (1.73–4.44)	0.99
Age (years)		
Time-loss groin problem	1.00 (0.93–1.09)	0.58
No time-loss groin problem	1.06 (1.00–1.12)	0.98
Short-lever squeeze strength (N·m/kg)		
Time-loss groin problem	0.65 (0.26–1.61)	0.82
No time-loss groin problem	0.73 (0.39–1.37)	0.84
HAGOS (Sport) (0-100)		
Time-loss groin problem	1.00 (0.98–1.01)	0.79
No time-loss groin problem	1.00 (0.98–1.01)	0.72
Long-lever Model		
Past-season groin pain (yes)		
Time-loss groin problem	1.55 (0.72–3.29)	0.87
No time-loss groin problem	2.60 (1.63–4.20)	0.99
Age (years)		
Time-loss groin problems	1.02 (0.94–1.10)	0.66
No time-loss groin problem	1.05 (1.00–1.11)	0.96
Long-lever squeeze strength (N·m/kg)		
Time-loss groin problem	0.50 (0.26–0.94)	0.98
No time-loss groin problems	0.67 (0.43–1.04)	0.96
HAGOS (Sport) (0-100)		
Time-loss groin problem	1.00 (0.99–1.01)	0.72
No time-loss groin problem	1.00 (0.99–1.00)	0.77

RR: Relative Risk; ICr: Credibility Interval; Prob.: Probability of the parameter estimator (log(RR)) being different from 0

DISCUSSION

This study highlights the relevance of capturing information about the presence of groin pain in the previous season, together with pre-season long-lever hip adductor squeeze strength measures, as both are associated with the risk of a groin problem in the new in-season.

Risk factor for all groin problems

Past-season groin pain and age

Previous time-loss groin injury is the most consistent risk factor,[5,6,23] increasing the risk of new groin injury between 1.4 and 7 times.[8,23–27] The risk of new groin injury also increases with time-loss from a different injury sustained in the past-season.[23] We found that the simple presence of groin pain increased the risk of a groin problem by 2.4 times in the new season. This has important implications, as the seasonal prevalence of groin pain in male football can be up to 50%.[1,3,4]

We did not identify age as a significant risk factor for a groin problem in male amateur adult football players, which is in line with previous studies.[7,8,24,26,28] Where age has been found to be a significant risk factor in initial univariate analyses, the effect disappears when adjusting for the known confounder of previous injury.[8,26]

Pre-season hip adduction squeeze strength

Our findings indicate that the long-lever squeeze test may play a more important role than the short-lever test on pre-season risk-factors screening. This is in line with previous research in football.[7,8,13]The long-lever hip adductor squeeze is more demanding on the hip adductor muscle group,[29] which are in high demand in key playing actions in football, such as kicking,[30] as well as the primary clinical entity in groin pain cases among male football players.[28] The long-lever test also displays a higher adductor torque production and better discriminative capabilities compared to the short-lever test, even when taking values from one single repetition, as performed in the present study.[16]

Baseline differences on the long-lever peak torque (Table 1) between players reporting any in-season groin problem and players who remained symptom-free were minimal (4%). However, adjusted estimates (RR) revealed that the lower the peak-torque value obtained from the long-lever test the higher the risk of experiencing an in-season groin problem. By way of illustration, from a reference long-lever peak torque value of 2.8 N·m/kg (mean value from the group of players not reporting in-season groin problems), per every reduction in 0.5 N·m/kg (19% reduction), the risk of an in-season groin problem would be increased by 17.5%. This is independent of having had past-season groin pain, player age and football exposure.

In-season sporting function

We found HAGOS (Sport) subscale scores, registered every four weeks, were not associated with the risk of an in-season groin problem, when adjusting for past-season groin pain and hip adductor strength. In contrast, two studies found that pre-season HAGOS scores increased the risk of time-loss groin injury in the subsequent season in Gaelic footballers, [31] and professional football players. [13] Methodological differences, such as HAGOS administration frequency (single point at pre-season vs continuously during in-season), and the fact that these two studies were at risk of including symptomatic players at baseline,[3] could explain these differences.[11]

Differences between groin problems with and without time loss

Past-season groin pain and age were associated with a higher risk of experiencing a groin problem without time loss in the new in-season, but this association was not found for groin problems with time loss. The low number of groin problems with time loss may partly explain this difference.[10] However, the past-season injury form and the in-season groin-pain survey referred to groin pain, irrespective of time-loss, and thus, one could expect that the past-season injury form and the in-season groin-pain survey captured groin problems of similar nature (likely due to overuse). An increased chance of sustaining a groin problem without time loss due to older age, could be the result of greater exposure to potentially injurious loads over time and/or the recurrent and persistent nature of any previously encountered problems.

Methodological considerations and limitations

Sixty-nine (28.2%) players that dropped out before study completion; 48 changed to a team not participating in the study; 7 ended their sports career; 1 was not interested in participating anymore; 8 suffered a long-term injury; and for 5 players the reason could not be determined. We found that players who dropped out from the study were younger (mean age: 21.7 years) compared to players who did not drop out (mean age: 23.4 years). The youngers were probably less consolidated players or starting their careers and changed team more frequently, which may explain this difference. We are aware that loss to follow up may introduce bias through selection, although this could be expected to be minimal in the present study due to the small age difference.

To reduce the impact of a potential bias through recall, the past-season injury form contained a small number of questions and limited recall to a 12-month time frame.[32,33] Generalization of the present finding should be made with caution, as this study was conducted in a convenience sample, although we were able to include a relatively large sample of players where none refused to participate. There is little reason to believe that estimates would have led to different conclusions using a random sample.

We used only the Sports and Recreation (Sport) subscale from the HAGOS questionnaire, instead of the full HAGOS. In part to avoid a potential negative effect on rate of response due to attrition. There are moderate to high correlations between all sub-scale scores, suggesting that measuring all subscales may not be necessary when assessing injury risk.[13] HAGOS (Sport) was administered every four weeks, but it refers only to the past seven days. It is at this point unknown if sampling more frequently would result in a different result.

CONCLUSIONS

Players who suffered from groin pain in the previous season had an elevated risk of experiencing a groin problem in the new in-season. Higher pre-season values on the long-lever adductor squeeze test reduced the risk of experiencing groin problem in the new in-season, whereas short-lever testing, age and in-season HAGOS (Sport) were not associated with groin problems in the new in-season. Pre-season hip adductor strength assessment using the long-lever adduction squeeze strength test and past-season groin pain

information identifies players with an elevated risk of groin problems in the new in-season. Early implementation of hip adductor strengthening and close monitoring of groin health on these players, could reduce the risk of groin problems in the new in-season.

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Patient consent Obtained.

Provenance and peer review Not commissioned; externally peer reviewed

What are the new findings?

- The presence of groin-pain in the previous season increases the risk of a groin problem in the subsequent in-season.
- Higher pre-season strength on the long-lever adductor squeeze test reduce the risk of groin problems in the new in-season.
- In-season monitoring of the hip and groin sporting function, using the Sports and Recreation HAGOS subscale every four weeks, was not able to detect players at risk, when adjusting for past-season groin pain and pre-season hip adductor squeeze strength.

How it may impact on clinical practice in the future?

- In-season monitoring with HAGOS Sport and Recreation subscale scores registered every four weeks was not able to detect players with an elevated risk of a new groin problem.
- Future risk assessments at the beginning of the season should include information on past-season groin pain irrespective of time-loss or not
- At preseason, the long-lever adductor squeeze strength test is preferred over the short-lever test when assessing the risk of new in-season groin problems.

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Supplementary file

Table 1 Short- and Long-lever multivariate models for groin problems

Variables	RR (95% credibility interval)	Prob.
Short-lever Model		
Past-season groin pain (yes)	2.50 (1.60–3.40)	0.99
Age (years)	1.05 (0.99–1.11)	0.96
Short-lever squeeze strength (N·m/kg)	0.72 (0.39–1.30)	0.86
HAGOS - Sport/Rec (0-100)	1.00 (0.99–1.00)	0.65
Exposure (hours)	1.09 (1.02–1.17)	0.99
WAIC = 2164.777		
Long-lever Model		
Past-season groin pain (yes)	2.40 (1.52–3.74)	0.99
Age (years)	1.05 (0.99–1.11)	0.94
Long-lever squeeze strength (N·m/kg)	0.65 (0.42–0.99)	0.97
HAGOS - Sport/Rec (0-100)	1.00 (0.99–1.01)	0.66
Exposure (hours)	1.09 (1.03–1.17)	0.99
WAIC = 2162.622		

RR: Relative Risk; ICr: Credibility Interval; Prob.: Probability of the parameter estimator (log(RR)) being different from 0; WAIC: Watanabe-Akaike information criterion

Table 2 Short-lever and Long-lever models with separate estimates for groin problems with and without time loss

Variables	RR (95% ICr)	Prob.
Short-lever Model		
Past-season groin pain (yes)		
Time-loss groin problem	1.60 (0.75–3.40)	0.88
No time-loss groin problem	2.76 (1.73–4.44)	0.99
Age (years)		
Time-loss groin problem	1.00 (0.93–1.09)	0.58
No time-loss groin problem	1.06 (1.00–1.12)	0.97
Short-lever squeeze strength (N·m/kg)		
Time-loss groin problem	0.65 (0.26–1.61)	0.82
No time-loss groin problem	0.73 (0.39–1.37)	0.83
HAGOS - Sport/Rec (0-100)		
Time-loss groin problem	1.00 (0.98–1.01)	0.79
No time-loss groin problem	1.00 (0.98–1.01)	0.72
Exposure (hours)		
Time-loss groin problem	1.08 (0.94 –1.26)	0.85
No time-loss groin problem	1.09 (1.01–1.17)	0.99
WAIC = 2034.771		
Long-lever Model		
Past-season groin pain (yes)		
Time-loss groin problem	1.55 (0.72–3.29)	0.87
No time-loss groin problem	2.60 (1.63–4.20)	0.99
Age (years)		
Time-loss groin injury	1.02 (0.94–1.10)	0.66
Groin pain	1.05 (1.00–1.11)	0.96
Long-lever squeeze strength (N·m/kg)		
Time-loss groin problem	0.50 (0.26–0.94)	0.98
No time-loss groin problem	0.67 (0.43–1.04)	0.96
HAGOS - Sport/Rec (0-100)		
Time-loss groin problem	1.00 (0.99–1.01)	0.72
No time-loss groin problem	1.00 (0.99–1.00)	0.77
Exposure (hours)		
Time-loss groin problem	1.10 (0.95–1.29)	0.88
No time-loss groin problem	1.10 (1.01–1.17)	0.99
WAIC = 2031.984		

RR: Relative Risk; ICr: Credibility Interval; Prob.: Probability of the parameter estimator (log(RR)) being different from 0; WAIC = Watanabe-Akaike information criterion

Chapter 6
General discussion

This thesis has revised the steps for "the sequence of injury prevention",[1] with the aim of broadening knowledge to prevent groin problems in male football players. The first step, "establishing extent of the injury problem" was addressed in Papers I and II, which investigated the prevalence and severity of groin problems beyond the traditional time-loss definition, in a football in-season and pre-season, respectively. The second step, "establishing the aetiology and mechanisms of sports injuries" was addressed in Papers III and IV, which investigated whether a known risk factor such as hip adductor strength may be influenced by with previous groin pain and player's age, and lastly, assessed known and novel risk factors for future groin problems.

Prevalence and severity of groin problems

In Paper I, we identified a high seasonal prevalence of groin problems of 53.1% in a cohort of Spanish male football players. On a weekly average, the prevalence of groin problems was 11.7%, with 1.3% of the players reporting groin problems with time loss, and 10.4% of the players reporting groin problems without time loss. These findings further support that the extent of groin problems in male football is greater than the time-loss injury definition is able to capture, and that players often continue to train and compete despite experiencing groin symptoms.[2–8]

Traditionally, the time-loss definition has been adopted by injury surveillance studies not only for registering injury frequency, but also as a surrogate measure of injury severity.[9] As documented in this present thesis (Papers I and II), this has important limitations in the case of groin injuries. We evaluated the severity of groin problems, such as hip- and groin-related sporting function, using the Sports and Recreation subscale (Sport) from the HAGOS questionnaire (HAGOS (Sport). In Paper I, we found that players reporting groin problems showed lower HAGOS (Sport) scores compared to players not reporting groin problems during the season. Furthermore, we found no difference in the HAGOS (Sport) subscale scores between players reporting groin problems with or without time loss. Paper I is the first study investigating whether the degree of impairment in the hip and groin sporting function (HAGOS (Sport)) may relate to time loss. This study revealed that in the case of groin injuries, the degree of impairment may not be the only cause of absence from football, and that players continue playing despite experiencing important limitations in their sporting function. All in all, present findings document that epidemiological studies using time-loss definitions not only underestimate the true extent of groin injuries, but also provide an incomplete picture of the actual problem.

