BMJ Open Sport & Exercise Medicine

Prognostic factors for specific lower extremity and spinal musculoskeletal injuries identified through medical screening and training load monitoring in professional football (soccer): a systematic review

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To cite: Hughes T, Sergeant JC, Parkes MJ, *et al*. Prognostic factors for specific lower extremity and spinal musculoskeletal injuries identified through medical screening and training load monitoring in professional football (soccer): a systematic review. *BMJ Open Sport Exerc Med* 2017;**3**:e000263. doi:10.1136/bmjsem-2017-000263

► Additional material is published online only. To view, please visit the journal online (http://dx.doi.org/10.1136/bmjsem-2017-000263).

Accepted 20 June 2017

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ABSTRACT

Background Medical screening and load monitoring procedures are commonly used in professional football to assess factors perceived to be associated with injury.

Objectives To identify prognostic factors (PFs) and models for lower extremity and spinal musculoskeletal injuries in professional/elite football players from medical screening and training load monitoring processes.

Methods The MEDLINE, AMED, EMBASE, CINAHL Plus, SPORTDiscus and PubMed electronic bibliographic databases were searched (from inception to January 2017). Prospective and retrospective cohort studies of lower extremity and spinal musculoskeletal injury incidence in professional/elite football players aged between 16 and 40 years were included. The Quality in Prognostic Studies appraisal tool and the modified Grading of Recommendations Assessment, Development and Evaluation synthesis approach was used to assess the quality of the evidence.

Results Fourteen studies were included. 16 specific lower extremity injury outcomes were identified. No spinal injury outcomes were identified. Meta-analysis was not possible due to heterogeneity and study quality. All evidence related to PFs and specific lower extremity injury outcomes was of very low to low quality. On the few occasions where multiple studies could be used to compare PFs and outcomes, only two factors demonstrated consensus. A history of previous hamstring injuries (HSI) and increasing age may be prognostic for future HSI in male players.

Conclusions The assumed ability of medical screening tests to predict specific musculoskeletal injuries is not supported by the current evidence. Screening procedures should currently be considered as benchmarks of function or performance only. The prognostic value of load monitoring modalities is unknown.

INTRODUCTION

The incidence of musculoskeletal injuries reported in European professional football (soccer) players is high. On average, players sustain two injuries and miss 37 days of training and match play per season,[1] with most injuries occurring to the lower extremities.[2] Team performance is negatively affected by increased injury incidence and severity[3] and the subsequent financial implications are considerable.[4] Therefore, injury prevention strategies are potentially of great benefit to professional clubs.[3]

In professional sport, general medical examination[5] and physical performance tests (PPTs)[6 7] are commonly used to screen for factors perceived to indicate enhanced injury risk.[8 9] A survey of elite European professional football teams has identified that 94% routinely use injury risk screening and monitoring with the most common methods including muscle flexibility, strength and imbalance assessment and joint mobility examination.[10]

Evaluation of training and match load through technological modalities such as Global Positioning Systems (GPS) and heart rate monitoring are also commonly employed for this purpose in football,[10 11] alongside subjective indicators such as perceived exertion ratings and wellness evaluation.[10]

Factors associated with injury and assessed through screening and load monitoring have been given many different names in the literature, such as risk factors, predictive factors and predictors. However, The PROGnosis RESearch Strategy Partnership, an international, interdisciplinary collaboration which aims to enhance the impact of

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prognosis research, terms such factors as prognostic factors (PFs). PFs are defined as variables associated with or predictive of clinical events (such as injury) in populations with a defined baseline state.[12 13] Importantly, PFs may or may not offer insights into injury causality, but by being associated with or predictive of the outcome of interest, they are potentially useful for developing multivariable prognostic models. These models aim to make meaningful individual risk predictions and inform stratified management approaches designed to reduce risk.[14] Hence, medical screening and training load monitoring processes are concerned with prognosis. Consequently within this review only the term PF will be used for measures derived from such practices. PFs are intrinsic (person specific) or extrinsic (environment specific)[15] and deemed modifiable or non-modifiable.[16] For intrinsic factors, an example of a non-modifiable factor is age, whereas a modifiable factor could be strength. For extrinsic factors, a non-modifiable factor example is weather, while modifiable factors include training load.

Previous systematic reviews have investigated PFs for injuries in sport[6 7 17–22] and football in general.[23] These findings have limited clinical relevance as analyses were not stratified by sport, skill level or both. PFs should be considered specific to sport and populations of amateur or professional athletes, as there are fundamental differences in metabolic, biomechanical and loading exposure characteristics that may also predispose to particular injuries. Specifically, in professional football, a previous systematic review found that history of a previous hamstring injury (HSI) may be associated with future HSIs, although the evidence relating to the prognostic value of isokinetic strength testing, functional movement screen, muscle imbalance assessment, use of psychological questionnaires and fatigue monitoring was either inconclusive or insufficient.[24] However, the analysis only included these commonly perceived PFs identified by an international survey of medical practice in professional clubs[25] and did not examine other potentially relevant factors. The only review of training load monitoring found that high intensity football training may be associated with increased injury propensity,[11] although these findings were limited to generalised injury categories rather than specific outcomes. There are no exhaustive systematic reviews that have investigated PFs identified through medical screening and training load monitoring procedures for specific injuries in professional football.

Therefore, the aims of this systematic review are to: i) identify PFs for specific lower extremity and spinal musculoskeletal injuries in adult professional/elite football players, from medical screening and training load monitoring processes and ii) identify any current prognostic models that are able to predict specific lower extremity and spinal injuries in adult professional/elite football players.

METHODS

The methodology was specified a priori through protocol registration with the International Prospective Register of Systematic Reviews.[26] This review has conformed to the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) guidelines (online supplementary file 6).[27]

Eligibility criteria

Types of studies

Prospective and retrospective cohort studies were included as these are best suited for prognosis research.[28] Studies of any other design were excluded.

Types of participants

Studies were included if participants were defined as professional/elite football players, aged between 16 and 40 years. Studies were excluded if they contained participants from non-football or mixed sports, or amateur/recreational football players of any age.

Types of outcome measures

Outcomes were any lower extremity or spinal musculoskeletal injury categories, defined by specific diagnosis and/or anatomical location. Outcomes that were not defined with specific diagnosis and/or location, or used generalised injury categories (eg, defined as injuries, match injuries, training injuries, overuse injuries, general muscle or ligament injuries) were excluded. Studies were included if the magnitude of association between PFs and outcomes were reported with appropriate summary effect measures, that is, odds ratios (OR), risk ratios (RR), incidence rate ratios (IRR) or hazard ratios (HR) alongside corresponding p values and confidence intervals (CI). Studies were excluded if measures of association were not reported, that is, only significance testing was reported.

Types of prognostic factors

Studies were included if any of the following were investigated: 1) general medical examination/questionnaire (including anthropometric information), 2) any clinical musculoskeletal examination/assessment methods (including flexibility, mobility and strength measurement) or PPT (including measures of core stability, functional movement control, strength and proprioception), 3) medical imaging, 4) training load measurement (time unit documentation, technology such as GPS and physiological parameters, eg, heart rate measures). Studies were excluded if PFs or models were not investigated or if treatment interventions were performed.

