Exercise-Based Strategies to Prevent Muscle Injury in Elite Footballers: A Systematic Review and Best Evidence Synthesis

Maurizio Fanchini, Ida Bo Steendahl, Franco M. Impellizzeri, Ricard Pruna, Gregory Dupont, Aaron J. Coutts, Tim Meyer, et al.

Sports Medicine

ISSN 0112-1642
Volume 50
Number 9

Sports Med (2020) 50:1653-1666
DOI 10.1007/s40279-020-01282-z

Sports Medicine (2020) 50:1653–1666
https://doi.org/10.1007/s40279-020-01282-z

SYSTEMATIC REVIEW

Exercise-Based Strategies to Prevent Muscle Injury in Elite Footballers: A Systematic Review and Best Evidence Synthesis

Maurizio Fanchini[1,2] · Ida Bo Steendahl[3,4] · Franco M. Impellizzeri[5] · Ricard Pruna[6] · Gregory Dupont[7] · Aaron J. Coutts[5] · Tim Meyer[3] · Alan McCall[6,8,9]

Published online: 18 March 2020

Abstract

Background Exercise-based strategies are used to prevent muscle injuries in football and studies on different competitive-level populations may provide different results.

Objectives To evaluate the effectiveness of exercise-based muscle injury prevention strategies in adult elite football.

Methods A systematic search was conducted in PubMed (MEDLINE), Web of Science, Cochrane Library, and SPORTDiscuss (EBSCO). We considered only elite adult (> 16 year-old) football players with no distinction for gender; the intervention to be any exercise/s performed with the target to prevent lower-limb muscle injuries; the comparison to be no injury prevention exercise undertaken; the outcome to be the number of injuries, injury incidence, and severity. We searched systematic reviews, randomized-controlled trials (RCTs), and non-randomized-controlled trials (NRCTs), limited for English language. Risk of bias was assessed using the Risk of Bias in Systematic Reviews tool, the Cochrane Collaboration's Tool for assessing risk of bias in RCTs, and the Risk of Bias in NRCTs of Interventions tool.

Results 15 studies were included. Three systematic reviews showed inconsistent results, with one supporting (high risk of bias) and two showing insufficient evidence (low risk of bias) to support exercise-based strategies to prevent muscle injuries in elite players. Five RCTs and seven NRCTs support eccentric exercise, proprioception exercises, and a multi-dimensional component to an injury prevention program; however, all were deemed to be at high/critical risk of bias. Only one RCT was found at low risk of bias and supported eccentric exercise for preventing groin problems.

Conclusion We found limited scientific evidence to support exercise-based strategies to prevent muscle injury in elite footballers.

Trial Registration Number PROSPERO CRD42017077705.

1 Introduction

Muscle injuries in professional football are of major concern to teams as they can have a negative impact on performance (through lower player availability) and club economy as well as the potential for increased risk of subsequent injury. Muscle/tendon injuries show high incidence (assessed as number of injuries per 1000 h of activity) compared to contusions, other injuries, joint and ligaments, bone fractures, and skins lesions (i.e., 4.6 vs 1.4, 0.6, 0.4, 0.2, 0.05 per 1000 h of activity, respectively) [1]. The mean absence from activity due to muscle injuries has been showed to be 15.9 days with an injury burden of 43.1 days per 1000 h of total activity that has been assessed in a cohort of 24 teams participating in the UEFA Champions League study [2]. A professional team with a squad of 25 players can expect approximately 16 time-loss muscle injuries per season with most (92%) affecting the hamstrings, quadriceps, adductors, and calves [2]. Specifically, the average number of muscle injuries in men's professional football can be broken down to 6 hamstring, 3 quadriceps, 3 adductors, 1–2 calves, and 1–2 'other' muscles [3].

The gold standard approach to optimising high-performance outcomes such as injury prevention in professional team sports is considered through the adoption of an 'evidence-based practice (EBP) approach' [4]. An EBP approach involves a combination of high-quality research (i.e., scientific evidence) and current best practice (i.e., practitioner

Electronic supplementary material The online version of this article (https://doi.org/10.1007/s40279-020-01282-z) contains supplementary material, which is available to authorized users.

✉ Maurizio Fanchini
maurizio.fanchini@gmail.com

Extended author information available on the last page of the article

Key Points

Systematic reviews (level 1 evidence) do not support the belief that exercise-based strategies are effective for preventing muscle injury in elite football players.

Randomized-controlled trials do support the use of eccentric exercise; however, they are mainly at high or unclear risk of bias.

Non-randomized-controlled trials also support eccentric and proprioception exercises with a multi-dimensional component to an injury prevention program, but they showed critical risk of bias.

There are no clear practical applications for exercise-based muscle prevention strategies in elite football players that are based on high level of scientific evidence.

experience). In professional environments, EBP can be implemented by integrating knowledge and key findings from research evidence with coach/practitioner experience, players' values, and feasibility/practicality of implementing such evidence.

Exercise-based strategies are frequently used by professional teams to prevent muscle injury [3]. To the authors' knowledge, the most recent systematic review (considered a high level of evidence) addressing exercise-based prevention strategies specifically in professional footballers was published in 2015 and searched only articles up until 3rd September 2014 (~ 5 years old) [3]. McCall et al. [3] assessed the scientific evidence underpinning what professional football team practitioners actually prescribe to their players. Overall, while the most commonly used exercise-based strategies included eccentric exercise and balance/proprioception, the actual scientific evidence supporting these strategies was weak. Since this systematic review, research, and practitioners interest in the area of injury prevention have continued to increase and, therefore, an update including the last half decade would be appropriate and useful. Additionally, while we expect to capture the same studies pre 2015 as the review by McCall et al. [3], they, however, did not assess the risk of bias of the studies and this would be a key insight for a more accurate interpretation of the results and practical applications.

Therefore, the aim of the present study is to carry out a systematic review to determine the current level of scientific evidence (i.e., based on the risk of bias of studies) regarding the effectiveness of exercise-based muscle injury prevention strategies in adult elite football.

2 Methods

The Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) has been used as guideline. The Methods section was registered at PROSPERO (ID = CRD42017077705) and no deviations have been made.

2.1 Eligibility Criteria

To provide a best evidence-based synthesis, we included a variety of levels of evidence (i.e., not only level I); meta-analysis, systematic reviews, randomized-controlled trials (RCTs), and non-randomized studies (NRCTs). All of these levels of evidence are used by practitioners to guide their practice and provide recommendations to their athletes; therefore, it was important not to exclude based on study type. To be included, studies were required to be full text (not abstract only) and satisfy the following criteria: only elite (defined as players involved in the top three leagues of each country) adult (> 16 years old) football players were considered with no distinction for gender. The only restriction in eligibility criteria was the language, as only articles in English were considered.