Previous studies conducted in Scandinavian male football showed similar seasonal prevalence of groin problems (49% to 67%).[2–5] The average weekly prevalence of groin problems identified in the present cohort of Spanish players (11.7%) was, however, lower compared to the reported weekly prevalence in Norwegian football (21% and 29%).[2,3] This difference seems to be explained by methodological differences in data collection between studies,[1,10] rather than relevant regional differences in prevalence of groin problems across European football.[11] In summary, many players from amateur to elite and across different

regions, are troubled with groin problems during a football season, experiencing pain and severe reductions in their function due to these problems.[2–4,8]

Harøy and colleagues, showed that the prevalence of groin problems increases during periods of match congestion (29% vs 21%). In Paper I, we found that the highest weekly prevalence (20.8%) was in the first competitive week. These data indicate that the prevalence of groin problems varies throughout the season, and that many players develop symptoms very early. Injury risk in football appears to be phase dependant, with a higher risk in the pre-season compared to the in-season, even at similar football loads.[12] In the case of groin injuries, the lack of sport-specific training during the off-season may increase the risk of a groin problem when football loads resume at pre-season.[13] In Paper II, we found that groin problems were twice as prevalent in pre-season as in-season. This difference resulted from a higher prevalence of groin problems without time loss in the pre-season (18.7%) compared to the in-season (10.4%), as there was no difference in the prevalence of groin problems with time loss between the two season periods. These findings support the seasonal variation of groin problems throughout the football season, which has further implications on how prevention of groin problems should be addressed.

The groin injury incidence identified in present studies (Paper I and II) is in line with previous groin-injury epidemiological studies in football.[14] Although previous studies in Spanish professional football have shown a higher incidence of lower limb injuries during pre-season,[15,16] in Paper II we found no difference in time-loss groin injury incidence between the pre- (1.2 groin injuries/1000h) and the in-season (0.9 groin injuries/1000h) in our amateur cohort. Similarly, we found (Paper II) no difference in time-loss groin injury burden between the pre- (8.4 days lost/1000h) and the in-season (8.6 days lost/1000h). In this case, our estimates were much lower compared to the highest level of football in Europe (16.1 days lost /1000h),[17] or in the Middle East (24.3 days lost/1000h),[18] suggesting that days lost due to groin injuries seem to be a major problem at higher football levels.

Implications for future groin-injury surveillance

The injury definition and data collection methods used are critical in determining the extent of injuries in sport,[9,10,19,20] which is, according to Van Mechelen, the starting point of injury prevention.[1] As clearly illustrated in the present thesis, relying solely on the time-loss definition of injury results in a low injury rate, despite a high prevalence of groin symptoms and impaired sporting function. This may be explained by the particular presentation of groin injuries, with a commonly gradual onset.[3,5,21,22] From the perspective of injury mechanism, these injuries are classified as overuse injuries (i.e. gradual-onset injuries),[9] and commonly caused by repeated stresses and strains that may gradually develop symptoms when the tissue capacity is exceeded.[23,24] During this process, players may adapt to the different football practice demands, avoiding most provocative activities, delaying time loss, and only seek medical attention in more advanced symptomatic stages.[25] This makes groin injuries difficult to detect, placing them beyond the scope of the time-loss approach.

Groin injuries, therefore, require different definition and registration methods, rather than the traditional time-loss, or medical attention approach. The use of self-reported instruments seems the tool of choice,[2,3] as also demonstrated in the present thesis. The registration method, but also the distribution frequency of self-reported instruments are important aspects to be considered. Both should aim at maximizing player's engagement while minimizing intrusion in daily team routines.[19] A weekly registration of self-reported groin problems performed through a smartphone application showed a very high rate of response (97%) during a short period of time (6 weeks) in male footballers.[3] However, the rate of response decreased (70%-80%) in longer in-season periods (28 weeks).[2] In Paper I, we showed that the administration of a written groin-pain survey every fourth week, asking about groin pain in any of the past four weeks, separately, over a 39-week period had a very high rate of response (93.3%). We also showed that response rates substantially decreased when sampling more frequently, weekly instead of every fourth week (74.3%-75.2%). Importantly, we showed there were no significant differences in sampling every week or every fourth week on the weekly prevalence of groin pain. Although this provides valuable information for future groin injury studies, it has to be noted that we made important efforts to help players recall, providing written structured information on dates and match features in the groin-pain survey, but also clarifying doubts verbally when players completed the surveys. Thus, the successful implementation of this approach may require overcoming some barriers.

The implementation of groin-injury registration methods, especially in a clinical setting, can be difficult when reports need to be completed by the players themselves. Electronic solutions distributed, for instance, through smartphone applications, as performed in Norwegian studies, seem optimal for cost-effectiveness in the long-term.[26] Written surveys, as performed in the present studies, are more easily handled and implemented,[27] but require more human resources,[26] and may cause greater disruption to team routines. However, both approaches may experience decreased player engagement, when registering groin problems in high frequency (i.e. weekly) and during long periods, such as full season, and/or including competitions breaks.[2] Difficulties may also increase considering that capturing complaints in other locations or illnesses, and not only groin problems, may be desirable as well.[28] An alternative to our approach could be to register every two weeks or every month, asking only about the last 7 days to reduce potential recall bias. Although groin problems of a shorter duration may go undetected with less frequent sampling (every two weeks, or every four weeks), it may still be useful for capturing more long-standing problems, with no significant variation in average weekly prevalence of reported problems.[20]

The definitions and the number of questions included in the registration instrument should also be considered carefully. In the written groin-pain survey used in present studies, the definition of groin problems included only pain, as it is believed to be the most representative symptom of an injury.[10,20,25,29,30] Nevertheless, other symptoms may also impair player's function. The number of registered problems depends necessarily, on the definition of "the problem", and the number of symptoms collected. This is clearly exemplified in the present thesis when comparing the present method of groin problem registration, which included only pain, with the previous one proposed in Norwegian studies, which included other symptoms apart from pain.[2,3] With the Norwegian approach, more complaints would be collected, resulting in a higher number of registered problems. It could be argued that the Norwegian

approach could be too sensitive, and register minor symptoms, such as muscle soreness, commonly derived from repetitive bouts of exercise. However, it becomes difficult to establish any preference over these two measures, as this is comparable to opening or closing the camera lens when taking a picture. Thus, coaches, players and clinicians should decide what is relevant to capture, and what should be shown in the picture in each particular context.

There are important variations in how stakeholders in injury surveillance (i.e. coaches, players and clinicians) interpret the injury definition.[10,20,25] Commonly, the mere presence of pain or other symptoms is not sufficient to identify a sports injury. Instead, a sports injury is often defined not only by its consequences, including pain, but by sports performance, and what the players can or cannot actually do.[20,25] Present findings further support that players suffering from groin problems experience a severe reduction in their sporting performance, apart from pain,[31] although none of these issues stop them from playing. Pain, and participation have been described as a subcomponent of a sports injury, especially to appraise severity, but both are highly dependent on personal and external factors.[25,32,33] Future groin injury surveillance may consider measuring groin problems, directly, at the level of player's function. For this purpose, the HAGOS questionnaire is a patient-reported outcome addressed to young and middle-age physically active people, and contains a specific subscale measuring hip- and groin-related sporting function (Sport) in the past seven days.[34] To quickly inform about player's groin health, an alert could be set in a particular HAGOS (Sport) score, and complemented with hip strength measurements.[35] This information could be aligned to each particular context, with participation and performance measures, together with a medical examination to determine whether a player is injured or not, and the optimal management.[25]

Thus, time-loss or medical attention definitions may still have some relevance in the case of groin injuries. In fact, the combination of both measures, together with novel measures irrespective of time loss, could provide a complete picture of the problem.[19] Records on time loss and medical attention would provide valuable information to determine the availability of players to be selected for a match, and the potential consequences on team performance, economical aspects, or the use of medical resources.[36] Little is known, however, on the impact of a higher presence of groin-related impairments among a team squad on factors such as team performance, which warrants further investigation in the future.

Assessing risk of future groin problems

In this project, we investigated if known risk factors, such as previous injury and hip adductor strength may be influenced by player's age and current groin pain. We also investigated associations of these factors with in-season groin problems, including the presence of groin pain in the previous season, and different hip adductor strength measures, together with age and novel risk factors, such as hip and groin sporting function. Furthermore, we also investigated whether associations of these risk factors may differ between groin problems with and without time loss.

Past-season groin pain

In Paper IV, we found that players who suffered from past-season groin pain had 2.4 times greater risk of experiencing an in-season groin problem. This is consistent with results from previous studies,[21,37–40] reinforcing the insight that groin problems are of a persistent and recurrent nature. In addition, the greater the number of previous injuries, the increased risk of injury in football,[40,41] with new injuries often differing in nature or anatomical location from previous index injuries.[8,38,42] Langhout and colleagues,[8] found that the risk of a new groin injury not only increased with a previous injury in the same location, but also with a previous injury in any body region other than the groin (5.1 HR; 95% CI 1.8-14.6). Insufficient rehabilitation, altered movement patterns, or detrimental effects on tissue capacity after a previous injury, are commonly pinpointed to potentially explain the increased risk of injury in the same or different body locations. Other factors, such as risk-taking behaviour, or genetics may also be important.[43] We demonstrated that the mere presence of groin pain in the previous season, irrespective of time loss, is sufficient to increase the risk of an in-season groin problem in the subsequent season. Considering that the reported seasonal prevalence of groin problems, which commonly include pain, is above 50% in male football,[3,4] this finding has great implications for future groin injury surveillance, as at least one in every two players will present this factor at the beginning of a new season. Future interventions, therefore, should not only be aimed at restoring full functional capacity before return-to-play decision-making after a time-loss injury,[44,45] but also at reducing the prevalence of ongoing groin symptoms that do not necessarily lead to time loss, in order to mitigate the risk of these injuries.

Age

The relevance of age as a risk factor in sport is controversial. Among male footballers, age seems more relevant for certain injuries, such as hamstring[46] or calf injuries,[47] while less relevant for others, such as knee and ankle injuries.[37] A large study including more than 2000 players over nine football seasons, registering 672 groin injuries, reported that the incidence of groin strains was highest in the 22-30 age range (2.71/1000h), and lowest in the 16-21 age range (1.61/1000h).[48] Hölmich and colleagues, combining time-loss and medical attention definitions, found that the age of the player seemed to be a risk factor for either missing at least one match (1.15 OR; 95% CI 1.00 to 1.32; *P*=0.05), or one training session (1.17 OR; 95% CI 0.98 to 1.40); *P*=0.08, although estimates did not reach statistical significance.

We found that age was not a significant risk factor (1.05 RR; 95% ICr 0.99 - 1.11; Prob 94%) for in-season groin problems using multivariate models in which groin pain in the previous season was included. Two previous studies showed that age was a significant risk factor in univariate analyses, but the effect disappeared when adjusting for previous injury, which supports our findings.[21,37] Previous injury might act as a confounding factor, as older players are more likely to have suffered a previous injury in the past.[37,49]

Hip adductor strength

Hip adductor strength is a known risk factor for groin injuries in sport.[13,50] Current groin pain,[31] and older age have been shown to reduce hip adductor strength values in athletes.[51] However, it is unknown whether suffering from groin pain in the previous season, and its duration, may influence hip adductor strength in the next pre-season.

Several methods for measuring hip adductor strength have been described in the literature.[52–54] Both the short- and the long-lever hip adductor squeeze test, measuring strength isometrically with a hand-held dynamometer, are among the most widely used.[13,31,50] In Paper III, we found that players who suffered from past-season groin pain for more than 6 weeks, and increasing age, had reduced short- and long-lever hip adductor squeeze strength pre-season values. Importantly, this influence was still significant even when considering the presence of current groin pain. This is supported by previous findings from Thorborg and colleagues,[4] showing that players with a groin pain duration of more than six weeks, in the previous season, displayed the lowest HAGOS scores at the beginning of the new season. These findings reveal that the duration of groin pain in the previous season is an important factor to consider, as it may negatively influence hip adductor strength in the next season. The reduced hip adductor strength seen in players with longer durations of groin pain, may partly explain the higher presence of groin symptoms and sporting limitations among these players at next pre-season, seen in previous studies.[4] Players suffering from groin pain for more than six weeks in the previous season, are more likely to develop a high groin-injury risk profile, including previous injury and reduced hip adductor strength.