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Table 1 Characteristics, prognostic factors, outcomes and QUIPS assessments for included studies

Study	Specific outcomes	N	Follow-up	Prognostic factors stated in text					QUIPS score per domain					
				Demographics/ anthropometrics	Neuromuscular	Anatomical	Physiological	Training load/ recovery	Participation	Attrition	Prognostic factors	Outcome measurement	Confounding measurement	Statistical reporting
Arnason *et al*[30]	Hamstring strains, groin strains, ankle sprains, knee sprains	306 males	1 season	Age, height, weight, BMI, body comp, PMH	Maximal average squat power, standing jump, CMJ	Flexibility	–	Match exposure, training: match ratio.						
Bengtsson *et al*[31]	Hamstring injuries, quadriceps injuries, adductor injuries and calf injuries	Unknown	1–11 seasons	–	–	–	–	Recovery time between matches						
Carling *et al*[32]	Hamstring strains, quadriceps strains, groin strains, calf strains, ankle sprains, knee sprains	35 males	6 seasons	–	–	–	–	No. of matches in 3/4 day cycle						
Faude *et al*[33]	Ankle sprains, knee sprains, ACL tears	143 females	1 season	Age, height, weight BMI, limb dominance, playing position, PMH	–	–	–	Training time, match time						
Fousekis *et al*[34]	Hamstring injuries, quadriceps injuries	100 males	10 months	Age, height, weight, PMH	Ankle isokinetic strength, knee isokinetic strength, functional knee strength ratio, stabilometry	Mid thigh girth, lower limb length, knee joint stability, ankle flexibility, hamstring and quadriceps flexibility	–	–						
Fousekis *et al*[35]	Ankle sprains	100 males	10 months	Age, height, weight, PMH, limb dominance	Ankle isokinetic strength, stabilometry	Tibia length, lower limb length, ankle joint stability, ankle flexibility	–	–						
Hagglund *et al*[36]	Ankle sprains, groin injuries, knee joint trauma	197 males	2 seasons	Age, height, weight, BMI, PMH	–	–	–	–						
Hagglund *et al*[37]	Hamstring injuries, quadriceps injuries, adductor injuries, calf injuries	1401 males	9 seasons	Age, height, weight, PMH, limb dominance, playing position	–	–	–	Training/match exposure, Match venue/ type, Period in season, Climate						

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Table 1 Continued

Study	Specific outcomes	N	Follow-up	Prognostic factors stated in text: Demographics/ anthropometrics	Neuromuscular	Anatomical	Physiological	Training load/ recovery	QUIPS score per domain: Participation	Attrition	Prognostic factors	Outcome measurement	Confounding measurement	Statistical reporting
Hagglund *et al*[38]	Patella tendinopathy	2379 males	4.3 seasons	Age, height, weight, playing position	–	–	–	Total exposure, Training/match exposure, Period in season, Team home playing surface						
Henderson *et al*[39]	Hamstring injuries	36 males	1 season	Age, height, weight, lean mass	Knee isokinetic strength, NCMJ jump, CMJ	Active hip flexion ROM (dominant side)	Yo-yo endurance test	–						
Nilstad *et al*[40]	Thigh injuries, knee injuries, ankle injuries, lower leg and foot injuries	173 females	1 season	Age, height, weight, BMI, PMH, seasons at elite level	Knee isokinetic strength, leg press, hip abductor strength, knee valgus during drop jump landing, SEBT	Knee joint stability, hypermobility, foot pronation	–	Training/match exposure						
Timmins *et al*[43]	Hamstring injuries	152 males	1 season	Age, height, weight, PMH	Eccentric hamstring strength/ imbalance, MVIC strength/MVIC imbalance	US passive fascicle length, passive fascicle length relative to BFlh length, 25% MVIC length, passive fascicle length imbalance, 25% MVIC fascicle length imbalance, passive muscle thickness, 25% MVIC muscle thickness	–	–						
Waldén *et al*[41]	Knee injuries, traumatic knee injuries, overuse knee injuries	310 males	1 season	Age, height, weight, PMH, limb dominance, playing position	–	–	–	Training/match exposure						
Van Dyk *et al*[42]	Hamstring injuries	614 males	4 seasons	–	Knee isokinetic strength, mixed hamstring/ quadriceps ratios	–	–	–						

BMI, body mass index; PMH, previous medical history; CMJ, countermovement jump; NCMJ, non-countermovement jump; QUIPS, Quality in Prognostic Studies; SEBT, Star Excursion Balance Test; MVIC, maximum voluntary isometric contraction; US, ultrasound;BFlh, biceps femoris long head.
■ Low risk of bias; ■ moderate risk of bias; ■ high risk of bias.

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Data sources and search strategy

The MEDLINE, AMED, EMBASE, CINAHL Plus, SPORTDiscus electronic bibliographic databases were searched from inception to 24 July 2016, and repeated on 12 December 2016 to identify new literature. The strategy is presented in the online supplementary file 1; terms were adapted to the requirements of each specific database. To ensure that all relevant studies were captured, a secondary search of the PubMed database was conducted on 2 January 2017 using a broad non-specific strategy of football OR soccer AND injuries. Where the full text was obtained, reference lists were searched. Searches were limited to original research articles, published in English through peer-reviewed journals. Systematic and narrative reviews, clinical commentaries, editorials, conference abstracts, grey literature or studies from non-peer-reviewed journals were excluded.

Study selection

Titles and abstracts of retrieved studies were independently screened by the lead reviewer (TH). The second reviewer (MJC) verified the results and relevant full-text articles were obtained. All were screened for eligibility in a standardised, unblinded manner jointly by both reviewers. Data were extracted by one reviewer (TH) using a standardised form (see online supplementary file 2) and verified by the second reviewer (MJC).

Risk of bias in individual studies

Risk of bias was assessed using The Quality in Prognostic Studies (QUIPS) tool,[29] which is advocated by the Cochrane Prognosis Methods Group and has moderate to near perfect inter-rater reliability.[29] QUIPS evaluates validity and bias through participation, attrition, PF, confounding variable and statistical reporting domains. Domains contained several items where extracted information was entered and this guided judgement of potential for bias. After consideration, each domain was rated as low, moderate or high risk of bias and the corresponding risk level for each domain was colour coded as green, amber or red, respectively.

Both reviewers assessed the evidence independently, but were not blinded to authors, title or journal. Disagreements were resolved through discussion. If consensus could not be reached, the third reviewer (JCS) was consulted.

Data analysis and synthesis

Extracted data and QUIPS appraisal summaries were tabulated to assess heterogeneity of study characteristics and quality (table 1). Subgroup analysis of male and female participants was planned a priori. The quantity, quality and heterogeneity of the literature prevented formal statistical evaluation, so a narrative synthesis was performed. All results were extracted for each study (see online supplementary file 3).

This synthesis process was based on the modified Grading of Recommendations Assessment, Development and Evaluation (GRADE) framework.[28] All significant PFs for a specific injury outcome were tabulated and grouped (table 2). Any PFs investigated by multiple studies for the same outcome, while using the same effect measures, were tabulated and presented graphically (figures 2–4). These data and QUIPS appraisals were used to make key judgements for each PF in the following domains: 1) study limitations, 2) consistency of results, 3) effect sizes, 4) precision of results, 5) publication bias, 6) overall quality (see online supplementary file 4 for detailed explanation of how judgements for each domain were made).

RESULTS

Study selection

From the searches, 6362 total results were returned with 1245 duplicates, leaving 5117 studies (figure 1). After screening titles and abstracts 4846 studies were excluded. The full texts of the remaining 271 studies were obtained; 257 studies were not eligible at this stage. All excluded studies are listed (with exclusion reasons) in online supplementary file 5. A final total of 14 studies were included.