2.2 Search Strategy

The same systematic search was performed in PubMed (MEDLINE), Web of Science, Cochrane Library, and SPORTDiscus (EBSCO) until June 2018 (with an updated search at November 2019) with no restriction for year of publication. The Medical Subject Heading (MeSH) tool was used to create a list of terms that were used to perform the systematic search. The text "exercise as prevention strategy of muscle injuries in elite football and soccer" was added in the MeSH on demand tool and the following terms resulted: soccer, football, muscular disease, and exercise. The following search strategy adapted for each database (full text and Medical Subheading terms where appropriate) was used: (soccer OR football) AND (exercise) AND (muscle injury prevention OR muscular disease). In addition, hand searching and reference checking have been performed to search other relevant reports in addition to consulting research experts in the relevant area. SPORTDiscus database was used for checking the Grey literature and clinicaltrials.gov for registered protocols and studies.

The inclusion criteria were based on the Population, Intervention, Comparison, Outcome (PICO) concept as follows: population was considered as elite (high level) adult soccer and/or football players; interventions were considered as all physical exercises performed to prevent lover limb muscle injuries; comparisons were considered as no injury prevention exercise undertaken; outcomes were considered as the number of injuries, injury incidence, and injury severity.

2.2.1 Study Selection

Two authors (MF and IBS) independently performed the study selection based on title and abstract screening and subsequent full-text evaluation. Studies were included following agreement between the two authors (MF and IBS). Disagreements were solved after involvement of a third author (AM). After inclusion of the studies, data regarding sample size, gender, age, muscle group, intervention, and results were extracted and reported independently by two authors (MF and AM) and verified for accuracy. PRISMA flow diagram for the description of the overall process is in Fig. 1. The list of included and excluded studies (with reasons) is presented as supplementary material (Appendix 1).

2.3 Level of Evidence and Risk of Bias

The level of evidence was assessed with the Oxford Centre for Evidence-Based Medicine 2011 levels of Evidence (OCEBM) for treatment benefits [5].

In addition as a summary of the level of scientific evidence, the following classifications as suggested by van Tulder et al. [6] have been adopted: strong evidence: provided by two or more high-quality studies and by generally consistent findings across these studies; moderate evidence: provided by one high-quality study and/or multiple studies of acceptable quality and by generally consistent findings; limited evidence: provided by one study of acceptable quality and/or one or more studies of borderline quality; conflicting evidence: inconsistent findings in multiple studies. Findings in the studies have been rated consistent or inconsistent when ≥ 75% or < 75% of the studies reported same directions in the findings [7].

Risk of bias for systematic reviews, RCTs and NRCTs, was assessed using the Risk of Bias in Systematic Reviews tool (ROBIS) [8], the Cochrane Collaboration's Tool for assessing risk of bias in randomized studies [9], and the Risk Of Bias In Non-Randomized Studies of Interventions tool (ROBINS-I) [10].

Each of the above tools for assessing risk of bias is domain-based evaluation tools. As supported by Higgins et al. [9], authors should assess the risk of bias with judgement through different domains and quotes to support their judgement. The author's judgement should be preferred to checklists or scales [9]. ROBIS has three phases: phase 1—assess relevance (that is optional and was not used in the present study), phase 2—assess concerns in different domains of bias (i.e., study eligibility, identification and selection of the studies, data collection and study appraisal, synthesis, and findings), and phase 3—judgement on risk of bias in the review. The Cochrane Collaboration tool consists of two parts (description of what has been done in the study and judgement on risk of bias) based on the assessment in following domains: sequence generation, allocation concealment, blinding, incomplete outcome data, selective outcome reporting, and other issues. The ROBINS-I tool assess the risk of bias in NRCTs based on a priori evaluation of confounders and co-interventions that may lead to bias in the studies. Previous injury, muscle strength, and/or endurance and exposure to training and competitions were considered confounders as they can be considered as risk factors to muscle injuries. Training and match loads, type of training (other than exercise prevention), strength training, flexibility, fitness level, and fatigue were considered as co-interventions, because they can interfere with the treatment (i.e., injury prevention exercise) and could affect the outcome of the study.

Two authors (MF and AM) independently performed the ROBIS and ROBINS-I, agreements and disagreements were checked and a third contributor (i.e., IBS) was involved in checking disagreements and had the deciding vote. Risk of bias for randomized-controlled trials was assessed with the Cochrane Risk of Bias tool by two authors (MF and IBS) with the contribution of a third author (AM) to check and solve disagreements. Percentage agreement between authors was assessed before the final decision of the third reviewer for study selection at two stages (i.e., title and abstract screening and full-test selection); in addition, Kappa coefficient was calculated (i.e., idostatistics.com) and considered as follows: 0.01–0.20 slight agreement, 0.21–0.40 fair agreement, 0.41–0.60 moderate agreement, 0.61–0.80 substantial agreement, and 0.81–1.00 almost perfect or perfect agreement.

3 Results

3.1 Search results

A systematic search through all the 4 databases provided 8382 records, which were imported into EndNote and deduplicated (i.e., 4207 records were duplicates). After screening title, abstract, and full text (using Covidence Software, Covidence.org), our search identified 3 systematic reviews, 4 RCTs, 1 cluster RCT, and 7 (2 after an additional update search) NRCTs that were included in the final systematic review. Percentage agreement and Kappa coefficient between the two reviewers were 97% and Kappa 0.60 for title and abstract selection, and were 81% and Kappa 0.36 for full-test selection, showing substantial and fair agreement between the two authors at the two stages before the third author's judgement. The OCEBM level of evidence is presented in Table 1 and the PRISMA flowchart in Fig. 1. Data