Studies investigating hip adductor strength as a risk factor for groin injuries in male footballers show opposite findings.[21,55,56] Differences between previous studies investigating this factor may be explained by the variety of devices and testing procedures used for strength assessment. In addition, in previous studies the presence of current groin pain is not considered,[21,55,56] even though it has been shown to reduce hip adductor strength.[31,57] In Paper IV, we showed that the association of the short-lever squeeze test with a future groin problem was lower compared to the long-lever squeeze test. This indicates that strength outputs obtained using longer levers provide most valuable information when assessing the risk of future groin problems. In this line, Engebretsen and colleagues found that players clinically diagnosed with weak hip adductor muscles, after performing unilateral long-lever squeeze tests, had 4 times (4.3 OR; 95% CI 1.31 -14.0) higher risk of a new groin injury compared to stronger players.[21] An Australian study found that combining data from both the short- and the long-lever squeeze test obtained from a field-testing device, players with greater hip adduction had reduced odds (0.77 OR; 95%CI 0.50 - 1.00) of suffering a future hip and/or groin injury.[55] However, Mosler and colleagues reported no significant association between the short-lever isometric hip adduction strength and subsequent hip and/or groin injuries (1.22 HR; 95% CI 1.00 - 1.49).[56] In comparison to the short-lever, the long-lever test produces more force, and is more demanding on the hip adductor muscle group, and hence, more reflective of most football actions.[58,59]

Findings from Paper III and IV have useful clinical implications for risk factors screening, and in particular, for pre-season hip adductor strength assessment. These findings, however, may require some contextualization to facilitate their clinical applicability, which is detailed in the

following lines. In Paper III having had past-season groin pain for more than six weeks reduced the peak-torque value in the long-lever adductor squeeze strength only by a 15%, which is close to the minimal detectable change (MDC 14%) when values are obtained from one repetition. Importantly, this difference is increased by 1% per year increase in player age. These findings may be especially useful for amateur team settings in which a hand-held dynamometer is often unavailable. Asking two simple questions about player age and past-season groin pain duration may be sufficient to identify players with potentially low values in pre-season long-lever adductor squeeze strength, a known risk factor. In those setting in which hand-held dynamometry testing is feasible, hip adductor strength could be tested to confirm (or discard) the presence of a hip adductor strength reduction. If a large reduction is present in one trial, then repeating the test to obtain three measures would increase precision (MDC of three repetitions 7%) to facilitate clinical decisions.[53]

Paper III also shows that the short-lever squeeze test seems to be less influenced by past-season groin pain duration and player age. Having had past-season groin pain for more than six weeks reduced the peak-torque value in the short-lever hip adductor strength by 12%, which is further below the MDC of 19%. Consequently, at least an eight years difference (1% reduction per year increased) should be added to reach clinical relevance. In this line, findings from Paper IV indicate that the long-lever test seems more suitable for testing hip adductor strength in footballers when assessing for groin injury risk. The risk of experiencing a groin problem in the new in-season increases as lower the peak-torque value obtained from the long-lever squeeze test at pre-season. Importantly, this is independent of having had past-season groin pain, player age, and football exposure. The risk increases by 35% per unit (N·m/kg) decreased in the long-lever adductor squeeze test. In this case, it should be noted that from a standard long-lever peak-torque value of 2.8 N·m/kg, any reduction from 0.4 N·m/kg (14% risk increase) should be considered of clinical relevance, when values are obtained from one repetition.[53]

Finally, testing with a hand-held dynamometer offers great versatility, with the possibility of testing different muscle activation modes, and body positions, while still using long levers. Unilateral isometric tests are reliable and allow for determining between leg imbalances. Eccentric hip adductor tests showed excellent measurement properties,[60] and are very useful at detecting football players with adductor-related groin pain.[54] Interestingly, the study by Mosler and colleagues, showed that having lower than normal (1SD below mean) eccentric adductor strength was a significant risk factor for adductor-related groin injury (1.7 HR; 95% CI 1.0-3.0) in professional footballers. However, the bilateral squeeze test not only displays better discriminative capabilities compared to the unilateral test, but is also more time-efficient, which is very important when testing full football squads.

Hip and groin sporting function

In Paper IV, we investigated whether in-season hip- and groin-related sporting function, measured every fourth week using HAGOS (Sport) subscale, was associated with a future groin problem. Our results showed that HAGOS (Sport) subscale scores had no effect on the risk of groin problems (1.00 RR; 95% CI 0.99-1.01). This finding seems to be in line with a study by Engebretsen and colleagues that measured pre-season self-reported "Function in

sports" using the Groin Outcome Score (GrOS), a screening tool especially developed for this study.

However, previous studies investigating HAGOS scores as a risk factor in football codes showed opposite results to our study. A study in Gaelic football, showed that players with pre-season HAGOS (Sport) subscale scores below 87.5 points had 9 times higher risk of groin injury. Similarly, a study on professional football players, showed that players with higher pre-season HAGOS scores were 23% less likely (0.77 OR; 95% CI 0.62-0.96) to suffer a hip and/or groin injury in the subsequent season, compared to players with lower values. There are important methodological differences that may explain differences between these two studies and present findings, such as HAGOS registration frequency or statistical methods. In our study (Paper IV) HAGOS (Sport) was registered continuously during the in-season, whereas in these previous studies, it was collected at a single time point at baseline. Importantly, these two previous studies suggest that pre-season groin health may influence groin-injury risk in the subsequent in-season, but the presence of current groin pain at baseline was not considered. The HAGOS questionnaire was designed for grading hip and groin problems in physically active individuals,[34] and hence, capable of detecting athletes suffering from current groin pain.[31]

Differences in risk factors for groin problems with and without time loss

In Paper IV we also investigated potential differences in risk factors for groin problems with and without time loss. We found that having suffered from groin pain in the previous season was associated with an increased risk (2.60 RR; 95% CI 1.63-4.2; Prob 99%) of experiencing groin problems without time loss in the new season, but this association was not found for groin problems with time loss. As expected,[61] the number of groin problems registered with the time-loss definition was low in our study, with 35 time-loss groin problems reported by 245 players. Necessarily, this limited the statistical power to detect any difference in injury risk,[61,62] which may explain this difference, at least in part.

Additionally, this difference may also be explained by the particular and persistent nature that groin problems with a more gradual onset, such as groin pain, commonly present. The past-season injury form referred to groin pain irrespective of time loss, as did the groin pain surveys administered every four weeks over the season. Then, it seems plausible that both registrations captured groin problems from a similar nature, likely with a gradual onset (i.e. due to overuse). Interestingly, this finding may add to the insight that groin problems with a gradual onset and groin problems with an acute onset seem to differ aetiologically.

Interestingly, we found that the association of age was higher with groin problems without time loss (1.05 RR; 95% ICr 1.00-1.11; Prob 96%) compared with groin problems with time loss (1.02 RR; 95% ICr 0.94-1.16, Prob 66%). Our results suggest, therefore, that older age may be more relevant in the case of groin problems with a more gradual onset. However, the possibility of a longer history of groin problems with an older age, and the influence of age on hip adductor strength,[51] both need to be considered when interpreting this factor.

Groin-injury prevention: when, and how to intervene

The overall aim of this thesis was to broaden knowledge to better prevent groin problems in male football players. Based on present findings, the application of measures to prevent these problems is discussed in this section.

Current evidence suggests that common pre-season football practice in itself may be protective against in-season groin problems. We showed that prevalence of groin problems is reduced by half from pre- to in-season, without the initiation of any controlled preventive intervention (Paper II). This is supported by previous findings from Harøy and colleagues.[2] This reduction in the prevalence of groin problems may be due to an increase in the level of sport-specific adaptions,[13] as a result of the gradual exposure to football demands accomplished during pre-season. Importantly, the in-season prevalence of groin problems can be further reduced by an early implementation of a preventive intervention focusing on strengthening hip adductor muscles.[2] A single-exercise approach using the Copenhagen Adduction exercise through multiple levels of difficulty, and as part of a regular warm-up, is able to reduce the risk of reported groin problems by 41%. A more intensive Copenhagen Adduction exercise dosage at pre-season seems key to explain the effect of this programme.[2] In conjunction, these findings highlight the importance of football pre-season in increasing player resilience against in-season groin problems, and in preparing for in-season optimal performance.

Targeting hip adductor muscles, therefore, seems important to reduce the prevalence of groin problems. In Paper IV, low hip adductor strength was associated to an increased risk of in-season groin problems. Hip adductor muscles are commonly involved in football actions, such as kicking.[58,59] Adductor-related is the primary clinical entity among male football players with groin pain.[17,18,63] The potential preventive effect of including specific adductor strength training into more extended programmes was identified in our systematic review on prevention of groin injuries in sport (Appendix I).[61] Pooled data from two studies on male football revealed a 22% (0.78 RR; 97% CI 0.49 to 1.25) risk reduction, but estimates were not significant. Even though these two studies included a variety of exercises for strengthening hip adductors, including different activation modes, and in coordination with abdominal muscles,[39,64] the intensity of these exercises might not have been sufficient.[61]

More comprehensive exercise-based interventions aimed at preventing various football injuries, such as the FIFA programmes, show inconsistent results for groin injuries in male football.[65–68] The efficacy of the FIFA 11+ programme is limited to one study showing a 40% (0.50 RR; 95% CI 0.37 to 0.98) reduction in the incidence of groin injuries.[66] Interestingly, the FIFA 11+ programme does not contain any specific exercise targeting hip adductor muscles.[69] In contrast, the FIFA 11+ includes different exercises on coordination, plyometrics, and abdominal muscles, which may improve strength and coordination of the muscles acting on the pelvis.[70] However, including the Copenhagen Adduction exercise as part of the FIFA 11+ seems advisable, as it provides missing hip adduction strength gains,[69] and therefore, could result in a further preventive effect. Importantly, settings adopting multicomponent preventive programmes should consider that compliance is a key factor for success,[2,64,66] as well as a

barrier for implementation.[71] The length of the programme,[64,72] but also the implication of medical and coaching staffs are important factors to be considered.[73–75]

We found a higher weekly prevalence of groin problems during pre-season, compared to in-season (Paper II). Harøy and colleagues, also found a higher prevalence of groin problems at the beginning of the season,[2] as well as during a period of match congestion.[3] These data document that the prevalence of groin problems is phase-dependant in male football, with a higher presence of groin symptoms when players are exposed to higher football loads. Wollin and colleagues showed that isometric hip adductor isometric strength, a known risk factor, is reduced >15% during higher football loads in elite youth players.[35] Monitoring of groin health, thus, seems even more relevant during periods in which a high prevalence of symptoms is expected.[4,35] Monitoring long-lever adductor squeeze strength and HAGOS may allow an early detection of existing problems,[35] which is crucial for optimal management before the problem deteriorates.[76] The five-second squeeze test with the traffic-light approach proposed by Thorborg and colleagues could provide a quick-screening alternative.[77] Increasing coaches' awareness of the presence of complaints, such as pain, may facilitate the management of symptomatic players,[35,44] as well as paying greater attention to optimal progression of football loads.

In Paper IV, we found that having suffered from groin pain in the previous season increased the risk of experiencing a groin problem in the new in-season. In Paper III, we found that players with longer durations of groin pain in the previous season showed reduced hip adductor strength at the next pre-season. It is therefore not surprising that football players are at high risk of carrying their groin problems from one season to the next.[4,57] Prescribing exercise interventions during the off-season period, and focusing on adductor muscles seem urgent for these players as they will present a high-risk groin injury profile including, at least, history of groin pain and low hip adductor strength. The Hölmich protocol includes different hip adductor exercises and is effective for treating long-standing groin pain cases.[70] Hip adductor strength could be further developed by including exercises with minimal or no equipment, such as using elastic bands,[78] or performing the Copenhagen Adduction exercise.[79] The off-season break also provides the opportunity to implement more comprehensive strength and conditioning programmes, including strengthening exercise for the adductors but also sports-specific training, which could be effective in reducing the risk of future injury in players with a high-risk profile. Although this approach has been shown to be effective in ice-hockey players,[80] its effectiveness and feasibility remain unknown in football.

Methodological considerations and limitations

In the present thesis we combined the use of a written groin pain surveys (Appendix III) together with the traditional time-loss injury registration method to document the true extent of groin problems in male football. Frequent contact with team physiotherapists and players led to a high rate of response (ranging: 73% to 95%) to the survey, which we consider a major strength. The written groin pain surveys used in the present studies was able to detect 10 times more injuries than the traditional time-loss registration, in which injuries are commonly recorded by medical staff (Paper I). Although a direct comparison between these two methods is difficult, as they not only propose two different definitions, but also two different registration methods, this approach has been successful in illustrating the need for a paradigm shift in groin injury surveillance.

However, we were not able to report specific diagnosis for groin injuries, according to the Consensus Agreement adopted in Doha, Qatar, during the 1st World Congress in Groin Pain (Weir). Although this would have been desirable, it would have required standardized and reliable examinations that would have put too much work load on team physiotherapists, considering that most of them were unpaid, or only minimally paid by clubs. We adopted, therefore, the term “groin problems”, as used previously to record self-reported injuries covering different complaints.[2,3,20,30]

In Papers I and II, we used the total number of players participating in the study at the requested week as denominator to calculate prevalence proportions. In the Norwegian study, investigators used the number of players who answered the OSTRC questionnaire; hence, our estimates might be more conservative. However, this is unlikely to explain differences with previous observations, as response rates ranged from 70 to 97% in the Norwegian studies.[2,3]

We calculated time-loss groin injury incidence in Papers I and II, as the number of new groin injuries divided by the total player time at risk.[81] Due to two teams failing to collect individual exposure, player time at risk was calculated using weekly team exposure (training and matches). Player time at risk (total exposure), was calculated as the sum of weekly team exposures (training and matches) by the number of players participating in each team in each week. As some players participated in the study for a few weeks, we consider that this approach results in a more correct estimation than by just multiplying total team exposures by the number of players who participated in the study. Such an approach would be likely to result in a large overestimation of the total exposure, thereby underestimating the incidence of injury. In Paper IV, however, we preferred to calculate individual exposure for all players. Exposure to football was included as a covariate in all models estimating relative risk of future groin problems. From the two teams without this data, we estimated individual exposure by subtracting time loss due to injury from team exposure reports. Since, most of the players participating were paid some amount, absence from training or matches due to reasons other than injury was rare.