Characteristics and quality of included studies

For all included studies, the characteristics, PFs and outcomes investigated along with QUIPS risk of bias assessments are presented in table 1. A narrative summary across studies is provided in the sections below.

General

Studies predominantly originated from Europe[30–41] with one each from the Middle East[42] and Australia.[43] Follow-up ranged from 1 to 11 football seasons.[30–33 36–43] Two studies[34 35] stated a 10-month follow-up, equating to one season.

Participants

Participant numbers were provided in 13 studies[30 32–43] and totalled 5946 professional/elite players but as one study[31] did not report the number of included participants the true total is unknown. Two studies[33 40] exclusively investigated female players (n=316). All other studies used male participants only (n=5630).

Outcomes

All outcomes were defined as time loss injuries, that is, injuries that resulted in a player being unable to fully participate in training or match play. Nine outcomes were categorised by diagnosis and anatomical region, whereas seven were categorised by anatomical region

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Table 2 Summary of synthesis of prognostic factors for all injury outcomes with associated GRADE evaluation

									Adapted GRADE criteria				
Injury type	**Specific Outcomes**	**Potential prognostic factors**	**Number of studies**	**Authors**	**Effect measure**	**Univariate Effect size (95% CI)**	**Multivariate effect size (95% CI)**	**Study limitations**	**Consistency of results**	**Effect size**	**Precision of results**	**Publication bias**	**Overall quality**
Muscle injuries	Hamstring injuries	Increasing age	2	Hagglund *et al* [36 37]	HR	Figure 2	**1.1 (1 to 1.2)**	Many	No	Small	Imprecise	Likely	***Low***
		Increasing age	2	Arnason *et al*,[30] Henderson *et al* [39]	OR	–	Figure 3	Many	Yes	Small	Precise	Likely	***Low***
		Previous hamstring injury	2	Hagglund *et al* [36 37]	HR	Figure 2	Figure 2	Many	Yes	Moderate	Imprecise	Likely	***Low***
		Previous hamstring injury	2	Arnason *et al*,[30] Fousekis *et al* [34]	OR	**7.42 (2.9 to 19)**	Figure 3	Very many	No	Variable	Imprecise	Likely	***Very low***
		Stature (above mean)	1	Hagglund *et al* [37]	HR	**0.82 (0.68 to 1.0)**	**–**	Many	N/A	Small	Imprecise	Likely	***Very low***
		Previous quadriceps injury	1	Hagglund *et al* [37]	HR	**1.44 (1.08 to 1.93)**	**–**	Very many	N/A	Small	Imprecise	Likely	***Very low***
		Eccentric hamstring strength asymmetries	1	Fousekis *et al* [34]	OR	–	**3.88 (1.13 to 13.23)**	Very many	N/A	Moderate	Imprecise	Likely	***Low***
		BW adjusted eccentric hamstring strength (60 deg/s)	1	Van Dyk *et al* [42]	OR	–	**1.37 (1.01 to 1.85)**	Many	N/A	Small	Imprecise	Likely	***Very low***
		BW adjusted concentric quadriceps strength (60 degree/s)	1	Van Dyk *et al* [42]	OR	–	**1.41 (1.03 to 1.92)**	Many	N/A	Small	Imprecise	Likely	***Very low***
		Active hip flexion ROM (dominant leg)	1	Henderson *et al* [39]	OR	–	**0.77 (0.62 to 0.97)**	Many	N/A	Small	Imprecise	Likely	***Low***

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Table 2 Continued

Injury type	Specific Outcomes	Potential prognostic factors	Number of studies	Authors	Effect measure	Univariate Effect size (95% CI)	Multivariate effect size (95% CI)	Study limitations	Adapted GRADE criteria: Consistency of results	Effect size	Precision of results	Publication bias	Overall quality
		Increased NCMJ height	1	Henderson *et al* [39]	OR	–	**1.47 (1.02 to 2.12)**	Many	N/A	Small	Imprecise	Likely	***Low***
		Functional leg length asymmetry	1	Fousekis *et al* [34]	OR	–	**3.8 (1.08 to 13.33)**	Very many	N/A	Large	Imprecise	Likely	***Low***
		Position: goalkeeper	1	Hagglund *et al* [37]	HR	**0.11 (0.06 to 0.23)**	**0.11 (0.06 to 0.24)**	Very many	N/A	Large	Imprecise	Likely	***Very low***
		Time of season:											
		September-November	1	Hagglund *et al* [37]	OR	**2.24 (1.34 to 3.74)**	**2.16 (1.29 to 3.60)**	Very many	N/A	Moderate	Imprecise	Likely	***Very low***
		December–February	1	Hagglund *et al* [37]	OR	**2.56 (1.54 to 4.26)**	**2.55 (1.53 to 4.24)**	Very many	N/A	Moderate	Imprecise	Likely	***Very low***
		March–May	1	Hagglund *et al* [37]	OR	**2.56 (1.54 to 4.28)**	**2.49 (1.49 to 4.17)**	Very many	N/A	Moderate	Imprecise	Likely	***Very low***
		Playing league matches with ≤4 days recovery	1	Bengtsson *et al* [31]	RR	**–**	**1.28 (1.06 to 1.56)**	Many	N/A	Small	Imprecise	Likely	***Very low***
		Venue: away match	1	Hagglund *et al* [37]	OR	**0.75 (0.62 to 0.91)**	**0.76 (0.63 to 0.92)**	Very many	N/A	Small	Imprecise	Likely	***Very low***
	Quadriceps injuries	Previous adductor injury	1	Hagglund *et al* [37]	HR	**1.88 (1.31 to 2.69)**	**1.68 (1.16 to 2.41)**	Very many	N/A	Small	Imprecise	Likely	***Very Low***
		Previous quadriceps injury	1	Hagglund *et al* [37]	HR	**3.47 (2.49 to 4.84)**	**3.1 (2.21 to 4.36)**	Very many	N/A	Large	Imprecise	Likely	***Very low***
		Previous calf injury	1	Hagglund *et al* [37]	HR	**2.08 (1.37 to 3.17)**	**1.91 (1.24 to 2.93)**	Very many	N/A	Moderate	Imprecise	Likely	***Very low***
		Position: goalkeeper	1	Hagglund *et al* [37]	HR	0.46 (0.23 to 0.9)	**0.41 (0.2 to 0.82)**	Very many	N/A	Moderate	Imprecise	Likely	***Very low***