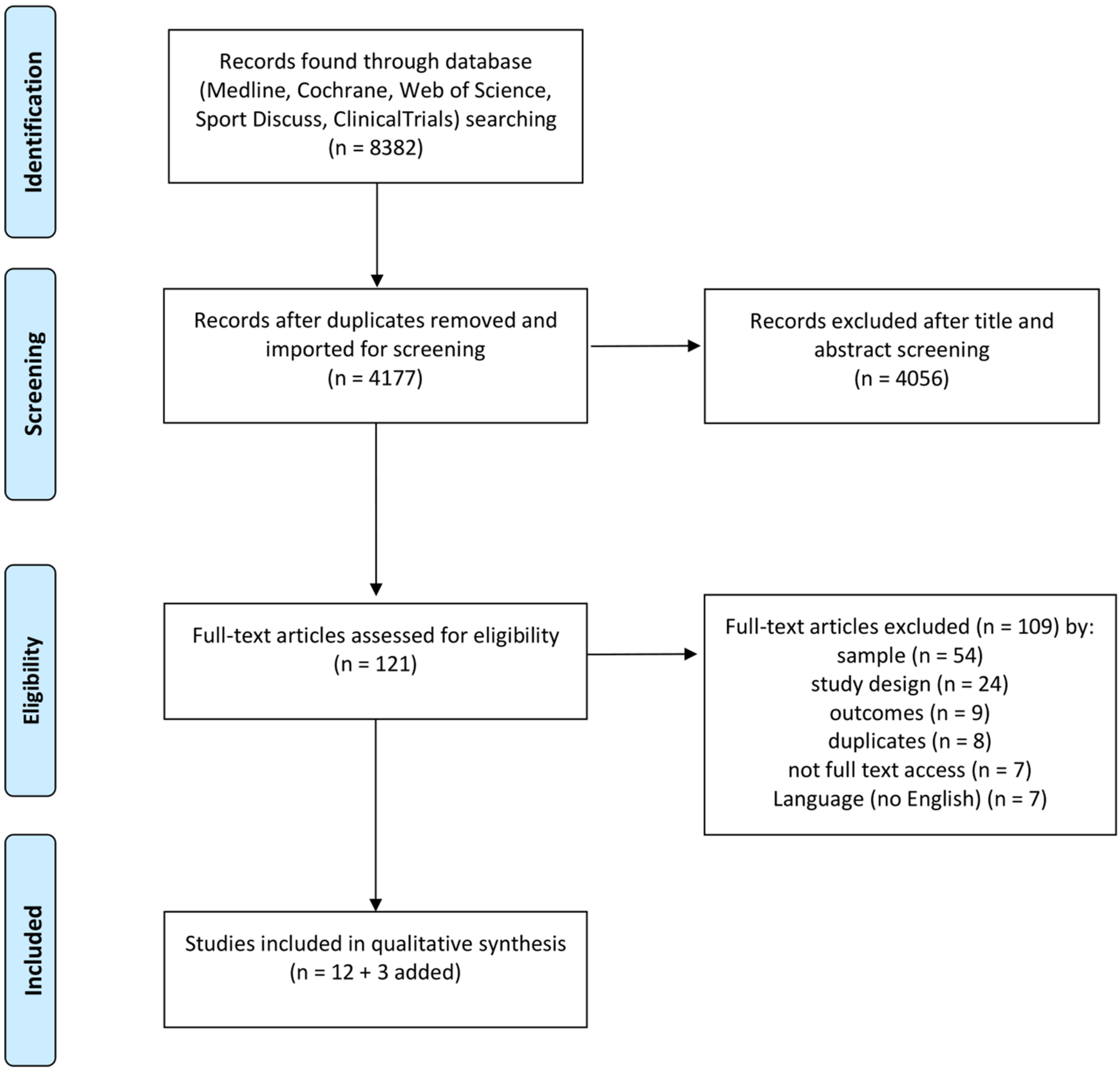

Fig. 1 PRISMA flow diagram for the description of the overall process

of the included RCTs and NRCTs are presented in Tables 2 and 3. List of excluded studies and reasons for exclusions are provided in Appendix 1.

3.2 Results from Different Level of Evidence

Level I studies showed contradictory results. The Systematic review of Michalis and Apostolos [11] supported the eccentric exercises and neuromuscular training programs with stabilization core exercises, balance, as well as flexibility exercises for reducing hamstring strain. However, the systematic reviews of McCall et al. [3] and Rogan et al. [12] showed that there is low evidence to support eccentric, balance, and static stretching as exercises to prevent muscle injuries. Level 2 studies (RCTs) showed contradictory results with some studies [13–15] supporting eccentric exercises and other studies [16, 17] not supporting eccentric exercise for muscle injury prevention. The level 3 and 4 studies (NRCTs) [18–24] all supported exercises as effective to prevent muscle injuries.

Between different levels of evidence, only two studies [14, 20] examined women's football. The RCT of Espinosa et al. [14] supported the eccentric exercise (i.e., Nordic Hamstring) to prevent the injuries of the hamstring muscles as well as the NRCT of Kraemer et al. [20] supported balance and proprioception exercises to prevent hamstring and calf muscle injuries.

3.3 Risk of Bias Assessment

Systematic reviews showed (ROBIS tool) high risk of bias in the study of Michalis and Apostolos [11] as well as low risk of bias in the studies of McCall et al. [3], and Rogan et al. [12] (Table 4, Fig. 2).

A summary of the risk of bias in RCT's and the various domains of potential bias (Cochrane Collaboration's tool) are displayed in Table 5 and Fig. 3. For all of the included RCTs, the main concerns relate to selection bias, performance bias, and detection bias. We considered that blinding outcomes (i.e., occurrence of injury) to the participants is impossible and, therefore, considered this less important in the summary of risk of bias assessment. The studies by de Hoyo et al. [16], Engebretsen et al. [17] and Espinosa et al. [14] were rated at high risk of selection bias due to a lack of describing the methods used to generate random sequences and to allocate the participants to experimental or control group. The study by Askling et al. [13] and Haroy et al. [15] was rated at unclear and low risk of selection bias, respectively.

Table 1 The Oxford Centre for Evidence-Based Medicine levels of Evidence (OCEBM) for the included studies

Author, year	Study	OCEBM level
Michalis 2016 [11]	Systematic review	1
McCall 2015 [3]	Systematic review	1
Rogan 2013 [12]	Systematic review	1
Askling 2003 [13]	RCT	2
de Hoyo 2015 [16]	RCT	2
Engebretsen 2008 [17]	RCT	2
Espinosa 2015 [14]	RCT	2
Harøy 2018 [15]	Cluster RCT	2
Arnason 2008 [18]	NRCT	3
Croisier 2008 [19]	NRCT	3
Kraemer 2009 [20]	NRCT	3
Elerian 2019 [21]	NRCT	3
Owen 2013 [22]	NRCT	4
Melegati 2013 [23]	NRCT	4
Izzo 2019 [24]	NRCT	4

RCT randomized-controlled trail, *NRCT* non-randomized-controlled trial

Performance bias was judged at high risk of bias for four studies [13, 15–17], because personnel involved (i.e., researchers, fitness coaches, or physiotherapist) were not blinded to the allocation of participants to the interventions; the study by Espinosa et al. [14] was judged at unclear risk of bias. Incomplete outcome reporting was found for de Hoyo et al. [16], because the number of subjects involved was different compared to follow-up group. In addition, another source of bias was found for de Hoyo et al. [16], because it was not possible to exclude the effects of difference in training load between the experimental and control groups. The study of Haroy et al. [15] was rated at low risk of bias in different domains (selection bias, attrition bias, and reporting bias).