In Paper IV, we chose to perform multivariate models to estimate the relative risk of future groin problems. Multivariable techniques allow the potential effect of different variables to be

controlled simultaneously.[62,82] Sports injuries have a multifactorial nature in which potential risk factors interact together.[1,62,82,83] In the literature, different model-building methods have been proposed to determine which variables should be included in the optimal model. It is often thought that the decision is based on statistical significance. A common approach is to use univariate analyses to determine which variables should be included in a multivariate model. The problem is that some variables might not be significant in a univariate association, due to a sample-size problem or a low injury rate.[62] If that were the case, non-significance variables would not be included in the final model, omitting that factors may work together to interact producing greater or lower risk.[84]

Our studies were conducted on football teams, and therefore, players were clustered around these teams. Teams, but also players may present particular known (i.e. team playing level, player age) and unknown (i.e. team training methodology, player behaviour) characteristics that may act as potential confounders when assessing risk of an outcome. Whenever possible we modelled team, player and also week as covariates, although this was subordinate to parsimonious principle. Comparisons in HAGOS (Sport) subscale scores were performed using Linear Mixed Models (LMMs); in Paper I player and team were included as nested random effects, while in Paper II, player was considered as random effect. In Paper IV, all multivariate models included team and player as covariates.

We estimated RR for future groin problems using a two-part model,[85] as groin problems included two dependent variables, time-loss groin injuries and groin pain episodes irrespective of time loss. These parts (that is, the models for each of the two dependent variables) could have been estimated separately. The problem with this approach (in fact, with all the approximations in several stages) is that when the two parts are not independent, the error, inherent in the estimation, committed in one part is dragged to the other part. If that error is random, the estimators would be unbiased but inefficient. That is, the confidence intervals would be very wide and it would be difficult to find statistically significant associations. However, if the error is not random, for example, when one of the parts of the model is not well specified, the estimators would be biased and their variances would be poorly calculated. We preferred, therefore, to estimate the two parts together.[85]

Given the complexity of this model, we estimated RR within a Bayesian framework, following the Integrated Nested Laplace Approximation (INLA) approach. The Bayesian approach allowed an easier fit of the model, handling variables with different distributions. Beyond Bayesian-Frequentist debate, which is outside the scope of the present work, there are some implications affecting interpretation that need to be mentioned. In a Frequentist approach, we make assumptions and estimate parameter to generate measures of uncertainty (i.e. standard errors, confidence intervals). From these, we can make statements about performance of estimator over repeated sampling (i.e. inference), that is, over repeated runs of the experiment (i.e.: 95% confidence intervals). In a Bayesian approach, all inferences (i.e. point estimates and interval estimates) are from a joined posterior distribution, which is the conditional distribution of uncertain quantity given the data. Posterior distribution is obtained from calculating the renormalized pointwise product from an assumed prior distribution and the likelihood function. Thus, the choice of the prior distribution of the model's parameters (i.e.

priors) have consequences on the results. We used priors that penalize complexity (PC prior)[86] defined in the INLA package,[87] which have been shown to be very robust.

This research project was conducted on a convenience sample of 17 male amateur teams. We acknowledge, therefore, that this may impact generalization of the present findings. However, we invited teams from similar football levels following a predefined list, based upon geographical criteria. In addition, none of the invited teams refused to participate. We consider, thus, the present sample to be representative of the target population of amateur male footballers, and that our results would rarely have differed using a random sample.

The risk of recall bias is present in different methods of the present project. Firstly, time loss due to groin injury was collected by team physiotherapists. Although we instructed them to register injuries and their characteristics as closely as possible to the time of occurrence, our control on this aspect was limited. Team physiotherapist attendance to trainings ranged from two days a week to daily (every training session), plus match at the weekend. We cannot ensure, therefore, that injury registration was delayed. To reduce this potential source of bias, a member of the research team contacted team physios frequently, at least once a month, to encourage them to continuously register. Present estimates on injury rate are similar to previous epidemiological studies,[14] and therefore, any potential bias due to recall was minimal. Secondly, we used retrospective information on past-season groin pain and its duration.[88] To minimize recall bias, the baseline questionnaire (Appendix II) included a limited number of questions with clear definitions, referring exclusively to the past season.[89] If present, however, recall bias seems to commonly tend to underestimate the prevalence of pain. Thirdly, the risk of recall bias is also present in the use of a retrospective groin pain survey successively during the football season. We used a written groin pain survey, asking players to recall from one to up to four weeks earlier whether they had suffered or not from groin pain during a specific week to estimate the weekly prevalence of groin pain. Importantly, we found that there was no difference in the weekly prevalence of groin pain when collecting information on groin pain every week, or every fourth week in our study. To minimize recall bias, all written groin pain surveys included information on match features, and a team physio or a researcher was available to address any doubts. Although we acknowledge that collecting information daily would have been optimal, we considered this unfeasible during a 44-week follow-up period.

Two teams did not have a physiotherapist, and one member of the research team was responsible for injury data collection. The researcher acting as team physiotherapist performed a similar role as a team physio, visiting teams at least twice a week, participating in return to play decisions and providing treatment and advice in case of injury. The only difference was that the researcher acting as team physiotherapist did not attend matches. We do not consider this as an important limitation as injuries sustained during matches were assessed and recorded in the next few days (1-2 days). In addition, we do not believe that the fact that a member of the research team was involved in injury data collection could have significantly influenced injury rate due to lack of trust from players (underreporting) or closer attention to injury collection. Only two teams out of seventeen (12%) had a researcher acting as physio, and overall injury rates in included studies were very similar to previous publications in the field.

We used a Spanish version of HAGOS (Appendix IV) for registering hip- and groin-related sporting function, whose measurement properties, including validity, reliability, and responsiveness, have not yet been evaluated. This Spanish version was previously translated and cross-culturally adapted from the original Danish and English versions according to the existing guiedelines.[90] Importantly, this process included testing a preliminary Spanish HAGOS on male football players, whose characteristics perfectly match with participants in the present project. Details of the translation and cross-cultural adaptation process can be seen at: www.koos.nu. Measurement properties of the Spanish version of HAGOS used in the present project is currently in the process of being validated with the collaboration of the present candidate.

Conclusions

- The traditional time-loss definition of injury has only captured a small fraction of the true extent of groin problems, as most players continue playing despite experiencing pain and limitations in their sporting function. This documents that previous studies using solely the time-loss approach, have underestimated the magnitude of this problem, which calls into question the adequacy of this measure in the case of groin injuries.

- We found a two-fold higher weekly prevalence of groin problems during the pre-season compared to the in-season. This difference was due to a higher prevalence of groin problems without time loss in pre-season, compared to in-season, but no difference in the prevalence of groin problems with time loss.

- Players who suffered from groin pain in the previous season for more than six weeks showed lower hip adductor squeeze strength at the next pre-season, compared to players without groin pain in the previous season, and this was irrespective of the presence of current of pain and player's age. Increased age reduced hip adductor strength in both the short- and long-lever squeeze test.

- Having suffered from groin pain in the previous season, and lower pre-season long-lever hip adductor squeeze strength were both associated with an increased risk of in-season groin problems. We found no association with pre-season short-lever squeeze strength, player's age, and in-season HAGOS (Sport) subscale scores.

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Appendices

Prevention of groin injuries in sports: a systematic review with meta-analysis of randomised controlled trials

E Esteve,[1] M S Rathleff,[2,3] C Bagur-Calafat,[1] G Urrútia,[4] K Thorborg[5,6]

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[1]Department of Physical Therapy, Universitat Internacional de Catalunya, Barcelona, Spain
[2]Department of Occupational Therapy and Physiotherapy, Aalborg University Hospital, Aalborg, Denmark
[3]Department of Health Science and Technology, Center for Sensory-Motor Interaction, Aalborg University, Aalborg, Denmark
[4]Iberoamerican Cochrane Centre, Sant Pau Biomedical Research Institute, Barcelona, Spain
[5]Faculty of Health Sciences, Sports Orthopedic Research Center, Arthroscopic Centre Amager, Amager-Hvidovre Hospital, University of Copenhagen, Copenhagen, Denmark
[6]Physical Medicine and Rehabilitation—Copenhagen (PMR-C), Amager-Hvidovre Hospital, Copenhagen University Hospital, Copenhagen, Denmark

Correspondence to
E Esteve, Department of Physical Therapy, Universitat Internacional de Catalunya, Josep Trueta s/n, Sant Cugat del Vallés, Barcelona 08195, Spain; ernest.esteve@uic.es

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ABSTRACT

Background/aim Groin injuries are common in football and ice hockey, and previous groin injury is a strong risk factor for future groin injuries, which calls for primary prevention. The aim of this systematic review was to evaluate the effect of specific groin-injury prevention programmes in sports.

Methods A comprehensive search was performed in May 2014 yielding 1747 potentially relevant references. Two independent assessors evaluated randomised controlled trials for inclusion, extracted data and performed quality assessments using Cochrane's risk of bias tool. Quantitative analyses were performed in Review Manager 5.3.

Results Seven trials were included: six on football players (four male and two female populations) and one on male handball players. In total there were 4191 participants with a total of 157 injuries. The primary analysis, including all participants, did not show a significant reduction in the number of groin injuries after completing a groin injury prevention programme (relative risk (RR) 0.81; 95% CI 0.60 to 1.09). Subgroup analysis based on type of sports, gender and type of prevention programme showed similar non-significant estimates with RR ranging from 0.48 to 0.81.

Conclusion Meta-analysis revealed a potential clinically meaningful groin injury reduction of 19%, even though no statistical significant reduction in sport-related groin injuries could be documented.

Trial registration PROSPERO registration ID CRD42014009614.

INTRODUCTION

Groin injuries represent 5–10% of all sports injuries.[1–4] They are highly prevalent in sports requiring kicking, high-speed direction changes and/or skating motions. In these sports groin injuries account for 10–23% of all injuries.[5–10] In football and ice hockey, groin injuries have an incidence of 1.1/1000 h exposure[9] and 1.3/1000 players exposure,[11] respectively, during a regular season. The hip adductors are the most commonly injured muscle group in sports-related groin injuries.[9–12] This is likely due to the eccentric forces stressing the muscle–tendinous complex during side-to-side cutting, kicking and powerful skating.[13 14] Groin injuries seem to be less frequent in female compared with male football players.[4 15 16] In men, more than 50% of groin injuries are classified as moderate or severe at elite level,[9 17] resulting in substantial periods of absence from football play. Recent studies showed that the prevalence of hip and groin pain during a season can be up to 70%,[18 19] suggesting that time-loss injury incidences represent the tip of the injury iceberg, with many athletes often continuing to play, but with pain.[20]

A previous history of groin injury[11 17 21] or hip adduction strength deficits[22–24] has been identified as a significant risk factor for a new groin injury. Groin injury prevention consists of active strength and coordination exercises, with emphasis on the adductor and abdominal muscles,[22–26] as these are modifiable risk factors.[21 27] An exercise programme including strengthening and coordination exercises for adductors and muscles around the pelvis has also been demonstrated to be effective in treatment of long-standing groin pain.[28] Similarly, a preseason adductor strengthening programme appeared to reduce the incidence of adductor strains in a group of professional ice hockey players.[29] Therefore, it seems reasonable to assume that groin injuries in sports may be prevented through specific prevention strategies targeting relevant risk factors and mechanism of injury despite the fact that this seems to remain unproven in randomised controlled trials.

Preventing groin injuries in sports such as football and ice hockey is of great importance, since these injuries induce substantial disability and loss of playing time, injury-related costs[30] and an increased risk of reinjury[9 17 21] and chronicity.[9 28 31] However, to the best of our knowledge, no systematic review or meta-analysis on the prevention of groin injuries in sports has been published to date. The aim of this systematic review was to evaluate the effect of specific groin-injury prevention programmes in sports.

METHODS

Search strategy

EMBASE, MEDLINE, SPORTDiscus, LILACS, PEDro and Cochrane Central Register of Controlled Trials were electronically searched from January 1970 to May 2014. A hand-search of the reference lists of relevant articles was also conducted for other potential relevant references. A review protocol was developed according to the PRISMA[32] recommendations and published in the PROSPERO database (http://www.crd.york.ac.uk/PROSPERO/display_record.asp?ID=CRD42014009614). The search strategy was constructed and followed the PICO approach (Population, Intervention and Outcome). Search terms were mapped to each component of the PICO and connected with Boolean operators adapted to the individual databases. When possible, filters for randomised controlled trials were applied. The

complete search strategy can be seen in online supplementary web-appendix 1.