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Table 2 Continued

Injury type	Specific Outcomes	Potential prognostic factors	Number of studies	Authors	Effect measure	Univariate Effect size (95% CI)	Multivariate effect size (95% CI)	Study limitations	Adapted GRADE criteria: Consistency of results	Effect size	Precision of results	Publication bias	Overall quality
		Playing league matches with ≤4 days recovery	1	Bengtsson *et al* [31]	RR	–	**1.8 (1.19 to 2.72)**	Many	N/A	Small	Imprecise	Likely	***Very Low***
		Match type: UEFA CL	1	Hagglund *et al* [37]	OR	0.51 (0.25 to 1.01)	**0.48 (0.24 to 0.97)**	Very many	N/A	Moderate	Imprecise	Likely	***Very low***
	Adductor injuries	Previous adductor injury	1	Hagglund *et al* [37]	HR	**1.48 (1.06 to 2.06)**	**1.40 (1 to 1.96)**	Very many	N/A	Small	Imprecise	Likely	***Very low***
		Position: goalkeeper	1	Hagglund *et al* [37]	HR	**0.58 (0.33 to 0.99)**	**0.51 (0.29 to 0.91)**	Very many	N/A	Moderate	Imprecise	Likely	***Very low***
		Venue: away match	1	Hagglund *et al* [37]	OR	**0.56 (0.43 to 0.73)**	**0.56 (0.43 to 0.73)**	Very many	N/A	Moderate	Imprecise	Likely	***Very low***
		Match type: other cup	1	Hagglund *et al* [37]	OR	**0.60 (0.37 to 0.97)**	**–**	Very many	N/A	Moderate	Imprecise	Likely	***Very low***
	Groin strain injuries	Previous groin strain	1	Arnason *et al* [30]	OR	**5.71 (2 to 15.9)**	**7.3 (2.3 to 23.2)**	Many	N/A	Large	Imprecise	Likely	***Low***
		Reduced ROM hip abduction	1	Arnason *et al* [30]	OR	–	**0.9 (0.8 to 1)**	Many	N/A	Small	Imprecise	Likely	***Very Low***
	Calf muscle injuries	Previous calf muscle injury	1	Hagglund *et al* [37]	HR	**2.83 (1.86 to 4.31)**	**2.33 (1.52 to 3.57)**	Very many	N/A	Moderate	Imprecise	Likely	***Very low***
		Increasing age	1	Hagglund *et al* [37]	HR	**2.02 (1.45 to 2.82)**	**1.93 (1.38 to 2.71)**	Very many	N/A	Moderate	Imprecise	Likely	***Very low***
		Previous adductor injury	1	Hagglund *et al* [37]	HR	**1.87 (1.26 to 2.77)**	**1.71 (1.15 to 2.55)**	Very many	N/A	Small	Imprecise	Likely	***Very low***
		Previous hamstring injury	1	Hagglund *et al* [37]	HR	**2.1 (1.51 to 2.54)**	**1.74 (1.24 to 2.44)**	Very many	N/A	Small	Imprecise	Likely	***Very low***
		Match type: UEFA CL	1	Hagglund *et al* [37]	OR	**2.43 (1.61 to 3.67)**	**2.72 (1.78 to 4.14)**	Very many	N/A	Moderate	Imprecise	Likely	***Very low***

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Table 2 Continued

Injury type	Specific Outcomes	Potential prognostic factors	Number of studies	Authors	Effect measure	Univariate Effect size (95% CI)	Multivariate effect size (95% CI)	Study limitations	Adapted GRADE criteria: Consistency of results	Effect size	Precision of results	Publication bias	Overall quality
		Position: goalkeeper	1	Hagglund *et al* [37]	HR	**0.43 (0.2 to 0.96)**	**0.36 (0.16 to 0.82)**	Very many	N/A	Moderate	Imprecise	Likely	***Very low***
Ligament injuries	Ankle sprain	Previous ankle sprain*	2	Arnason *et al*, [30] Faude *et al* [33]	OR	Figure 4	Figure 4	Many	No	Large	Imprecise	Likely	***Very low***
		Weight above median	1	Fousekis *et al* [35]	OR	–	**5.72 (1.37 to 23.95)**	Many	N/A	Large	Imprecise	Likely	***Very low***
		BMI > median	1	Fousekis *et al* [35]	OR	–	**8.16 (1.42 to 46.63)**	Many	N/A	Large	Imprecise	Likely	***Very low***
		Eccentric ankle strength asymmetry >15%	1	Fousekis *et al* [35]	OR	–	**8.88 (1.95 to 40.36)**	Many	N/A	Large	Imprecise	Likely	***Very low***
		Playing three matches within4 days	1	Carling *et al* [32]	IRR	**10.4 (1.9 to 57.9)**	**–**	Many	N/A	Large	Imprecise	Likely	***Very low***
	Knee sprain	Previous knee sprain*	2	Arnason *et al* [30] Faude *et al* [33]	OR	Figure 4	Figure 4	Many	No	Moderate	Imprecise	Likely	***Very low***
	ACL tear	Previous ACL tear†	1	Faude *et al* [33]	OR	–	**5.24 (1.42 to 19.59)**	Many	N/A	Large	Imprecise	Likely	***Very low***
Tendinopathy	Patellar tendinopathy	Age	1	Hagglund *et al* [38]	OR	–	**0.97 (0.93 to 1.01)**	Very many	N/A	Small	Imprecise	Likely	***Very low***
		Increased body weight (per 5 kg)	1	Hagglund *et al* [38]	OR	–	**1.15 (1 to 1.33)**	Very many	N/A	Small	Imprecise	Likely	***Very low***
		Total football exposure hours (per 10 hours increase)	1	Hagglund *et al* [38]	OR	**No data**	**1.02 (1 to 1.04)**	Very many	N/A	Small	Imprecise	Likely	***Very low***

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Table 2 Continued

Injury type	Specific Outcomes	Potential prognostic factors	Number of studies	Authors	Effect measure	Univariate Effect size (95% CI)	Multivariate effect size (95% CI)	Study limitations	Adapted GRADE criteria: Consistency of results	Effect size	Precision of results	Publication bias	Overall quality
Injuries defined by anatomical location	Traumatic knee injuries	Previous ACL injury‡	1	Waldén *et al* [41]	Rel. R	–	**2.6 (1.1 to 6.7)**	Very many	N/A	Moderate	Imprecise	Likely	***Very low***
		Previous ACL injury§	1	Waldén *et al* [41]	Rel. R	–	**2.7 (1.3 to 5.8)**	Very many	N/A	Moderate	Imprecise	Likely	***Very low***
		Previous knee injury	1	Hagglund *et al* [36]	HR	–	**3.10 (1.3 to 7.6)**	Very many	N/A	Moderate	Imprecise	Likely	***Very low***
	Overuse knee injuries	Previous ACL injury ‡	1	Waldén *et al* [41]	Rel. R	–	**7.9 (3.4 to 18.5)**	Very many	N/A	Large	Imprecise	Likely	***Very low***
		Previous ACL injury§	1	Waldén *et al* [41]	Rel. R	–	**4.8 (2.0 to 11.2)**	Very many	N/A	Large	Imprecise	Likely	***Very low***
	Thigh injuries	Increased BMI	1	Nilstad *et al* [40]	OR	1.37 (0.95 to 1.98)	**1.51 (1.08 to 2.11)**	Few	N/A	Small	Imprecise	Likely	***Very low***
	Knee injuries	Previous ACL injury ‡	1	Waldén *et al* [41]	Rel. R	–	**4.5 (2.3 to 8.8)**	Very many	N/A	Large	Imprecise	Likely	***Very low***
		Previous ACL injury§	1	Waldén *et al* [41]	Rel. R	–	**3.4 (1.8 to 6.3)**	Very many	N/A	Moderate	Imprecise	Likely	***Very low***
	Ankle injuries	Age	1	Nilstad *et al* [40]	OR	**0.64 (0.44 to 0.95)**	0.65 (0.4 to 1.05)	Few	N/A	Small	Imprecise	Likely	***Very low***
		Increased 1 RM leg press	1	Nilstad *et al* [40]	OR	**1.47 (1.05 to 2.05)**	1.41 (0.97 to 2.06)	Few	N/A	Small	Imprecise	Likely	***Very low***
		Foot pronation	1	Nilstad *et al* [40]	OR	**1.56 (1.13 to 2.15)**	1.55 (0.99 to 2.41)	Few	N/A	Small	Imprecise	Likely	***Very low***
		Reduced knee valgus angle	1	Nilstad *et al* [40]	OR	1.14 (0.49 to 2.66)	**0.64 (0.41 to 1)**	Few	N/A	Moderate	Imprecise	Likely	***Very low***