Of the NRCTs included, there were three cohort studies [18–20] and four case studies [21–24]. Our results showed an overall critical risk of bias in all the studies examined (Table 6). The potential effect of confounders was not controlled at baseline, during the study (by monitoring the overall process) and through appropriate analysis in any of the studies. Selection bias was serious in Arnason et al. [18] and Croisier et al. [19] (due to self-selection), since each team decided to be involved in the study as intervention or control group. Classification of the interventions was not clearly defined and details of training and/or match loads were not presented in all the studies. Bias due to deviation from intended intervention was critical, because co-interventions were not controlled as well as adherence and compliance were either not reported or they were low. Missing data without adjustment analyses were critical in Croisier et al. [19] and Melegati et al. [23]. Bias in the outcome assessment was found in all the studies as none of the assessors were blinded to the intervention received by the players. Bias due to selection of the reported results was low for almost all of the included studies; however, due to a lack of pre-registered protocol, the rating given was moderate [10]. Elerian et al. [21] registered (retrospectively) their study protocol; however, no statistical analysis has been presented in the method section of the protocol; therefore, the rating given was moderate.

4 Discussion

Exercise is one of the most common and importantly perceived strategies implemented by elite football teams to prevent muscle injury. Our results, however, revealed two low risk of bias systematic reviews both concluding that there is no high-level scientific evidence to support the effectiveness of exercise strategies to prevent muscle injuries in elite footballers. Despite a number of RCTs advocating the

Table 2 Randomized-controlled trials included in the systematic review

Study	Sample	Muscle group	Intervention	Outcome measure	Results	Main findings
Askling 2003 [13]	30 (15 INT, 15 CON) male (24 yrs), soccer players, Premier-league Sweden	Hamstring	Eccentric training; Yo–Yo Leg Curl, 4 sets × 8 reps (1° warm-up)	N of injuries	INT 3; CON 10. Lower injuries in INT vs CON ($p < 0.05$)	Support the eccentric training for hamstring injury prevention
de Hoyo 2015 [16]	36 (18 INT, 15 CON) male (17 yrs) young elite Spanish soccer players	All muscles	Eccentric training; Half squat and YoY o Leg Curl, 2 sessions × week, 3 sets × 6 reps in weeks 1–4, 4 sets × 6 reps in weeks 5–6, 5 sets × 6 reps in weeks 7–8, 6 sets × 6 reps in weeks 9–10	Injury incidence	Difference pre–post-intervention: INT 14.2% (90% CL, − 2; 28); CON − 22% (90% CL, 31; − 117). No different injury incidence in INT vs CON	Does not support the eccentric training as injury prevention
				Injury incidence	Difference pre–post-intervention: INT 48% (90% CL, 23; 64); CON − 48% (90% CL, − 260; 38). Less injury severity in INT vs CON	Support eccentric exercise for lower severity
Engebretsen 2008 [17]	508 (Hamstring 85 INT, 76 CON; Groin 62 INT, 98 CON) male Norwegian 1st, 2nd, or the top of the 3rd division	Hamstring	Eccentric training; Nordic Hamstring (progression from 2 sets × 5 reps to 3 sets × 12,10,8 reps after 4 weeks)	Injury incidence	Injury incidence: INT 1.5 (95% CL, 0.9–2.0); CON 0.9 (95% CL, 0.5–1.4). No different injury incidence in INT vs CON ($p = 0.17$)	Does not support the eccentric training as injury prevention
		Groin	Groin program (3 times/week a 15′ program with transverse abdominal, sideways jumps, sliding, diagonal walking)	Injury incidence	Injury incidence: INT 0.9 (95% CL, 0.4–1.4); CON 0.7 (95% CL, 0.4–1.1). No different injury incidence in INT vs CON ($p = 0.67$)	Does not support groin program as injury prevention
Espinosa 2015 [14]	43 female (22 INT, 21 CON) (21 yrs), Spain first and second Division	Hamstring	Eccentric training; Nordic Hamstring and eccentric band exercise for 21 weeks	N of injuries	INT 1; CON 5. Not significant relative risk in INT vs CON 0.19 (95% CL, 0.02–1.50). Reduction risk of injury 81%	Support eccentric training as injury prevention
Harøy 2018 [15]	652 male players (122 INT, 242 CON) (22-24 yrs) Norwegian 2 and 3 level	Groin-adductors	Adductor Strengthening Program. Pre-season 2 to 3 weeks session of 1 set × 3–15 reps, in-season 1 session of 1 × 12–15 reps.	N of injuries	Groin problems (with no severe reduction of activity) EXP 11.7% (95% CL, 10.9-12.5) CON 21.3% (95% CL, 20–22.6); Substantial groin problems (with substantial reduction of activity) EXP 4.5% (95% CL, 4.1–5.1) % CON 8% (95% CL, 7.5–8.5)	Support eccentric exercise for groin problems

INT intervention group, *CON* control group, *RR* relative risk

Table 3 Non-randomized-controlled trials included in the systematic review

Study	Sample	Muscle group	Intervention	Outcome measure	Results	Main findings
Arnason 2008 [18]	Male, Icelandic and Norwegian top leagues	Hamstring	Flexibility exercise	Injury incidence (injuries/1000 h)	INT 0.54/1000 h; CON 0.35/1000 h; RR 1.53 (95% CI 0.76; 3.08); no different incidence in EXP vs CON	Does not support flexibility as injury prevention
					INT 0.54/1000 h; CON (all teams previous year) 0.52/1000 h; RR 1.03 (95% CI 0.59; 1.79); no different incidence in INT vs CON in the previous year	Does not support flexibility as injury prevention
					INT 0.54/1000 h; INT (previous year) 0.61/1000 h; RR 0.89 (95% CI 0.42; 1.85); no different incidence in INT vs INT in the previous year	Does not support flexibility as injury prevention
			Eccentric training; Nordic Hamstring 3 × 12, 10, 8		INT 0.22/1000 h; CON 0.62/1000 h; RR 0.35 (95% CI 0.19; 0.62); injury incidence 65% lower in INT vs CONC	Support the eccentric training as injury prevention
			Flexibility exercise	Severity	INT 12% minor, 29% moderate, 59% severe; CON 50% minor, 50% moderate, 0% severe; lower severity ($p = 0.0006$) in INT vs CON	Support flexibility for low injury severity
					INT 12% minor, 29% moderate, 59% severe; INT baseline 10% minor, 20% moderate, 70% severe; no different severity ($p = 0.85$)	Does not support flexibility for lower severity
			Eccentric training; Nordic Hamstring 3 × 12, 10, 8		INT 27% minor, 64% moderate, 9% severe; CON 36% minor, 50% moderate, 14% severe; no difference ($p = 0.88$) in INT vs CON	Does not support eccentric training for lower severity
					INT 27% minor, 64% moderate, 9% severe; INT baseline 29% minor, 21% moderate, 50% severe; more severe ($p = 0.024$) in INT at baseline vs INT	Support the eccentric training for lower severity

Table 3 (continued)