Inclusion and exclusion criteria

Data from randomised and cluster-randomised controlled trials were included. We included studies with athletes that reported the incidence of groin injuries as an outcome. Only full text trials in English were considered. Studies conducted in army recruits were excluded.

Review process

Titles and abstracts identified in the search were downloaded into EndNote X7 (Thomson Reuters, Carlsbad, California, USA); cross references and duplicates were deleted. All publications potentially relevant for inclusion were independently assessed for inclusion by two reviewers (EE and KT) and full texts were obtained, if necessary. Any discrepancies were resolved during a consensus meeting, and a third reviewer was available (CB), if needed.

Data extraction

Two reviewers (EE and KT) independently extracted data using a specifically designed standardised form. General study information, participants and intervention characteristics, compliance, withdrawals and outcome measures were extracted. If data were not available from tables or the result section, the authors were contacted. If the authors did not have access to their data, data on outcome were extracted from figures and graphs. Whenever possible, results from the intention-to-treat population were used.

Assessment and risk of bias

The studies included were assessed for the risk of bias by two independent raters (KT and EE), with any disagreements resolved by consultation with a third party (GU). An assessment of the methodological quality was not performed, as no evidence for such appraisals and judgments exists and therefore can be misleading when interpreting the results.[33] The use of quality scales and summary scores is considered problematic, due to considerable variations between items and dimensions in scales covered, with little evidence relating to the internal validity of these assessments.[34] The risk of bias assessment was done using the Cochrane Collaboration's tool for assessing risk of bias in randomised trials.[33] The trial was evaluated across six domains of bias, including one or more items that were appraised in two parts. First, the relevant trial characteristics related to the item were summarised. Second, each bias domain was judged as high or low risk of bias, according to its possible effect on the results of the trial. When the possible effect was unknown or insufficient detail was reported, the item was judged as unclear. When we assessed risk of bias in cluster-randomised trials, particular biases were included in the 'other bias' domain, as assessing risk of bias in cluster-randomised trials is recommended in the Cochrane Handbook for Systematic Review of Interventions, V.5.1 (Part 3: 16.3.2).[33]

Study analysis

Relative risk (RR) and 95% CIs were estimated as relative effect size using the extracted data. In the analysis of cluster randomised controlled trials, we used the intracluster correlations coefficient (ICC) from the trials to adjust for a potential cluster effect. If the authors did not report the ICC we used the ICC from similar trials.

Data synthesis

Review Manager V.5.3 (Copenhagen: The Nordic Cochrane Centre, The Cochrane Collaboration) was used to calculate RR. A forest plot was used to allow easy visual comparisons between studies. The level of statistical heterogeneity for pooled data was established using the χ^2 and I^2 statistics. The χ^2 and I^2 statistics describe heterogeneity or homogeneity of the comparisons with $p<0.05$, indicating a significant heterogeneity.[35] A fixed-effect model was used when studies were statistically homogeneous. The Mantel-Haenszel[36 37] method was selected as default option. This method has been recommended when there are low event rates.[33] If studies were statistically heterogeneous, the Mantel-Haenszel[36 37] random-effects model was applied. Sensitivity analyses were planned on the primary outcome, focusing on methodological quality and risk of bias assessment. We considered aspects such as: allocation concealment, outcome assessor blinding, incomplete data, selective reporting and other bias.

Analysis of subgroups or subsets

Possible interactions between groups were evaluated using the technique outlined by Altman and Bland.[38] Relations sustained on type of sports, gender and type of preventive programmes were assessed.

RESULTS

Search results

The initial search identified 1747 unique references (figure 1). After exclusion by title and abstract, 33 were read in full text. From the 33 articles, 26 were excluded. The most common reason for exclusion (15 studies) was that studies did not report the incidence of groin injuries in isolation. Eleven studies were not RCTs and were therefore also excluded. Finally, seven studies were included.

Description of studies

The most relevant characteristics of the seven included studies are summarised in table 1. For detailed information on study design, participants, exposure and statistics see online supplementary web-appendix 2. Six studies were cluster-randomised controlled trials, where teams or clubs were the unit of randomisation, while one study performed randomisation at the individual level. In total, the included studies involved 4648 participants. Three studies reported exposure data.[39–41] Among cluster-randomised trials, one study was adjusted for clustering effects, reporting an ICC value equal to zero.[42] Compliance reports were not specified according to prescribed or optimal dosage (see table 1) and only three studies reported intention-to-treat data.

Time-loss groin injury definition was used in six of the seven included studies,[39–41 43–45] while the last study used time-loss as well as medical-attention definitions.[42] The authors of two studies were contacted to provide extra data for exposure, age of participants and number of groin injuries.[42 43] Data from van Beijsterveldt *et al*[43] were obtained, but exposure data from Hölmich *et al*[42] were not available. Results of the risk of bias assessment are presented in meta-analysis figures (figure 2A–F). Specific justification for each assessment is included in online supplementary web-appendix 2.

Total estimate

In total, 4191 players were included in the primary analysis. For the primary outcome, number of groin injuries in the control

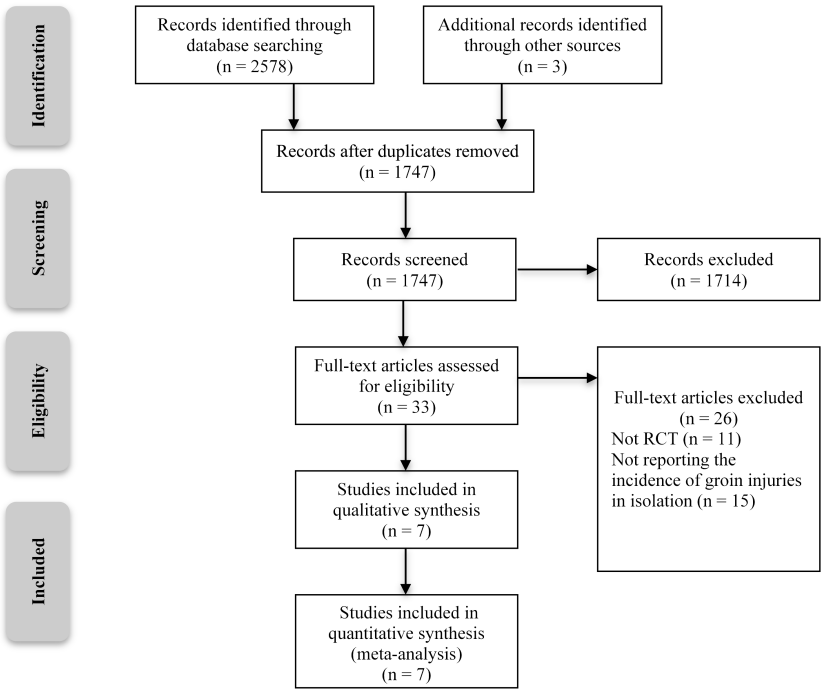


Figure 1 Flow chart of included studies.

group versus the intervention group, the effect estimates based on 157 injuries (figure 2A), was RR 0.81 (95% CI 0.60 to 1.09; I^2=7% χ^2 p=0.37).

Type of sport analysis

The study on handball players did not report any groin injuries.[45] The subgroup analysis on type of sport (figure 2B), therefore, included the remaining six football studies,[39–44] which showed an effect estimate of RR 0.81 (95% CI 0.60 to 1.09; I^2 =7% χ^2 p=0.37).

Gender analyses

A gender specific subgroup analysis of two football studies conducted among female players, including active exercise programmes (figure 2C),[41 44] showed an estimate of RR 0.48 (95% CI 0.20 to 1.13; I^2 =46% χ^2 p=0.17). Pooled data from the three football studies, including active exercise programmes, performed among men (figure 2D),[40 42 43] showed an effect estimate of RR 0.84 (95% CI 0.60 to 1.18; I^2 =0% χ^2 p=0.57).

Type of preventive programme analyses

An active adductor strength programme was tested in two studies,[40 42] with a pooled effect estimate (figure 2E) of RR 0.78 (95% CI 0.49 to 1.25; I^2 =0% χ^2 p=0.34). 'The 11' preventive programme (figure 2F) was tested in two trials,[41 43] with a pooled effect estimate of RR 0.68 (95% CI 0.40 to 1.14; I^2 =55% χ^2 p=0.13).

DISCUSSION

The aim of this systematic review was to evaluate the effect of specific groin-injury prevention programmes in sports. No statistical significant reduction in sport-related groin injuries could be documented. Meta-analysis revealed a potential clinically meaningful groin injury reduction of 19% (RR 0.81; 95% CI 0.60 to 1.09).

Subgroup analyses

Football

An identical non-significant estimate was identified in the subgroup analysis in football players (RR 0.81; 95% CI 0.60 to 1.09). Five of the six studies conducted on football players assessed the efficacy of active exercise strategies to prevent groin injuries.[40–44] The potential effect of such type of intervention was previously documented in a prospective study of ice hockey players at high risk,[29] but has never been tested in a randomised controlled trial. Nevertheless, in a randomised trial an active strengthening programme was very effective in the treatment of long-standing adductor-related groin pain in athletes.[28] Moreover, the effect of this therapeutic intervention was found to be long-lasting,[46] suggesting a possible secondary preventive effect.

Among the six studies conducted on football players, two studies[40 41] reported limited compliance. A deterioration of compliance during the season has been shown previously in football studies, which may affect the results, as higher compliance allows for better results in preventive interventions.[47 48] Compliance was very low in one study[40] of a home-prevention programme, where less than 20% of the participants completed 20 or more of the 30 planned sessions. It is important to consider that an active programme under supervision usually gives higher compliance and more benefits in strength and physical conditioning.[49]

Sex

The sex-specific subgroup analysis, including studies looking at active exercise programmes, showed a non-significant risk reduction of 52% among female football players (RR 0.48; 95% CI 0.20 to 1.13). In comparison, the analysis including male football players showed a non-significant risk reduction of 16% (RR 0.84; 95% CI 0.60 to 1.18). Although non-statistical, the apparent difference in estimates is interesting. We speculate that if this difference exists it could be because these programmes are

Table 1 Characteristics of the included studies

Study	Population	Intervention	Completion (players)	Compliance	Follow-up	Number of groin injuries	Conclusion
Arnason *et al*[39]	Football, elite, male (age not specified)	15 min presentation and video-based awareness. 2 h workshop in the respective clubs. Once only intervention	Intervention 127 Control 144	Not reported	1 season, 4 months	Intervention 7 Control 6	No significant difference was observed in the number of groin injuries (χ^2: z=0.50)
Van Beijsterveldt *et al*[43]*	Football, amateur, male (18–40)	'The 11': 10 exercises for core stability, eccentric training of the thigh muscles, proprioception, dynamic stabilisation and plyometric with straight alignment. 10–15 min warm-up programme during regular practice	Intervention 223 Control 233	'The 11' was performed on an average of 1.3 per week of two per week that were prescribed, at least	1 season, 9 months	Intervention 20 Control 23	Not reported for groin injury
Engebretsen *et al*[40]†	Football, elite, male (age not specified)	Isometric adductor muscles exercises, transverse abdominal training, sideways jumping, sliding and diagonal walking. 15 min training session at home	Intervention 62 Control 98	19,4% of players completing 20 sessions or more out of how many prescribed	1 season including 10-week preseason	Intervention 11 Control 16	No significant difference was observed in the number of groin injuries (RR=1.18; 95% CI 0.55 to 2.54)
Holmich *et al*[42]*	Football, amateur, male (18–42.4)	Isometric and eccentric hip adductors strengthening, abdominal and hip flexors training, one leg coordination and stretching of iliopsoas muscle. 13 min as an integrated part of regular warm-up	Intervention 477 Control 430	Not reported	1 season, 42 weeks	Intervention 23 Control 30	No significant difference was observed in time to groin injury, 31% of risk reduction not significant (HR=0.69, p=0.18)
Soderman *et al*[44]	Football, female (age mean 20.4 intervention 20.5 control)	Balance board training. 10–15 min of home training	Intervention 62 Control 78	Performed on an average 65±19 times out of how many prescribed (≥70 times, 30 in preseason, 3× week in a 7 months season)	1 season, 7 months	Intervention 1 Control 0	Not reported for groin injury
Steffen *et al*[41]	Football, adolescent, young female (13–17)	'The 11': 10 exercises for core stability, lower extremity strength and neuromuscular control and agility. 10–15 min warm-up programme during regular practise	Intervention 1073 Control 947	Average player completed approximately 15 sessions. Once a week after 15 consecutive sessions in an 8 months season were prescribed	1 season, 8 months	Intervention 6 Control 14	No significant difference was observed in the number of groin injuries. Rate ratio 0.4 (CI 0.2 to 1.1)
Wedderkopp *et al*[45]	Handball, young female (16–18)	Ankle disk practise and functional activities for both lower and upper extremities. 10–15 min during training sessions	Intervention 111 Control 126	Not reported	1 season, 10 months	Intervention 0 Control 0	Not reported for groin injury

*Data provided by authors (number of groin injuries).
†Data from group of players at increased risk of groin injuries.