Continued

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Table 2 Continued

Injury type	Specific Outcomes	Potential prognostic factors	Number of studies	Authors	Effect measure	Univariate Effect size (95% CI)	Multivariate effect size (95% CI)	Study limitations	Adapted GRADE criteria: Consistency of results	Effect size	Precision of results	Publication bias	Overall quality
	Lower leg/foot injuries	Previous knee injury	1	Nilstad *et al* [40]	OR	**3.73 (1.47 to 9.46)**	**3.57 (1.27 to 9.99)**	Few	N/A	Large	Imprecise	Likely	***Low***
		Increased BMI	1	Nilstad *et al* [40]	OR	1.44 (0.84 to 2.49)	**1.4 (0.90 to 2.17)**	Few	N/A	Small	Imprecise	Likely	***Very low***
		Increased age	1	Nilstad *et al* [40]	OR	**1.48 (1 to 2.21)**	1.47 (0.98 to 2.2)	Few	N/A	Small	Imprecise	Likely	***Very low***
	Groin injuries	Previous groin injury	1	Hagglund *et al* [36]	HR	**2.40 (1.2 to 4.6)**	–	Very many	N/A	Small	Imprecise	Likely	***Very low***

RR, rate ratio; Rel. R, relative risk; IRR , incidence rate ratio; BMI, body mass index; ACL, anterior cruciate ligament; BW, body weight; N/A, not available; GRADE, Grading of Recommendations Assessment, Development and Evaluation; NCMJ, non-countermovement jump; RM, repetition maximum; UEFA CL, UEFA Champions League match;
Effect size and CIs in **bold** indicate significant value. Effect sizes and CIs in normal font indicate non-significant result. Effect sizes classed as small if measures between 0.66–1 and 1 – 2.4, moderate 0.33–0.66 and 2.5 – 4.4, large 0–0.33 and ≥4.5.
*Arnason *et al* [30] investigated male subjects, whereas Faude *et al* [33] investigated female subjects—see figure 4 for details.
† Faude *et al* [33] have investigated female participants only.
‡Denotes where knee used as unit of analysis,
§ Denotes where player used as unit of analysis.

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only without diagnosis (table 2). No spinal outcomes were investigated.

Prognostic factors

Demographic/anthropometric factors frequently included age, height, weight, body mass index and past medical history.[30 33–41 43] Neuromuscular factors included strength, power, jumping, knee control and proprioceptive tests,[30 34 35 39 40 42 43] although there was a variety of testing procedures.

Five studies[34 35 39 40 42] investigated isokinetic strength tests. For ankle plantarflexor and dorsiflexor muscle groups, only two studies by the same group[34 35] used a comparable concentric-eccentric strength testing protocol. For quadriceps and hamstring isokinetic strength testing, four studies[34 39 40 42] investigated peak torque, although different protocols and measurements were used.

Anatomical factors included lower limb muscle flexibility, hypermobility, ankle range of motion, ankle stability and foot pronation assessments,[30 34 35 39 40] although considerable variation in methods existed. One study[43] investigated biceps femoris architecture through ultrasound examination. Two studies investigated anterior knee laxity using a KT 1000 arthrometer,[34 40] although it was unclear if identical protocols were followed.

Training and match exposure in hours was reported in six studies,[30 33 37 38 40 41] although only one evaluated this as a PF (for patellar tendinopathy).[38] Technological evaluation of training load variables were not investigated as PFs for specific injuries in any study. One study investigated match fixture congestion[32] and another studied recovery time[31] between games.

Eight studies performed univariate PF analyses.[30–32 36–38 40 43] Thirteen studies used multivariable statistical models to assess the independent value of PFs.[30 31 33–43] However, there was no evidence of an attempt to develop a prognostic model for making individual predictions or validation of a model's prospective performance.

Effect summary measures

Considerable heterogeneity was evident for reported effect estimates which prohibited meta-analysis. Effect measures included ORs,[30 33–35 37–40] HRs,[36 37] rate ratios[31 32] and relative risk.[41 43]

Risk of bias within and across studies

The quality of reporting was generally of a poor to moderate standard. Overall, out of 84 domains, 19 (23%) were classed as low risk, 26 (31%) were classed as moderate risk and 39 (46%) were classed as high risk of bias.

Study participation

Three studies were classed as high risk,[31 34 35] eight studies were of moderate risk,[30 32 37–39 41–43] while three[33 36 40] were considered low risk of bias in terms of participation reporting. Ten studies did not report eligibility criteria,[30 31 33 36–41 43] whereas four reported this but in insufficient detail.[32 34 35 42] Papers considered low risk[33 36 40] had good descriptions of recruitment period, location, source and sample population characteristics. In studies considered high or moderate risk,[30–32 34 35 37–39 41–43] these factors were either not reported or reported inadequately.

Study attrition

Eight studies[30–32 34 36–38 42] were considered high risk as attrition rate, characteristics and reasons for participants lost to follow-up were either not reported or inadequately described. Two studies[40 41] were of moderate risk as reasons for attrition were reported but no participant characteristics were reported. Four studies[33 35 39 43] were of low risk of bias as response rate was 100% so attrition was not applicable.

Prognostic factor measurement

Across 12 studies,[30 31 33–39 41–43] PF measurement reporting was of moderate to high risk of bias. Validity of PF measurement was reported adequately in only one study.[43] Frequently, reliability of measurement was not reported[33 34 36–39 41 42] or inadequately described.[30 35 39] Two studies reported reliability appropriately[40 43] and were considered low risk. There were no missing data for PF measurements in seven studies,[30 33–35 40–42] although this was either not reported or inadequately described in the other studies.[31 32 36–39 43]

Outcome measurement

Eleven papers[30–38 41 43] were considered high risk of bias because specific clinical or imaging diagnostic criteria for injury outcomes were not stated or inadequately described. Reliable or validated methods for diagnosis confirmation were also not reported in any of these studies and may be a source of misclassification bias. In studies considered moderate risk, one[43] stated clinical criteria for HSIs with diagnosis confirmed with MRI, although this was not standardised. One study[39] did not state specific clinical criteria, although reported HSI was confirmed through MRI; it was unclear whether only structural HSIs were included for analysis. Only one study[40] was considered low risk. Instead of documenting injury type, outcomes were reported per body location. By using non-diagnostic anatomical outcome measures, the implications of misclassification bias were less in this study.