Study	Sample	Muscle group	Intervention	Outcome measure	Results	Main findings
Croisier 2008 [19]	462 male (26 years), Belgian, Brazilian, and French professional teams	Hamstring	Treatment at own Club (no details)	Frequency % of injuries per players in each group	CON_A no imbalance: 4,1%; INT_B imbalance, no compensation: 16,5%; INT_C imbalance, compensation, normalization not verified: 11%; INT_D imbalance, compensation, normalization verified: 5.7%	Restoring a normal balance between agonist and antagonist muscle groups (isokinetic assessment) significantly decreases the risk of injury
Kraemer 2009 [20]	24 female (22 years) Elite Germany premiere league	Hamstring	Balance training	Injury incidence (injuries/1000 h)	INT 7.0/1000 h; CON 11.9/1000 h; ($p < 0.05$)	Support the proprioception balance training as injury prevention
		Calf	Balance training		INT 3.4/1000 h; CON 6.0/1000 h; ($p < 0.05$)	Support the proprioception balance training as injury prevention
Melegati 2013 [23]	36 male soccer players elite Italian team	All	Multicomponent prevention intervention	Injury incidence (injuries/1000 h)	CON period 5.6/1000 h; INT period 2.5/1000 h	Support the multicomponent training as injury prevention
Owen 2013 [22]	28 male elite soccer players	All	Multicomponent prevention intervention	N of injuries	INT period n 22 injuries; CON period n 37 injuries. INT less muscle injuries ($p < 0.001$)	Support the multicomponent training as injury prevention
Elerian 2019 [21]	34 male professional football players	Hamstring	Eccentric training: Nordic Hamstring Group 1 = pre- and post-training, Group 2 = only pre-training	N of injuries	INT Group 1 n 1 injury and Group 2 n 4 injuries; CON 20 injuries	Support eccentric training as injury prevention
Izzo 2019 [24]	25 male professional soccer players (Italian 3rd division)	All	Functional Primitive Movement WTA (dynamic movement to activate muscles kinetics chains)	N of injuries	INT period n 2; CON period n 8, ($p < 0.05$)	Support dynamic movements as injury prevention

INT intervention group, *CON* control group, *RR* relative risk

Table 4 Risk of bias in different domains in the reviews (i.e., ROBIS)

Review	Study eligibility criteria	Identification and selection of studies	Data collection and study appraisal	Synthesis and findings	Risk of bias in the review
McCall 2016 [3]	☺	☺	☺	☺	☺
Michalis 2016 [11]	☹	☹	☹	☹	☹
Rogan 2013 [12]	☺	☺	☺	?	☺

☺ = low risk; ☹ = high risk; ? = unclear risk

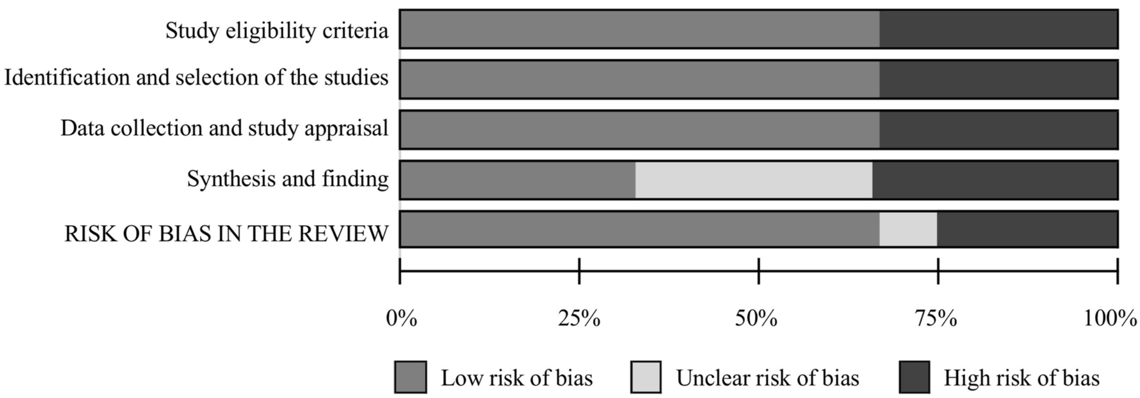

Fig. 2 Risk of bias graph of the included systematic reviews

Table 5 Risk of bias in different domains in the RCTs

Study	Random sequence generation (selection bias)	Allocation concealment (selection bias)	Blinding of participants and personnel (performance bias)	Blinding of outcome assessment (detection bias)	Incomplete outcome data (attrition bias)	Selective reporting (reporting bias)	Other bias
Askling 2003 [13]	?	?	☹	☹	☺	☺	?
de Hoyo 2015 [16]	☹	☹	☹	?	☹	☺	☹
Engebretsen 2008 [17]	☹	☹	☹	☹	?	☺	?
Espinosa 2015 [14]	☹	?	?	?	☺	☺	?
Harøy 2018 [15]	☺	☺	☹	?	☺	☺	☺

☺ = low risk; ☹ = high risk; ? = unclear risk

effectiveness of exercise strategies in the same population, the majority were at high risk of bias. Finally, level 3 evidence studies (NRCTs and case studies) that also supported exercise strategies were also deemed to be at high risk of bias. Therefore, we find limited evidence, (as there is only one study of acceptable quality and some studies of borderline quality) showing the effectiveness of exercise-based strategies to prevent muscle injuries in elite footballers.

During recent years, there has been (and continues to be) an influx of scientific research papers published in the injury prevention domain, with many practitioners looking to this research to guide and enhance their practice [3]. The primary source of information for practitioners is recommended to be studies with the highest level of evidence (i.e., systematic reviews and meta-analyses) [25] or RCTs (of high quality). However, as aptly suggested by Weir et al. [26] "all that glitters is not gold" and readers must critically consider the

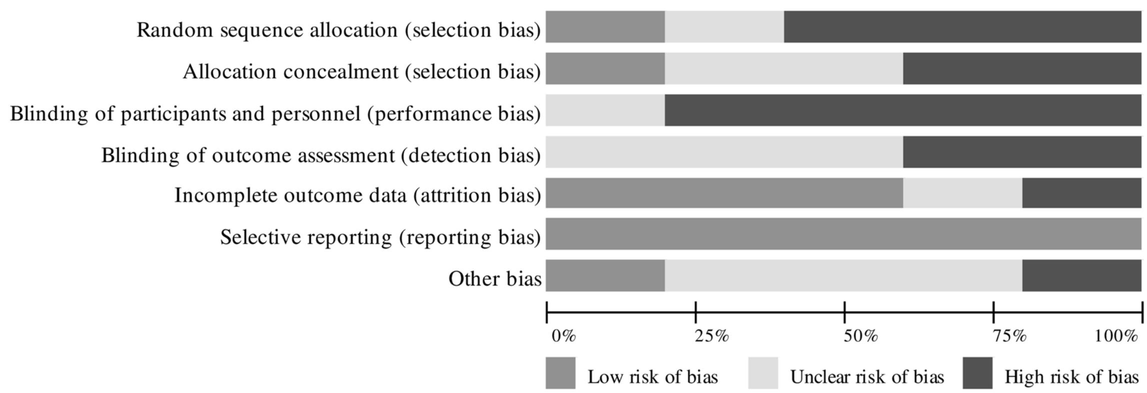

Fig. 3 Risk of bias graph of the included RCTs

quality of the systematic reviews and RCTs. It is essential that the discussion in research articles place emphasis not only on the findings of studies but also on the methodology, thus allowing readers to judge the validity and generalisability of research themselves [27]. As such, in our ensuing discussion, we will place a stronger emphasis on the risk of bias results within the interpretation of our findings, rather than on a narrative review of our findings.