Esteve E, *et al*. *Br J Sports Med* 2015;**49**:785–791. doi:10.1136/bjsports-2014-094162

different in nature. Furthermore, groin injuries in women seem to be more related to hip joint and hip flexors,[12] and significant differences in kinematics and muscle activation have been identified between genders during single-leg actions or cutting manoeuvres.[50–53] It may be that women could obtain a better effect from preventive interventions focused on lower extremity alignment and neuromuscular control, as suggested by a possible large reduction in groin injuries among women, when initiating balance and coordination type exercises. Among male football players, groin injuries are often related to the hip adductor muscle group,[10 12] and hip adduction weakness seems to be a significant risk factor in this group of athletes.[23 24] Considering apparent hip strength[54] and coordination differences[50–53] between men and women, it seems relevant to consider in the future whether groin prevention approaches must be specifically adapted to sex in the future.

Type of preventive programme

A non-significant risk reduction of 32% (RR 0.68; 95% CI 0.40 to 1.14) in the number of groin injuries was identified in the subgroup analysis on type of preventive programme. The potential preventive effect of 'The 11' programme in reducing the risk of groin injuries in female football players was recently highlighted in a systematic review.[55] However, a revised

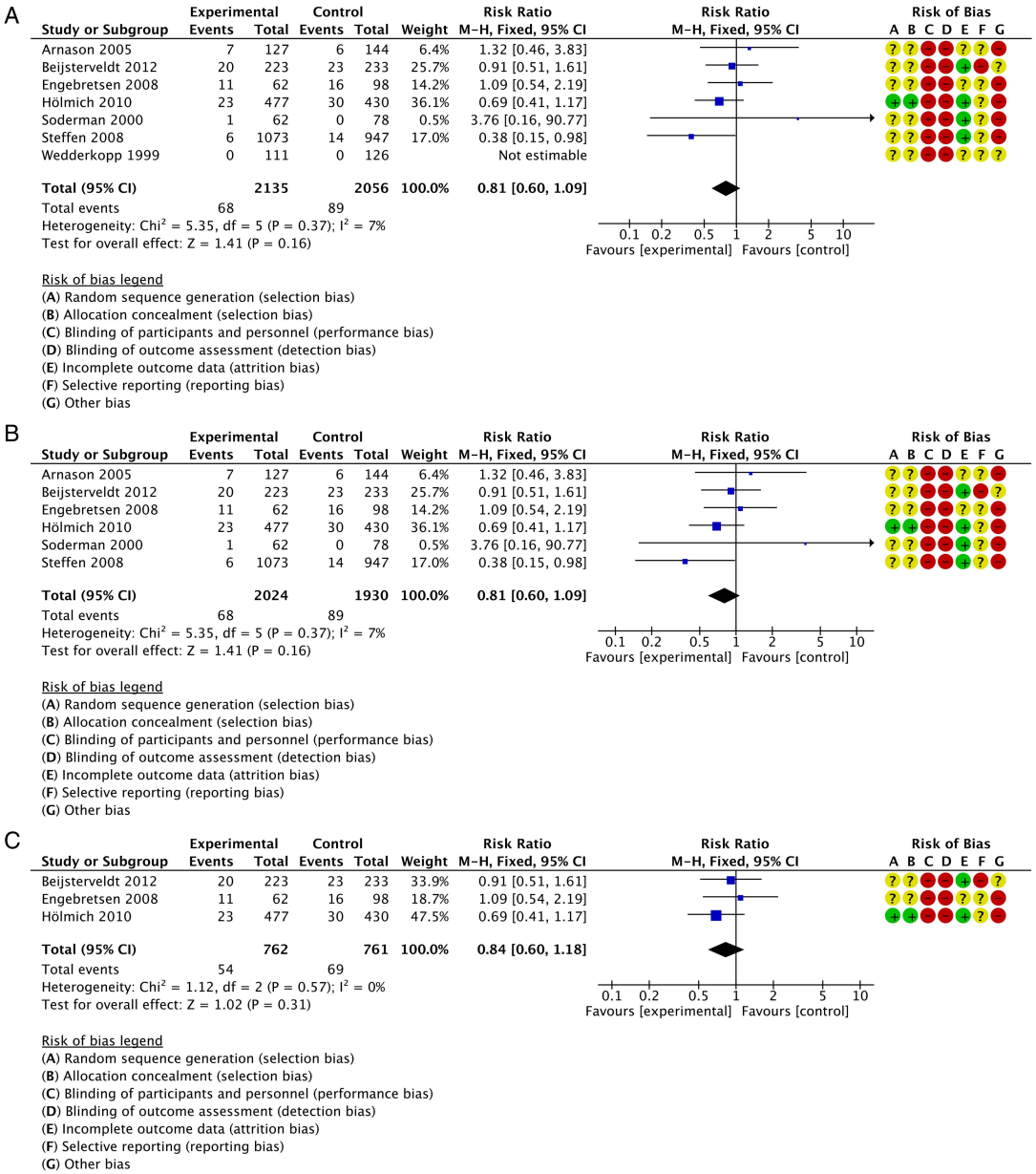
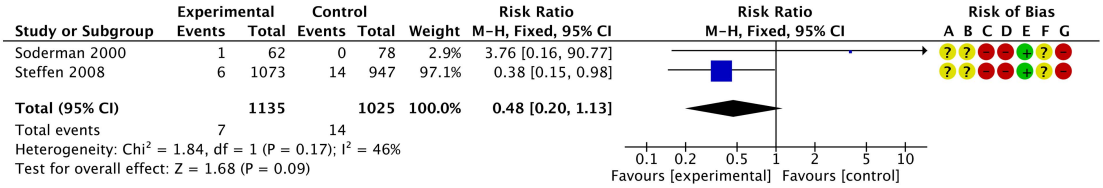


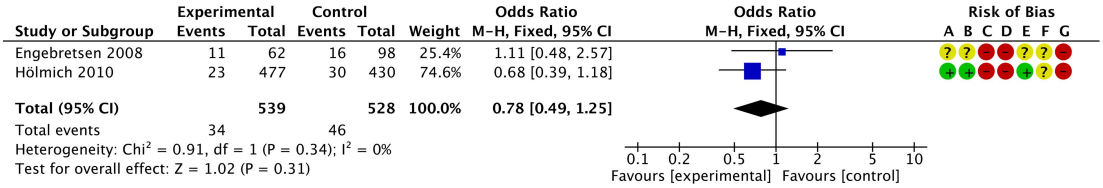
Figure 2 (A) Primary analysis including all seven studies. (B) Subgroup analysis based on type of sport. (C) Subgroup analysis based on gender (only women). (D) Subgroup analysis based on gender (only men). (E) Subgroup analysis based on type of preventative programme (active adductor strength programme). (F) Subgroup analysis based on type of preventative programme ('The 11').

D



Risk of bias legend
(**A**) Random sequence generation (selection bias)
(**B**) Allocation concealment (selection bias)
(**C**) Blinding of participants and personnel (performance bias)
(**D**) Blinding of outcome assessment (detection bias)
(**E**) Incomplete outcome data (attrition bias)
(**F**) Selective reporting (reporting bias)
(**G**) Other bias

E



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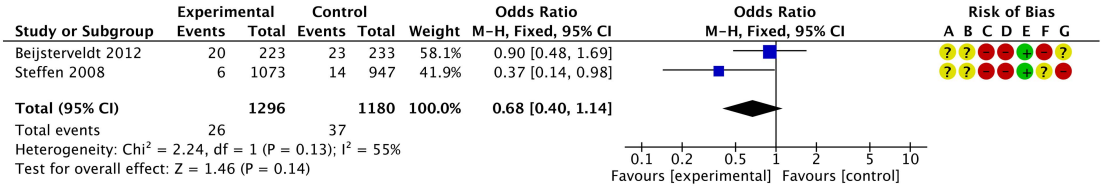

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(**F**) Selective reporting (reporting bias)
(**G**) Other bias

Figure 2 Continued.

programme, 'The 11+', including additional but very similar exercises to allow for variations and progressions, showed no effect on prevention of hip and groin injuries in young female football players.[56] Further, in the same study, only 19 hip and groin injuries were included, in approximately 1900 players during a football season, suggesting that this problem is either minor or severely underreported, providing insufficient power to produce robust estimates on hip and groin injury preventative effects in this study.[56]

Pooled data for the effectiveness of adductor strength programmes in male football revealed a non-significant risk reduction of 22% (RR 0.78; 95% CI 0.49 to 1.25). Exercises in these interventions included concentric and eccentric adductor muscle contractions in coordination with abdominal muscles to target hip adductor weakness.[23] We feel that the use of no or minimal equipment, such as elastic bands, progressing into more relevant contraction-specific exercise and positions,[57 58] could be more beneficial for hip-adductor strengthening as a preventative measure in male football.[24 57]

Risk of bias assessment

In the risk of bias assessment, we considered the seven studies included at high risk of bias concerning blinding of participants and outcome assessors. In these types of preventive studies consisting of active interventions and subjective outcomes, true blinding is considered impossible. Further, the injuries were reported subjectively and participants were aware of the outcome. Thus, the outcome assessors were dependent on the subjective report, which theoretically could be influenced by study participants. Lastly, in five of the six included cluster randomised trials, insufficient information was reported and studies were considered as unclear on selection bias. Despite the fact that all seven studies included had several methodological aspects displaying high risk of bias, no obvious methodological differences in terms of blinding, concealment allocation, outcome definition or study designs, were present between studies. Therefore, we considered the seven studies included to be sufficiently homogeneous to allow for a meaningful meta-analysis, providing the best available evidence.

Studies in the present review mainly included interventions based on active exercise strategies with the aim of improving hip/core strength, and/or lower limb balance and coordination exercises.[40–45] The only study with a different approach was the study by Arnason *et al*,[39] including a video-based awareness session in the respective clubs as a one-time intervention. Future studies may need to consider prevention strategies other than those aiming to improve hip/core strength and lower limb coordination. Regular physical screening and load monitoring in place of a sole preseason strategy have been suggested as a worthwhile strategy for early groin symptom identification and prevention.[59–61] Future randomised controlled trial studies concerning early groin symptom identification and load management strategies are needed to investigate the effect of this kind of groin injury prevention strategy.

Limitations

More than 4000 players were included in the meta-analysis. However, the total number of injuries was very low (157 groin injuries in total). The outcome (groin injuries) in these studies was rare and large studies with at least 4000 players in each group are required to detect a 20% reduction in the number of groin injuries assuming that 8% of the players develop a groin injury.[42] Unfortunately, all analyses in the present study are not sufficiently powered to statistically support the estimates provided, although they all suggest a reduced effect of different groin injury prevention strategies across different groups of athletes.

Owing to the lack of compliance reporting and specific definitions on compliant and non-compliant behaviour in the included studies, we believe that the estimates of the present study may, in fact, resemble the interventions' 'true' effectiveness (effect when applying intervention in real life), and not necessarily their efficacy (effect when applying intervention under controlled research conditions).[62] Three of the included studies[39 42 45] did not report information about compliance, and in the remaining four,[40 41 43 44] the participants did not perform the prescribed number of sessions. Above all, studies were not adjusted for compliance, meaning that the estimates are suggested to represent the intentions' effectiveness, and the efficacy of these interventions, at present, remains unknown.

An important limitation is that groin injury was not specifically defined in any of the included studies, and none of them reported the use of a standardised diagnostic protocol. Groin injury diagnosis is extremely challenging due to the possible multiple pathologies and overlapping symptoms.[12 63] It is known that the lack of consensus regarding injury definitions, diagnostic and standardised data collection procedures could influence the reported incidence of sports injuries.[64] Importantly, in six of the seven included studies, a time-loss definition was used.[39–41 43–45] When this definition is used one must take into account that minor injuries and/or especially overuse problems will not always be recorded. This will cause an underestimation of the total number of injuries. To avoid this problem, the use of questionnaires aimed at pain, function and sporting activity has been suggested for more detailed groin injury registration.[65] The Copenhagen Hip and Groin Outcome Score (HAGOS)[66 67] has previously been validated in athletes with and without hip and/or groin pain and should be considered in future evaluations of preventive interventions for sports-related groin injuries.

CONCLUSION

Meta-analysis revealed a potential clinically meaningful groin injury reduction of 19%, even though no statistical significant reduction in sport-related groin injuries could be documented. Insufficient statistical power from the included studies makes it difficult to provide firm conclusions on the effect of groin injury prevention.

What are the new findings?