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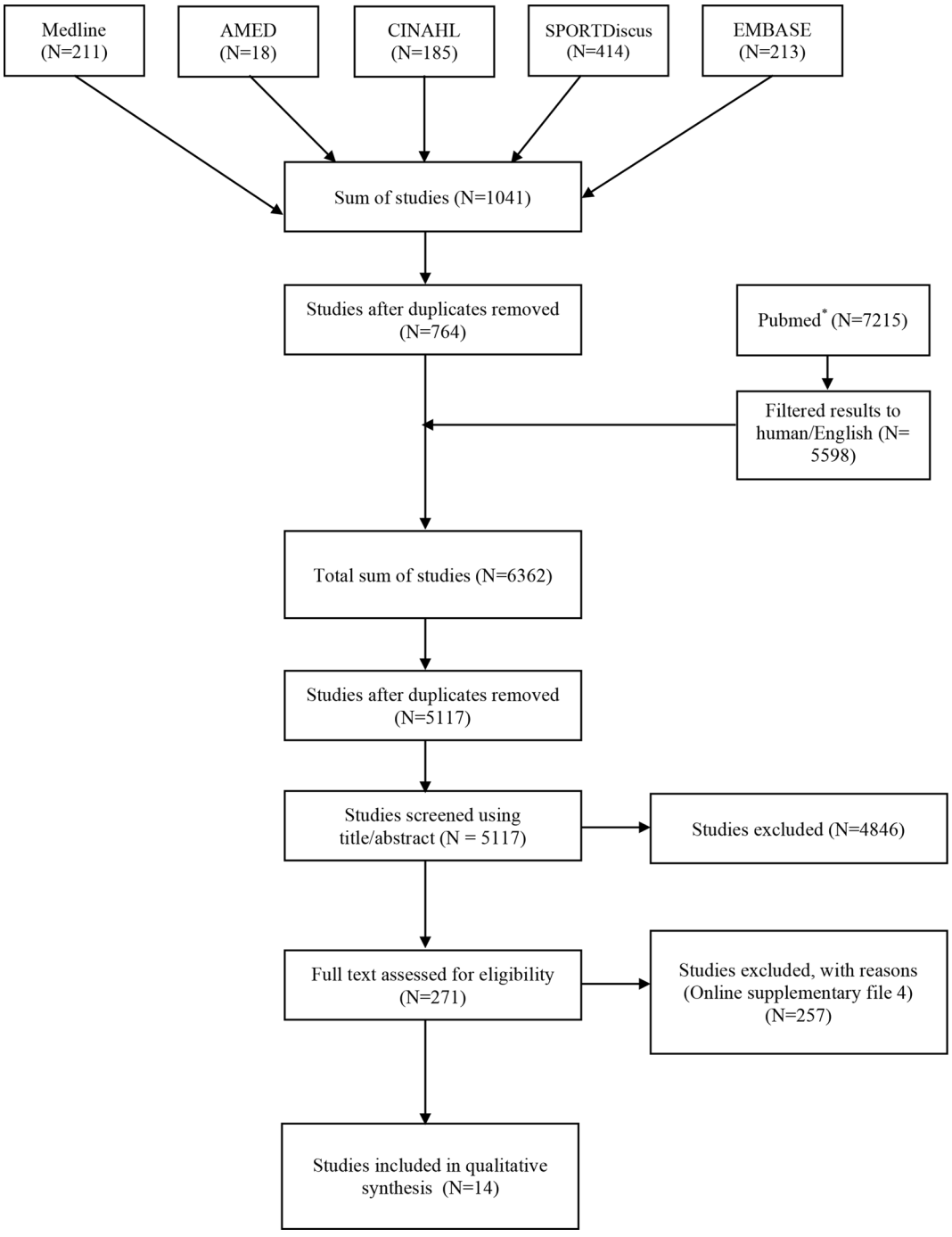


Figure 1 Preferred Reporting Items for Systematic reviews and Meta-Analyses flow chart, highlighting the study selection process. *Search results from non-specific search strategy of football OR soccer AND injuries.

Study confounding

Ten studies[30 32–38 40 41] were considered high risk for confounding reporting. Definitions of confounding factors were either not reported or unclear. Three studies[36 37 40] stated that adjustments were made for one factor in the statistical analysis. It was assumed that these were considered as confounding factors, although not explicitly defined as such.

Four studies[31 39 42 43] were considered as moderate risk. Confounding factors were clearly defined and appropriately adjusted for in the analyses by one study.[42] Three studies[31 39 43] stated that analyses were adjusted for covariates. In these papers it was assumed that these were confounders, although were not specifically defined as such. Dataset completeness for defined confounding variables and methods of missing data management were also not reported in any study.

Statistical analysis

Statistical analysis reporting was of low risk of bias in nine studies;[30 31 34–37 40 42 43]data were presented in sufficient detail, with the justification for statistical

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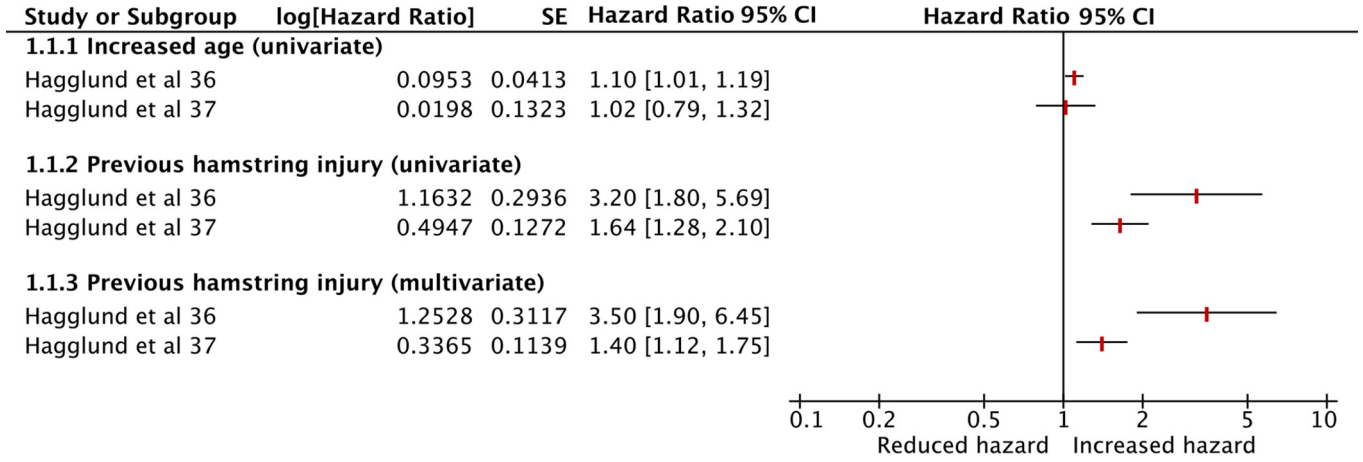


Figure 2 Graph presenting hamstring injury prognostic factors in male participants, investigated by multiple studies—HR analyses.

modelling outlined and no evidence of selective reporting. Two studies[32 39] were considered as moderate risk because of selective reporting of significant findings. Three studies[33 38 41] were considered high risk. One[33] did not use any form of statistical modelling and selective reporting was evident. Another[41] described the effect measure as relative risk, which was either inappropriate for the Cox proportional hazard model used or due to reporting inaccuracy. One study[38] reported only significant PFs, using a high significance level of 0.20, and referred the reader to online appendices for all results, which were unavailable for download.

Data synthesis

Results of studies

All PFs with associated effect measures, CIs and p values for all included studies are presented in online supplementary file 3. Significant PFs, or factors investigated by multiple studies, per outcome are summarised in table 2. To aid understanding of this table, PFs have been grouped according to specific injury outcomes that were defined within the included literature. For factors presented in the table, the evaluation of the related evidence according to modified GRADE assessment domains is also presented.

All evidence was low or very low quality (table 2). Significant methodological limitations were evident and as significant PFs were derived predominantly from single studies, examination of consistency was limited. Effect measures were variable across factors, but imprecision of effect was common and a sample size calculation was reported by only two studies.[34 43] Due to the paucity of literature, publication bias was likely.