Table 6 Risk of bias (ROBINS-I) in different domains in the NRCTs

Study	Risk of bias pre-intervention and at-intervention domains			Risk of bias post-intervention domains				Overall
	Bias due to confounding	Bias in selection of participants into the study	Bias in classification of interventions	Bias due to deviations from intended interventions	Bias due to missing data	Bias in measurement of outcomes	Bias in selection of the reported result	
Arnason 2008 [18]	Critical	Serious	Critical	Critical	NI	Serious	Moderate	Critical
Croisier 2008 [19]	Critical	Serious	Serious	Serious	Critical	Serious	Moderate	Critical
Kraemer 2009 [20]	Serious	NI	Serious	Critical	NI	Moderate	Moderate	Critical
Owen 2013 [22]	Critical	NI	Serious	Critical	NI	Serious	Moderate	Critical
Melegati 2013 [23]	Critical	NI	NI	Critical	Critical	Critical	Serious	Critical
Elerian 2019 [21]	Critical	Moderate	Serious	Moderate	Moderate	Moderate	Moderate	Critical
Izzo 2019 [24]	Critical	NI	Serious	Critical	NI	Serious	Moderate	Critical

NI no informations

4.1 Scientific Evidence from OCEBM Level 1 Studies (Systematic Reviews)

The three systematic reviews [3, 11, 12] included in the present study showed different risk of bias and inconsistent results. The systematic review by McCall et al. [3] showed low concerns in the review process and their conclusions were, therefore, judged at low risk of bias. Specifically, McCall et al. [3] concluded that there was insufficient evidence to support the effectiveness of many common exercise practices (eccentric, balance training, and hamstring focused eccentric exercises in particular) adopted by professional teams to prevent muscle injuries. In the individual studies assessed by McCall et al. [3], eccentric exercises were included in wide-spread strategies to prevent muscle injuries, in combination with both concentric contractions and other types of exercises. Due to the lack of isolation and the high risk of bias which we found in the empirical studies, also included in the present systematic review, the true effect of the eccentric exercises could not be appropriately evaluated.

The systematic review by Rogan et al. [12] showed low concerns in the review process and the study was, therefore, rated as a low risk of bias overall. Rogan et al. [12] found insufficient evidence to support static stretching as a prevention tool for hamstring muscle injuries. Unlike the reviews by McCall et al. [3] and Rogan et al. [12], the systematic review by Michalis and Apostolos [11] showed several concerns in the review process and was, therefore, rated at high risk of bias. Their conclusions supported performing eccentric exercise and neuromuscular warm-ups (i.e., FIFA 11 +) to prevent hamstring injuries; however, there were several concerns regarding different domains including; study eligibility criteria, identification and study selection, data collection and study appraisal, synthesis, and findings, which all introduced an overall risk of bias into their concluding take home messages for the readers. A recently published systematic review and meta-analysis showed that eccentric exercise (specifically, the Nordic hamstring exercise) to be very effective to prevent hamstring injury (i.e., halves the rate) [28]. Eligibility criteria used in our study are different compared to van Dyk et al. [28] as their search strategy and inclusion were different from ours (not limited by sport discipline and different age and playing level).

When systematic reviews suffer from high risk of bias, are not recent, or the overall findings may not provide practical applications, the next place to go for the most up-to-date scientific evidence to support decision-making in practice is RCTs (i.e., OCEBM Level 2); however, RCTs should also be appropriately analyzed for risk of bias. The Cochrane Collaboration's tool for assessing risk of bias was used in the present study to control the risk of bias of the included Level 2 RCTs (Table 5 and Fig. 3).

4.2 Scientific Evidence from OCEBM Level 2 Studies

OCEBM Level 2 studies included in the present systematic review showed different risk of bias with only one study [15] considered at low risk of bias. Conclusions from all included RCT studies investigating the effectiveness of exercise strategies on muscle injury prevention in elite footballers should, therefore, be considered with caution. Specifically, Askling et al. [13] supported the eccentric overload exercise (i.e., leg curl) for the prevention of hamstring injuries. de Hoyo et al. [16] concluded that eccentric overload training (half squat and leg curl exercises) was effective to reduce muscle injury severity but not incidence; however, differences in load between the experimental and control group may have influenced the results. Espinosa et al. [14] found that eccentric training of the hamstrings (i.e., Nordic Hamstring and eccentric band exercise) reduced injury risk in female football players. On the contrary, Engebretsen et al. [17] did not support the efficacy of exercise (Nordic hamstring and groin exercises) for muscle injury prevention as both experimental and control groups had the same injury incidence and severity following the intervention. The contradictory results showed by Engebretsen et al. [17] compared to previous studies may be explained by the poor compliance to the exercise program by the experimental group. The low risk of bias found in the study by Haroy et al. [15] showed that a strengthening program for the adductor muscles using the Copenhagen Adduction Exercise may be useful in reducing the groin problems in football players, but this should be replicated by further low risk of bias studies in other elite football leagues.

4.3 Scientific Evidence from OCEBM Level 3 and 4 Studies

As suggested by Arden and Winters [29] when RCTs are not present or are of high risk of bias, "it is reasonable to consider lower level of evidence" such as NRCTs, case studies, and expert opinion. The NRCTs examined in our study were rated at critical risk of bias, meaning that they were likely to be too biased to allow for any contribution to our research question [10].

In our study, the results of the level 3 studies revealed two studies supporting the implementation of eccentric exercises for the hamstrings (i.e., Nordic Hamstrings) [18, 21] and another study suggested restoring the isokinetic strength balance between opposite muscles (quadriceps and hamstrings) to prevent hamstring injuries [19]. The fourth study suggested the introduction of a balance proprioception program (including also jumps and running activities) in female soccer players to prevent calf and hamstring injuries; however, despite the questionable efficacy of the treatment, the specific rationale has also not been described [20]. The level 4 studies (i.e., case studies) suggested the implementation of a multicomponent program (balance, Nordic hamstring, core stability, and dynamic movements) [22–24]. Overall, the results of level 3 and 4 evidence studies recommend that eccentric exercise can be effective to prevent muscle injuries and it should be included in a multi-dimensional muscle injury prevention program. However, potential confounders and co-interventions were not controlled in all of the studies (i.e., critical or serious). For example, reporting details of external and internal loads are of critical importance. Indeed, the loads provided by the interventions (i.e., external load) and how the athletes respond to that load (i.e., internal load) should be detailed as they provide stimulus that concurrently changes the outcome and influence the risk of injury. Therefore, intensity, duration, and frequency of the injury prevention program should be reported and subjectively administered as "one size does not fit all". The critical risk of bias, as alluded to above, limits the ability to draw valid conclusions and provide any useful evidence from the NRCTs included in the present systematic review.