- No statistical significant reduction in sport-related groin injuries could be documented.
- Estimates of groin injury reduction of 19–52% after implementing active groin injury prevention programmes, including specific exercise programmes, suggest that such an approach may be of clinical relevance and potentially worthwhile to consider in football players.
- Estimates concerning the efficacy of groin injury programmes in football are unknown as compliance and compliance reporting have been inadequately addressed in existing trials.

Twitter Follow Ernest Esteve at @EsteveErnest

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SPORTCLÍNIC
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REGION Amager Hospital

PMR-C

BASELINE QUESTIONNAIRE

Personal information

Today's date: _____/_____/_____	**Team**: _____
Name: _____	**Date of birth:** _____/_____/_____
Are you currently injured? ☐Yes ☐No	

Questions on groin injuries

1. Do you currently have groin pain (inguinal region including adductors, pubic etc.)?

   Yes ☐ No ☐

2. Did you suffer from groin pain (inguinal region including adductors, pubic etc.) during the **past season**?

   Yes ☐ No ☐

3. For how long did you suffer from groin pain (inguinal region including adductors, pubic etc.) during **past season**?

   0 days ☐ 1 week or less ☐ more than 1 until 3 weeks ☐ more than 3 until 6 weeks ☐ more than 6 weeks ☐

4. Have you previously suffered from groin pain (inguinal region including adductors, pubic etc.) **prior to the past season**?

   Yes ☐ No ☐

Annex 1 Supplementary file

GROIN PAIN 1-WEEK VERSION STRUCTURED SURVEY

Personal information

Today's date: _____/_____/_____	**Team**: _____
Name: _____	**Date of birth:** _____/_____/_____

This questionnaire asks about groin pain during **the past week**. Please, take your time to think about before you answer the question questions.

1. Did you have groin pain (inguinal region including adductors, lower abdomen and pubic region) during **the past week?**

Yes ☐ No ☐

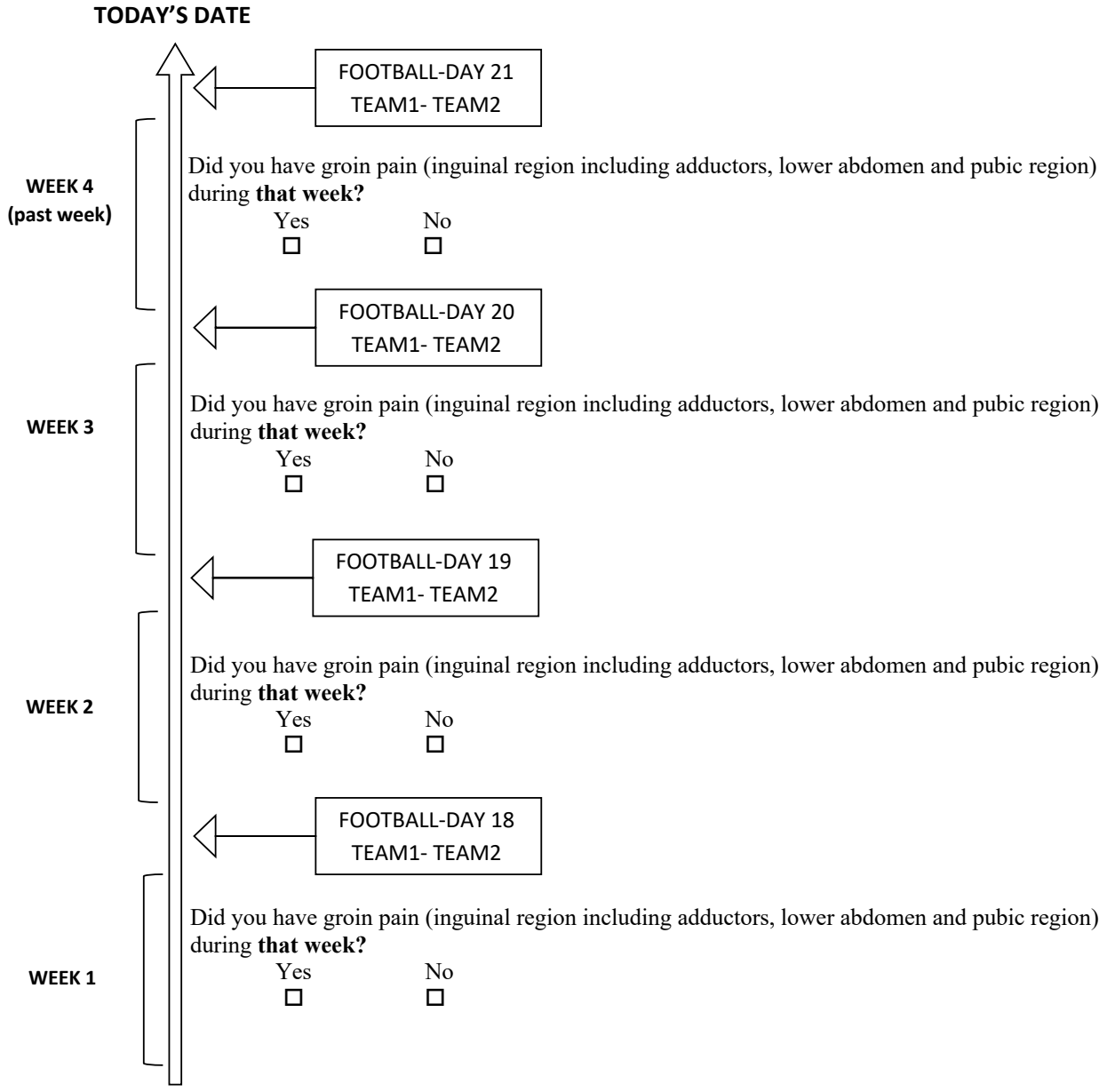
Note: the 1-week structured survey was used during the introductory study period in preseason and until the first official match in week 1. The survey was provided whether by team physiotherapist or a member of the research team, who were present and available for any doubt.

GROIN PAIN 4-WEEK VERSION STRUCTURED SURVEY

Personal information

Today's date: _____/_____/_____	**Team**: _____
Name: _____	**Date of birth:** _____/_____/_____

This questionnaire asks about groin pain during **the past four weeks**. Please, take your time to think about it before you answer the questions.



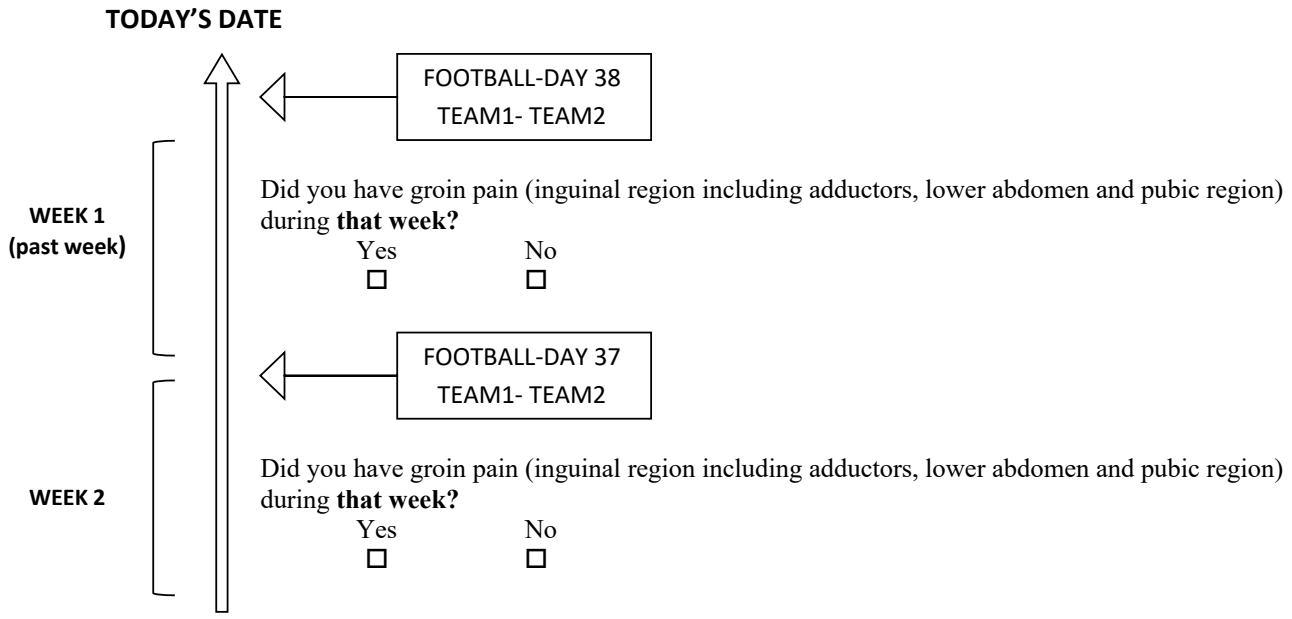
Note: the 4-week structured survey was used from week 2 until week 38. The survey was provided whether by team physiotherapist or a member of the research team, who were present and available for any doubt.

GROIN PAIN 2-WEEK VERSION STRUCTURED SURVEY

Personal information

Today's date: _____/_____/_____	**Team**: _____
Name: _____	**Date of birth:** _____/_____/_____

This questionnaire asks about groin pain during **the past two weeks**. Please, take your time to think about it before you answer the questions.



Note: the 2-week structured survey was used from week 38 until week 39. The survey was provided whether by team physiotherapist or a member of the research team, who were present and available for any doubt.

Spanish translation and cross-cultural adaptation of the Copenhagen Hip And Groin Outcome Score (HAGOS)

Esteve, E[1,2,3], Cordt, M[4], Cerdán, J[5], Thorborg K[2,3]
[1]Sportclinic. Physiotherapy and Sports Training Centre. Girona, Catalonia. Spain.
[2]Sports Orthopedic Research Center – Copenhagen (SORC-C), Arthroscopic Centre Amager, Copenhagen University Hospital.
[3]Physical Medicine and Rehabilitation – Copenhagen (PMR-C), Amager-Hvidovre Hospital, Copenhagen University Hospital.
[4]Clinica Institución Montebello, Nordsjællands hospital,.Benalmádena, Málaga. Spain.
[5]Optimov ApS. Porcelænshaven 26, 2000 Frederiksberg, Denmark.

Introduction: The Copenhagen Hip And Groin Outcome Score (HAGOS)[1] was developed as a Patient-Reported Outcome (PRO) questionnaire, in accordance with the COnsensus-based Standards for the selection of health Measurement INstruments (COSMIN) recommendations. Addressed to young to middle-aged physically active individuals with long-standing hip and groin pain, the HAGOS assesses across six separate subscales: Pain, Symptoms, Physical function in daily living, Physical function in Sport and Recreation, Participation in Physical Activities, and hip and/or groin-related Quality of Life (QOL). In the original version of the questionnaire, all six separate subscales showed to have adequate measurement qualities regarding validity, reliability and responsiveness[1].
Objective: To perform a translation and trans-cultural adaptation of the Hip And Groin Outcome Score (HAGOS) to Spanish, according to existing guidelines[2].
Design and Methods: Two forward translations from Danish and one from English into Spanish were independently performed by three bilingual translators, all with a health-professional background. The two Danish to Spanish versions were discussed and combined in a consensus meeting to provide a preliminary Spanish version. In case of disagreement or uncertainty of the wording the English version was included in the process of finding the correct and optimal wording. The preliminary consensus version was tested on physically active patients, with hip/groin problems, for wording understanding and comprehension by two health professionals. The testing procedure was performed in blocks of five patients until data saturation was achieved. This involved in total 15 patients with hip and/or groin pain (12 male, 3 female), mean age: 30.9 years (SD 10.3), range: 21-54 years. Any problem in completing the preliminary questionnaire because of language or understanding was registered and rephrasing was performed whenever necessary. A non-medical professional translator back-translated the preliminary Spanish version into Danish and the original author of the HAGOS compared the back-translation with the original Danish version. Comments from the original author were discussed with the translators and final adjustments were made to obtain a final Spanish version of the HAGOS.
Results: Minor discrepancies were found on a few items concerning wording, understanding and phrasing. After discussion in the group these were found to be small and they were solved by consensus with the originator. P3 and P4 were slightly rephrased due to minor linguistic differences, and in general terms used when rating degree of pain or difficulty were changed due to cultural differences.
Conclusion: Spanish HAGOS can be used to assess symptoms, activity limitations, participation restrictions and QOL in physically active, young to middle aged patients with long-standing hip and/or groin pain. However, measurement qualities, including validity, reliability, and responsiveness of the Spanish HAGOS should be evaluated in the future in a Spanish population.

1) Thorborg K, Hölmich P, Christensen R, Petersen J, Roos EM. The Copenhagen Hip And Groin Outcome Score (HAGOS): development and validation according to the COSMIN checklist. Br J Sports Med. 2011;45(6):478-91.
2) Beaton DE, Bombardier C, Guillemin F, et al. Guidelines for the process of cross-cultural adaptation of self-report measures. Spine 2000;25:3186–91.