Muscle injuries

Muscle injury outcomes were investigated in male participants only. Six significant PFs were identified for quadriceps and calf injuries and four for adductor injuries (table 2), derived from one study.[37] Two significant factors for groin strain were found in one study[30] (table 2).

It was unclear whether adductor and groin strain injuries were comparable due to lack of diagnostic criteria presented and have been treated as separate entities.

Nineteen significant factors associated with HSIs were identified, with 14 via single studies (table 2). Two studies[36 37] investigated increased age and history of previous HSI using HRs, as summarised in figure 2.

Increased age was investigated through univariate analysis only. Hagglund *et al*[36] reported that for every 1 year increase in age, there was an associated small increase in hazard, with a narrow CI lying on the border of significance. However, their later study[37] demonstrated no significant association. In both studies, previous HSI was significantly associated with increased hazard for further HSI, in both univariate and multivariate analyses. Hagglund *et al*[36] reported a greater estimated association with larger CIs, possibly due in part to the much smaller sample size. Using ORs, two studies investigated increased age[30 39] and two studies investigated previous HSIs[30 34] as PFs for new HSIs using multivariate analyses (figure 3).

Similar to the HR analysis, there was consensus that for every 1 year increase in age, odds of developing a HSI were significantly increased,[30 39] although effect sizes were small (range 1.40–1.78). In contrast, there was no agreement regarding the effect of previous HSI on the odds of sustaining a new HSI; point estimates lay either side of the line of no effect with very wide CIs, suggesting a considerable lack of precision and may be related to methodological or sample size differences.

Ligament injuries and tendinopathies

Outcomes related to ligament injuries and tendinopathies relied on a smaller evidence base, also of low to very low quality (table 2) and included ankle and knee

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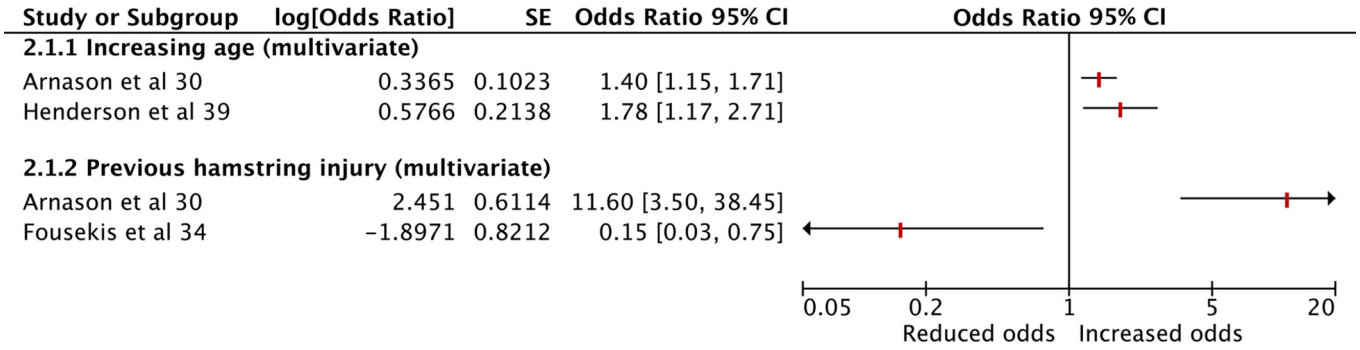


Figure 3 Graph presenting hamstring injury prognostic factors in male participants, investigated by multiple studies—OR analyses.

sprain, ACL tear and patellar tendinopathy. Two studies[30 33] investigated the association of a previous ankle sprain with new ankle sprain and a previous knee sprain with new knee sprain, using ORs in male and female participants, respectively. This permitted a limited subgroup analysis (figure 4).

Significant positive associations for both outcomes were found in the male-only study,[30] while non-significant positive associations were reported in the female-only study.[33] It was difficult to ascertain whether these inconsistencies were due to gender, methodological quality or statistical power. Differences in statistical methods may also have been influential. In terms of ankle sprain outcomes, all other PFs of weight, body mass index and eccentric ankle strength asymmetry related to male players only and were reported by one study (table 2).[35] One study reported that a previous anterior cruciate ligament (ACL) injury was significantly associated with a new ACL injury in females,[33] while another study reported that previous ACL injury was significantly associated with both traumatic and overuse knee injuries in males[41] (table 2). Three significant factors associated with patellar tendinopathy were observed by one study of male participants.[38]

Injuries defined by anatomical location

PFs for outcomes defined per anatomical location rather than by diagnosis are summarised in table 2. Predominantly these were obtained from a single study[40] of female players, although groin and knee injuries in males were investigated by one study per respective outcome.[36 41] None of these outcomes could therefore be compared in multiple studies.

DISCUSSION

This review has evaluated the evidence related to PFs or prognostic models for specific lower extremity and spinal musculoskeletal injuries identified through medical screening and training load monitoring processes in professional football. Overall, the paucity, heterogeneity and methodological limitations of the literature meant that the current evidence was of very low or low quality. Within our review, the between-study heterogeneity which limited comparisons between PFs and outcomes may be partly explained by differences in individual clubs' screening and monitoring practices, confirmed previously through international questionnaires.[10 25] The overall limitations in quantity of evidence may be explained in part by a possible reluctance of individual clubs to share data within the research community for fear of losing a competitive advantage. This highlights the potential value of conducting large multi-team cohort studies of professional players such as those identified within this review.[30 31 33–38 40–43] On the few occasions where multiple studies could be used to compare PFs and

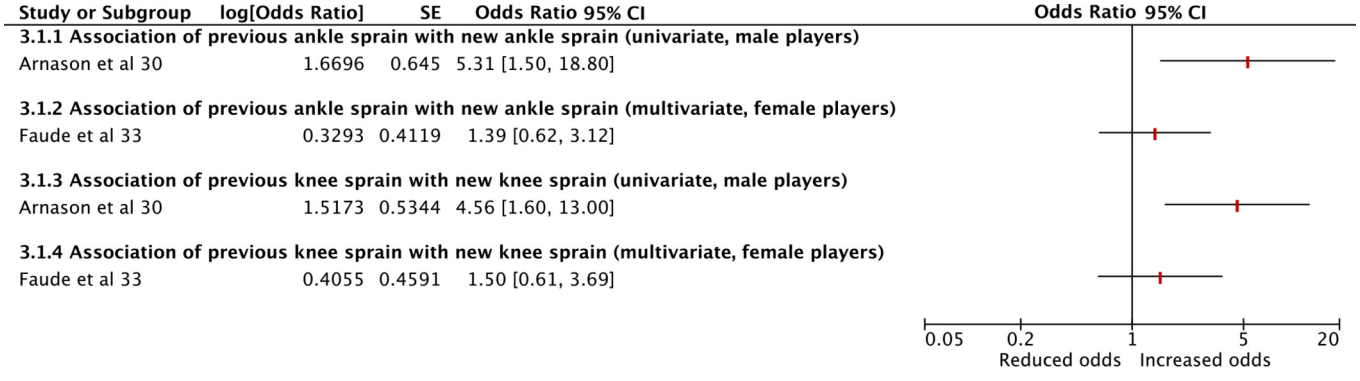


Figure 4 Graph presenting prognostic factors for ankle sprain and knee sprain injuries, investigated by two or more studies—OR analyses.