4.4 Can We Improve the Level of Scientific Evidence for Evidence-Based Muscle Injury Prevention Strategies?

A recent call for action has been put out for more RCTs to be performed in high-risk football populations [30], and elite footballers are clearly a high-risk population for injury. However, while RCTs are the best way to evaluate the effectiveness of an intervention and the only design that allows valid inferences of cause and effect [27], to be done well, they require significant resources (e.g., time, money, equipment, and energy) that may not be possible in the high-level context, as well as access to players and coaches/clubs who are willing to participate and disclose player information. Therefore, before investing and engaging resources necessary to perform a well-designed RCT with low risk of bias, feasibility studies should be performed to determine if they can and should actually be done.

Unfortunately, even if well-designed RCT's are deemed to be feasible in high-level football, it is not much help to football in the short or medium term (given the time to plan and conduct both feasibility and full RCT trials) where muscle injuries remain the most common injury in players. To gain practical recommendations, practitioners may extrapolate evidence from other populations (e.g., sub-elite and amateur); however, given that the adaptations of both muscle strength and architecture are likely dependent on training status, such extrapolation may not be appropriate [31]. The necessity to understand "what to do" in the absence of RCT results is common in other fields such as medicine. The only alternative is to rely on observational data. Although this is not the preferred choice, modern epidemiology has developed methods to estimate causal effects from observational data [32, 33]. This, however, necessitates well-designed and properly analyzed observational studies, which are rare in sports medicine and even more so in injury-related studies. The NRCT examined in the current systematic review not only did not try to estimate causal effects, but were also at high risk of bias as descriptive observational studies, thus limiting the possibility to make any inferences from their results. In the absence of quality recommendations based on high-level scientific evidence in the relevant population, it is recommended that the development of a relevant evidence base can be established using expert consensus techniques [34]. Through this method of establishing an evidence base, practitioners are not restricted to only rely on their own experiences as they will have access to a knowledge base established by a larger expert group which using a scientific process can gain an agreement among experts on what to do/what not to do [34].

5 Limitations

Our synthesis has been based on and influenced by the risk of bias assessment of the included studies; no measures of consistency or meta-analysis were carried out. However, given the high risk of bias in individual studies, it would have likely been inappropriate to pool the data. Language is another limit in our systematic review, as due to resources, we have included only articles written in English and this may have limited the number of papers retrieved. Finally, while our inclusion criteria defined an 'elite' team as a team from one of the top three divisions in a country, we acknowledge that the heterogeneity between countries could be significant and future studies should consider this when defining their populations.

6 Conclusions

Our findings revealed that, according to OCEBM Level 1 scientific evidence, there is no strong scientific evidence to support the belief that exercise-based strategies are effective for preventing muscle injury in elite football players. Level 2 evidence, while it was generally supportive to the use of eccentric-based exercise, is also mainly at high or unclear risk of bias of these studies and, therefore, does not provide any confidence into the actual effectiveness (or not) of exercise strategies. Level 3 and 4 evidence also supports the use of eccentric-based exercise in addition to proprioception exercises and a multi-dimensional component to injury prevention; however, the studies included showed critical risk of bias and they cannot, therefore, provide any useful evidence for practitioners.

7 Practical Applications

Based on the results of this systematic review, there are no clear practical applications based on credible scientific evidence that practitioners can confidentially implement in practice. Future research such as consensus-based techniques are urgently needed to provide useful insights based on experts' experience, while researchers should work on developing and implementing low risk of bias original studies in the elite population.

Author Contributions MF, AM, and IBS: concept, design, and assessment of the risk of bias, and writing the manuscript. FMI and AJC: writing and editing the manuscript. RP, GD, and TM: controlling and editing the manuscript.

Compliance with Ethical Standards

Funding The authors did not receive any specific grant for this research from any funding agency in the public, commercial, or not-for-profit sectors.

Conflict of interest The authors declare that they have no conflict of interest relevant to the content of this review.