Contact information regarding the Spanish version of HAGOS:
Ernest Esteve
Sportclinic. Physiotherapy and Sports Training Center. Girona, Catalonia. Spain.
mail: ernest.esteve@sportclinic.cat

The Copenhagen Hip And Groin Outcome Score (HAGOS). Spanish version LK 1.0.

HAGOS

Cuestionario sobre problemas de cadera e/o ingle

Fecha actual: ___/___/_____ Núm. de identificación (NIF, CIP, etc.):_____

Nombre: _____ Fecha de nacimiento: ___/___/_____

INSTRUCCIONES: Este cuestionario contiene preguntas sobre sus problemas de cadera e/o ingle. Responda a las preguntas considerando los síntomas durante la **última semana**. La información recogida nos va a ayudar a realizar un seguimiento de como se siente y de su capacidad para realizar sus actividades habituales.

Responda **todas** las preguntas marcando la casilla apropiada. Marque solo una casilla por pregunta. Si una pregunta no corresponde a lo que ha sentido o ha realizado durante la última semana por favor, haga su "mejor suposición" sobre que respuesta sería la más precisa.

Síntomas

Responda a estas preguntas considerando los síntomas que ha experimentado en la cadera e/o ingle durante la **última semana**.

S1 Siente molestias en la cadera e/o ingle?

Nunca	Rara vez	A veces	Frecuentemente	Siempre
☐	☐	☐	☐	☐

S2 Oye chasquidos o algún otro tipo de ruido en la cadera e/o ingle?

Nunca	Rara vez	A veces	Frecuentemente	Constantemente
☐	☐	☐	☐	☐

S3 Tiene dificultades para conseguir separar las piernas hacia los lados?

No tengo	Leves	Moderadas	Severas	Muy severas
☐	☐	☐	☐	☐

S4 Tiene dificultades para dar pasos completos cuando camina?

No tengo	Leves	Moderadas	Severas	Muy severas
☐	☐	☐	☐	☐

S5 Siente punzadas repentinas en la cadera y/o en la ingle?

Nunca	Rara vez	A veces	Frecuentemente	Constantemente
☐	☐	☐	☐	☐

The Copenhagen Hip And Groin Outcome Score (HAGOS). Spanish version LK 1.0.

Rigidez

Las siguientes preguntas se refieren al grado de rigidez que ha sentido en la cadera y/o en la ingle durante la **última semana**. La rigidez es una sensación de restricción o lentitud en la facilidad con que se mueve la cadera y/o la ingle.

S6 Cuál es el grado de rigidez de su cadera y/o su ingle al levantarse por la mañana?

No tengo	Leve	Moderado	Severo	Extremo
☐	☐	☐	☐	☐

S7 Cuál es el grado de rigidez de su cadera y/o su ingle después de estar sentado, acostarse o irse a descansar **al final del día**?

No tengo	Leve	Moderado	Severo	Extremo
☐	☐	☐	☐	☐

Dolor

P1 Con que frecuencia experimenta dolor en la cadera y/o en la ingle?

Nunca	Cada mes	Cada semana	Cada día	Siempre
☐	☐	☐	☐	☐

P2 Con que frecuencia experimenta dolor en otras partes del cuerpo, en las que usted piense que puede estar relacionado con su problema de cadera e/o ingle?

Nunca	Cada mes	Cada semana	Cada día	Siempre
☐	☐	☐	☐	☐

Las siguientes preguntas se refieren al grado de dolor que ha experimentado durante la **última semana** en su cadera y/o en su ingle. **Cuanto dolor ha tenido en la cadera e/o ingle en la última semana al realizar las siguientes actividades?**

P3 Extendiendo completamente la cadera (echar la pierna hacia atrás)

No tengo	Leve	Moderado	Intenso	Muy intenso
☐	☐	☐	☐	☐

P4 Flexionando la cadera completamente (llevar el muslo y la rodilla en dirección al abdomen)

No tengo	Leve	Moderado	Intenso	Muy intenso
☐	☐	☐	☐	☐

P5 Subiendo o bajando escaleras

No tengo	Leve	Moderado	Intenso	Muy intenso
☐	☐	☐	☐	☐

P6 Durmiendo por la noche, en la cama (dolor que perturba su sueno)

No tengo	Leve	Moderado	Intenso	Muy intenso
☐	☐	☐	☐	☐

P7 Estando sentado/a o tumbado/a

No tengo	Leve	Moderado	Intenso	Muy intenso
☐	☐	☐	☐	☐

Las siguientes preguntas conciernen al grado de dolor que ha experimentado durante la **última semana** en su cadera y/o en su ingle. **Cuanto dolor ha tenido en la cadera e/o ingle durante la última semana al realizar las siguientes actividades?**

P8 Estando de pie

No tengo	Leve	Moderado	Intenso	Muy intenso
☐	☐	☐	☐	☐

P9 Caminando sobre superficies duras (asfalto, hormigón, etc.)

No tengo	Leve	Moderado	Intenso	Muy intenso
☐	☐	☐	☐	☐

P10 Caminando en superficies irregulares

No tengo	Leve	Moderado	Intenso	Muy intenso
☐	☐	☐	☐	☐

Actividades cotidianas

Las siguientes preguntas se refieren a su actividad física, es decir, su capacidad para moverse y valerse por si mismo. **Para cada una de las siguiente actividades, indique el grado de dificultad que haya experimentado durante la última semana debido a su cadera e/o ingle.**

A1 Subiendo escaleras

No tengo	Leve	Moderado	Severo	Muy severo
☐	☐	☐	☐	☐

A2 Agachándose, por ejemplo, para recoger algo del suelo

No tengo	Leve	Moderado	Severo	Muy severo
☐	☐	☐	☐	☐

A3 Entrando/saliendo del coche

No tengo	Leve	Moderado	Severo	Muy severo
☐	☐	☐	☐	☐

A4 Estando acostado/a en la cama (dándose la vuelta o manteniendo la cadera en la misma posición por un largo tiempo)

No tengo	Leve	Moderado	Severo	Muy severo
☐	☐	☐	☐	☐

A5 Realizando tareas domésticas pesadas (barrer, fregar el piso, mover cajas pesadas, etc.)

No tengo	Leve	Moderado	Severo	Muy severo
☐	☐	☐	☐	☐

The Copenhagen Hip And Groin Outcome Score (HAGOS). Spanish version LK 1.0.

Actividades deportivas y recreacionales

Las siguientes preguntas se refieren a su estado físico cuando realiza actividades de mayor esfuerzo. Responda **todas** las pregunta marcando la casilla apropiada. Marque solo una casilla por pregunta. Si una pregunta no corresponde a lo que ha sentido, siente o ha realizado durante la última semana por favor, haga su "mejor suposición" sobre que respuesta seria la más precisa. **Las preguntas deben responderse considerando el grado de dificultad que ha experimentado realizando las siguientes actividades durante la ultima semana, debido a sus problemas en la cadera e/o ingle.**

SP1 Agachándose de cuclillas

No tengo	Leve	Moderado	Severo	Muy severo
☐	☐	☐	☐	☐

SP2 Corriendo

No tengo	Leve	Moderado	Severo	Muy severo
☐	☐	☐	☐	☐

SP3 Girándose/retorciéndose o al pivotar sobre la pierna afectada

No tengo	Leve	Moderado	Severo	Muy severo
☐	☐	☐	☐	☐

SP4 Caminando sobre superficies irregulares

No tengo	Leve	Moderado	Severo	Muy severo
☐	☐	☐	☐	☐

SP5 Corriendo lo más rápido posible

No tengo	Leve	Moderado	Severo	Muy severo
☐	☐	☐	☐	☐

SP6 Echando la pierna bruscamente hacia delante y/o el costado, como dando una patada o patinando.

No tengo	Leve	Moderado	Severo	Muy severo
☐	☐	☐	☐	☐

SP7 Realizando movimientos bruscos, explosivos que requieren de un rápido movimiento de pies, tales como aceleraciones, frenadas, cambios de dirección, etc.

No tengo	Leve	Moderado	Severo	Muy severo
☐	☐	☐	☐	☐

SP8 Situaciones donde la pierna es estirada hacia una posición lateral (tales como estirar la pierna hacia el lado, lo más lejos posible del cuerpo)

No tengo	Leve	Moderado	Severo	Muy severo
☐	☐	☐	☐	☐

Participación in actividades físicas

Las siguientes preguntas son acerca de su capacidad para participar en sus actividades físicas preferidas. Como actividades físicas no solamente nos referimos a actividades deportivas, sino también a todas las demás actividades que puedan dificultarle el aliento. **Marque en que grado su capacidad para participar en actividades físicas durante la última semana se ha visto afectado por sus problemas de cadera e/o ingle.**

PA1 Es capaz de participar en sus actividades físicas preferidas durante el tiempo deseado?

Siempre	Frecuentemente	A veces	Rara vez	Nunca
☐	☐	☐	☐	☐

PA2 Es capaz de participar en sus actividades físicas preferidas a su nivel normal de rendimiento?

Siempre	Frecuentemente	A veces	Rara vez	Nunca
☐	☐	☐	☐	☐

Calidad de vida

Q1 Con que frecuencia es usted consciente de su problema de cadera e/o ingle?

Nunca	Mensualmente	Semanalmente	A diario	Constantemente
☐	☐	☐	☐	☐

Q2 Ha modificado su estilo de vida para evitar actividades potencialmente dañinas par su cadera e/o ingle?

Para nada	Levemente	Moderadamente	Drásticamente	Totalmente
☐	☐	☐	☐	☐

Q3 En general, cuantas dificultades le crea su cadera e/o ingle?

Ninguna	Leves	Moderadas	Severas	Muy severas
☐	☐	☐	☐	☐

Q4 Sus problemas de cadera e/o ingle, afectan negativamente a su estado de ánimo?

Para nada	Rara vez	A veces	Frecuentemente	Constantemente
☐	☐	☐	☐	☐

Q5 Se siente limitado debido a sus problemas de cadera e/o ingle?

Para nada	Rara vez	A veces	Frecuentemente	Constantemente
☐	☐	☐	☐	☐

Muchas gracias por completar todas la preguntas de este cuestionario.

Generalitat de Catalunya
Comitè d'Ètica d'Investigacions Clíniques de l'Administració Esportiva de Catalunya

Dr. RAMON BALIUS MATAS, ACTING AS SECRETARY OF THE "COMITÈ D'ÈTICA D'INVESTIACIONS CLÍNIQUES DE L'ADMINISTRACIÓ ESPORTIVA DE CATALUNYA" CERTIFIES THAT:

At the meeting in the 22nd of May of 2015, this Ethical Committee, agreed to positively evaluated the project presented by Mr. Ernest Esteve with reference number 08/2015/CEICEGC, entitled "Prevention of groin injuries in male footballers".

I note this positive appraisal for any circumstances that this will apply

Espluges del Llobregat, 22nd of May 2015
Dr. Ramon Balius Matas

List of other publications

Thorborg K, Krommes KK, **Esteve E**, Clausen MB, Bartels EM, Rathleff MS. Effect of specific exercise-based football injury prevention programmes on the overall injury rate in football: a systematic review and meta-analysis of the FIFA 11 and 11+ programmes. *Br J Sports Med*. 2017;51(7):562-571. doi:10.1136/bjsports-2016-097066

Thorborg K, Krommes KK, **Esteve E**, Clausen MB, Bartels EM, Rathleff MS. Infographic: Effects of specific injury prevention programmes in football. *Br J Sports Med*. 2017;51(20):1493. doi:10.1136/bjsports-2017-098305

Thorborg K, Krommes K, **Esteve E**, Clausen MB, Bartels EM, Rathleff MS. High Risk of Bias and Low Transparency in "How Effective are F-MARC Injury Prevention Programs for Soccer Players? A Systematic Review and Meta-Analysis". *Sports Med*. 2016;46(2):293-294. doi:10.1007/s40279-015-0458-9

Vicens-Bordas J, **Esteve E**, Fort-Vanmeerhaeghe A, Bandholm T, Thorborg K. Is inertial flywheel resistance training superior to gravity-dependent resistance training in improving muscle strength? A systematic review with meta-analyses. *J Sci Med Sport*. 2018;21(1):75-83. doi:10.1016/j.jsams.2017.10.006

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Vicens-Bordas J, **Esteve E**, Fort-Vanmeerhaeghe A, et al. ECCENTRIC HAMSTRING STRENGTH IS ASSOCIATED WITH AGE AND DURATION OF PREVIOUS SEASON HAMSTRING INJURY IN MALE SOCCER PLAYERS. *Int J Sports Phys Ther*. 2020;15(2):246-253.

Vicens-Bordas J, **Esteve E**, Fort-Vanmeerhaeghe A, et al. Performance changes during the off-season period in football players - Effects of age and previous hamstring injury [published online ahead of print, 2020 Jul 13]. J Sports Sci. 2020;1-11. doi:10.1080/02640414.2020.1792160

Universitat de Girona