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outcomes, only two factors demonstrated consensus. That is, in terms of prognostic value for future HSIs in male professional football players, a history of previous HSI appears to increase hazard ratio,[36 37] while increasing age appears to elevate the odds of a new HSI occurring.[30 39] No studies were found to have examined spinal injury outcomes.

Although most studies used multivariable models to examine PF interactions, none had set out to develop a prognostic model or validated injury prediction performance of a model prospectively. Therefore, the current evidence base is relevant only to the initial stages of prognostic model development, which is identifying potential candidate PFs to consider including in models.[14 44]

While PFs from traditional medical screening methods were assessed,[30 33–42] surprisingly only one study examined an imaging modality[43] and no studies investigated training load monitoring derived from technology such as GPS or heart rate measures. Although five studies[30 33 37 40 41] recorded training and match exposure in terms of time units, only one study analysed this as a PF, for patellar tendinopathy. The results of this study suggested that for every 10 hours increase in total football exposure, the odds of developing patellar tendinopathy in male professional players increased by a factor of 1.02 (95% CI 1.0 to1.04).[38] No other studies were available to assess the consistency of these findings and with the insufficient volume of evidence it could be argued that the prognostic value of training load monitoring for specific lower extremity or spinal injuries is unknown at present.

After identifying high-quality cohort studies of professional footballers, an earlier review found that a history of previous injury was a significant PF for future injuries of the same type and other locations. This included that a history of HSI was strongly associated with new HSI.[24] McCall *et al*[24] also found that there was insufficient evidence to evaluate the effect of fatigue, muscle imbalance, FMS and isokinetic testing as PFs for injuries. Although McCall et al[24] did not locate studies relating to fatigue, our review identified two studies[31 32] which investigated recovery time between games or match fixture congestion. These factors could be indirectly related to fatigue. We found that in agreement with McCall *et al*,[24] there was insufficient evidence to establish the prognostic value of isokinetic muscle testing and FMS. Our review demonstrates consensus with this prior review that a previous HSI increases risk of a future HSI. However, we have also identified that increasing age may also be influential on HSI, which has not been reported previously. Despite this agreement there was a discrepancy noted in the quality of included studies in our review and the findings of McCall *et al*.[24] Our review found that all evidence related to previous injury was potentially subject to major biases and consistency of results could not be examined for most factors, other than the effects of increasing age and previous HSI on future HSIs.[24]

The differences in reported evidence quality between reviews may be due to different appraisal systems. McCall *et al*[24] used the Scottish Intercollegiate Guidelines Network (SIGN) tool for appraisal, whereas we used the QUIPS tool and modified GRADE framework which are specific to prognostic research and arguably more suitable for the study designs reviewed. Considerable differences in inclusion and exclusion criteria existed and also, our study chose to investigate specific musculoskeletal outcomes of the the lower extremities and spine only rather than musculoskeletal injuries affecting all body areas. Additionally, McCall *et al*[24] investigated only a limited selection of PFs and screening tests identified through a survey, whereas this review attempted to provide an exhaustive examination of all PFs related to screening and training load monitoring in professional football.[45]

In terms of reporting quality, all studies within our review consistently performed poorly in the domains of PF measurement and study confounding. Outcome measurement was a very serious limitation and subject to risk of major misclassification bias due to the lack of specific diagnostic criteria or utilisation of gold standard diagnostic measures. This diagnostic imprecision means that it is questionable if these outcomes can actually be attributed to specific pathologies. It is clear that research quality in football prognostic studies needs to improve through transparent reporting of reliability and validity measurements, explicit identification of confounding factors and the use of clinical diagnostic criteria and/or confirmatory diagnostic modalities to accurately establish the presence of an injury outcome. Until such time, associations between potential PFs and specific injuries should be considered non-robust. A greater and improved evidence base is also necessary to assist future development of prognostic models in an attempt to predict individual injury outcomes. Many of the issues highlighted in this review relate to the reporting rather than necessarily the conduct of the studies included. It is hoped that recommendations aiming to improve the transparency of prognosis research[46] will improve the quality of evidence available in the future.

What does this mean to clinicians?

Our results suggest that the ability of medical screening tests to predict specific musculoskeletal injury risk is not supported by the current evidence. Extrinsic non-modifiable factors of age and previous injury may be the only PFs associated with further HSIs, although this is supported by low-quality evidence. At present, screening tests should only be considered as markers of individual musculoskeletal function or performance and therefore primarily useful as benchmarks following

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injury or in the evaluation of training effects. Presently, when considering specific lower extremity or spinal injuries the prognostic value of load measures is unknown.

Limitations

Despite a thorough literature search using MeSH terms and keywords, certain relevant studies may have been missed. As the search was limited to articles published in academic journals only, this may have introduced some publication bias. Also, both reviewers were not blinded to the authors of the papers included for appraisal. Also, although the QUIPS appraisal tool has been stated to have moderate to near perfect reliability,[29] inter-rater reliability was not formally evaluated in our review. Nevertheless, this is the only known systematic review that has evaluated PF for lower extremity and spinal injuries in professional football (soccer) players, using specific prognostic research appraisal and synthesis tools.

CONCLUSION

The current evidence suggests that a previous HSI and increasing age may be associated with development of future HSIs in male professional football players. This must be interpreted with caution, as significant issues and complexities within the literature have been highlighted. This limits current understanding of PF accuracy through medical screening and training load monitoring. Further research is essential to help further the knowledge base of this important area of football and sports medicine.

Summary box

WHAT IS ALREADY KNOWN?

- In professional football, the risk of sustaining a lower extremity musculoskeletal injury is considerable.
- Medical screening and training load monitoring processes are commonly used to identify prognostic factors for injury and develop preventative strategies to reduce risk.
- Several previous systematic reviews have investigated prognostic factors for injury identified through screening tests generally in sport.
- One previous review has investigated a limited number of prognostic factors through screening tests in professional football.

WHAT ARE THE NEW FINDINGS?

- The evidence is of low to very low quality.
- Previous hamstring injury and increasing age may increase the risk of a future hamstring injury in male professional players. The limitations of the evidence mean that the contribution of other prognostic factors cannot be fully excluded and currently the ability of medical screening procedures to predict specific injury risk is unsubstantiated.
- The prognostic value of training load monitoring is unknown.
- Future studies are needed to improve understanding of the prognostic value of medical screening and training load monitoring in professional football.

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Acknowledgements The authors would like to thank Professor David Felson, Professor Ian Bruce and Mary Ingram at the University of Manchester. The authors would also like to thank all staff within the medical department at Manchester United (especially Dr. Steve McNally, Neil Hough, John Davin, Richard Merron, Jonathan Picot and Russ Hayes) for their help and support with this review. This report includes independent research supported by the National Institute for Health Research Biomedical Research Unit Funding Scheme. The views expressed in this publication are those of the authors and not necessarily those of the NHS, the National Institute for Health Research or the Department of Health. The authors also thank Arthritis Research UK for their support: Arthritis Research UK grant number 20380.

Contributors Literature searching (TH, MP), data extraction (TH, MJC), data appraisal (TH, JCS, MJC), data synthesis (TH), data interpretation (TH, JCS, MJC) manuscript writing (TH, JCS, MJC), manuscript review (TH, JCS, MP, MJC).

Funding The lead reviewer (TH) is currently receiving sponsorship by Manchester United Football Club Limited to complete a PhD study programme.

Competing interests None declared.

Patient consent None.

Provenance and peer review Not commissioned; externally peer reviewed.

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