References

1. Lopez-Valenciano A, Ruiz-Perez I, Garcia-Gomez A, Vera-Garcia FJ, De Ste Croix M, Myer GD, et al. Epidemiology of injuries in professional football: a systematic review and meta-analysis. Br J Sports Med. 2019. https://doi.org/10.1136/bjsports-2018-099577.
2. Ekstrand J, Hagglund M, Walden M. Epidemiology of muscle injuries in professional football (soccer). Am J Sports Med. 2011;39(6):1226–32. https://doi.org/10.1177/0363546510395879.
3. McCall A, Carling C, Davison M, Nedelec M, Le Gall F, Berthoin S, et al. Injury risk factors, screening tests and preventative strategies: a systematic review of the evidence that underpins the perceptions and practices of 44 football (soccer) teams from various premier leagues. Br J Sports Med. 2015;49(9):583–9. https://doi.org/10.1136/bjsports-2014-094104.
4. Coutts AJ. Challenges in developing evidence-based practice in high-performance sport. Int J Sports Physiol Perform. 2017;12(6):717–8. https://doi.org/10.1123/IJSPP.2017-0455.
5. Howick J, Chalmers I, Glasziou P, Greenhalgh T, Heneghan C, Liberati A et al. Ocebm levels of evidence working group. "The oxford 2011 levels of evidence". 2011.
6. van Tulder M, Furlan A, Bombardier C, Bouter L, Editorial Board of the Cochrane Collaboration Back Review G. Updated method guidelines for systematic reviews in the cochrane collaboration back review group. Spine (Phila Pa 1976). 2003;28(12):1290–9. https://doi.org/10.1097/01.brs.0000065484.95996.af.
7. Furlan AD, Malmivaara A, Chou R, Maher CG, Deyo RA, Schoene M et al. 2015 updated method guideline for systematic reviews in the cochrane back and neck group. Spine (Phila Pa 1976). 2015;40(21):1660–73. https://doi.org/10.1097/brs.0000000000001061.
8. Whiting P, Savovic J, Higgins JP, Caldwell DM, Reeves BC, Shea B, et al. Robis: a new tool to assess risk of bias in systematic reviews was developed. J Clin Epidemiol. 2016;69:225–34. https://doi.org/10.1016/j.jclinepi.2015.06.005.
9. Higgins JP, Altman DG, Gotzsche PC, Juni P, Moher D, Oxman AD, et al. The cochrane collaboration's tool for assessing risk of bias in randomised trials. BMJ. 2011;343:d5928. https://doi.org/10.1136/bmj.d5928.
10. Sterne JA, Hernan MA, Reeves BC, Savovic J, Berkman ND, Viswanathan M, et al. Robins-i: a tool for assessing risk of bias in non-randomised studies of interventions. BMJ. 2016;355:i4919. https://doi.org/10.1136/bmj.i4919.
11. Michalis AH, Apostolos S. Hamstring strains in football. Prevention and rehabilitation rules. Systematic review. Biol Exerc. 2016;12(1):121–48. https://doi.org/10.4127/jbe.2016.0104.
12. Rogan S, Wust D, Schwitter T, Schmidtbleicher D. Static stretching of the hamstring muscle for injury prevention in football codes: a systematic review. Asian J Sports Med. 2013;4(1):1–9. https://doi.org/10.5812/asjsm.34519.
13. Askling C, Karlsson J, Thorstensson A. Hamstring injury occurrence in elite soccer players after preseason strength training with eccentric overload. Scand J Med Sci Sports. 2003;13(4):244–50. https://doi.org/10.1034/j.1600-0838.2003.00312.x.
14. del Ama Espinosa G, Pöyhönen T, Aramendi JF, Samaniego JC, Emparanza Knörr JI, Kyröläinen H. Effects of an eccentric training programme on hamstring strain injuries in women football players. Biomed Hum Kinet. 2015;7(1):125–34. https://doi.org/10.1515/bhk-2015-0019.
15. Haroy J, Clarsen B, Wiger EG, Oyen MG, Serner A, Thorborg K, et al. The adductor strengthening programme prevents groin problems among male football players: a cluster-randomised controlled trial. Br J Sports Med. 2019;53(3):150–7. https://doi.org/10.1136/bjsports-2017-098937.
16. de Hoyo M, Pozzo M, Sanudo B, Carrasco L, Gonzalo-Skok O, Dominguez-Cobo S, et al. Effects of a 10-week in-season eccentric-overload training program on muscle-injury prevention and performance in junior elite soccer players. Int J Sports Physiol Perform. 2015;10(1):46–52. https://doi.org/10.1123/ijspp.2013-0547.
17. Engebretsen AH, Myklebust G, Holme I, Engebretsen L, Bahr R. Prevention of injuries among male soccer players: a prospective, randomized intervention study targeting players with previous injuries or reduced function. Am J Sports Med. 2008;36(6):1052–60. https://doi.org/10.1177/0363546508314432.
18. Arnason A, Andersen TE, Holme I, Engebretsen L, Bahr R. Prevention of hamstring strains in elite soccer: an intervention study. Scand J Med Sci Sports. 2008;18(1):40–8. https://doi.org/10.1111/j.1600-0838.2006.00634.x.
19. Croisier JL, Ganteaume S, Binet J, Genty M, Ferret JM. Strength imbalances and prevention of hamstring injury in professional soccer players: a prospective study. Am J Sports Med. 2008;36(8):1469–75. https://doi.org/10.1177/0363546508316764.
20. Kraemer R, Knobloch K. A soccer-specific balance training program for hamstring muscle and patellar and achilles tendon injuries: an intervention study in premier league female soccer. Am J Sports Med. 2009;37(7):1384–93. https://doi.org/10.1177/0363546509333012.
21. Elerian AE, El-Sayyad MM, Dorgham HAA. Effect of pre-training and post-training nordic exercise on hamstring injury prevention, recurrence, and severity in soccer players. Ann Rehabil Med. 2019;43(4):465–73. https://doi.org/10.5535/arm.2019.43.4.465.
22. Owen AL, del Wong P, Dellal A, Paul DJ, Orhant E, Collie S. Effect of an injury prevention program on muscle injuries in elite professional soccer. J Strength Cond Res. 2013;27(12):3275–85. https://doi.org/10.1519/JSC.0b013e318290cb3a.
23. Melegati G, Tornese D, Gevi M, Trabattoni A, Pozzi G, Schonhuber H, et al. Reducing muscle injuries and reinjuries in one italian professional male soccer team. Muscles Ligam Tend J. 2013;3(4):324–30. https://doi.org/10.11138/mltj/2013.3.4.324.
24. Izzo R, Giovannelli M, D'Isanto T. The injury prevention program wta functional primitive movement in professional football players: a case study. J Phys Educ Sport. 2019;19(Supplement issue 5):1885-9. https://doi.org/10.7752/jpes.2019.s5279.
25. Impellizzeri FM, Bizzini M. Systematic review and meta-analysis: a primer. Int J Sports Phys Ther. 2012;7(5):493–503.
26. Weir A, Rabia S, Ardern C. Trusting systematic reviews and meta-analyses: all that glitters is not gold! Br J Sports Med. 2016;50(18):1100–1. https://doi.org/10.1136/bjsports-2015-095896.
27. Altman DG. Better reporting of randomised controlled trials: the consort statement. BMJ. 1996;313(7057):570–1. https://doi.org/10.1136/bmj.313.7057.570.
28. van Dyk N, Behan FP, Whiteley R. Including the nordic hamstring exercise in injury prevention programmes halves the rate of hamstring injuries: a systematic review and meta-analysis of 8459 athletes. Br J Sports Med. 2019;53(21):1362–70. https://doi.org/10.1136/bjsports-2018-100045.
29. Ardern CL, Winters M. Synthesising 'best evidence' in systematic reviews when randomised controlled trials are absent: three tips

for authors to add value for clinician readers. Br J Sports Med. 2018;52(15):948–9. https://doi.org/10.1136/bjsports-2017-097881.

30. Bricca A, Juhl CB, Bizzini M, Andersen TE, Thorborg K. There are more football injury prevention reviews than randomised controlled trials. Time for more rct action! Br J Sports Med. 2018;52(22):1477–8. https://doi.org/10.1136/bjsports-2018-099373.
31. Buchheit M, Eirale C, Simpson BM, Lacome M. Injury rate and prevention in elite football: let us first search within our own hearts. Br J Sports Med. 2019;53(21):1327–8. https://doi.org/10.1136/bjsports-2018-099267.
32. Robins JM. Data, design, and background knowledge in etiologic inference. Epidemiology. 2001;12(3):313–20. https://doi.org/10.1097/00001648-200105000-00011.
33. Pearl J. An introduction to causal inference. Int J Biostat. 2010;6(2):7. https://doi.org/10.2202/1557-4679.1203.
34. Minas H, Jorm AF. Where there is no evidence: use of expert consensus methods to fill the evidence gap in low-income countries and cultural minorities. Int J Ment Health Syst. 2010;4:33. https://doi.org/10.1186/1752-4458-4-33.

Affiliations

Maurizio Fanchini[1,2] · Ida Bo Steendahl[3,4] · Franco M. Impellizzeri[5] · Ricard Pruna[6] · Gregory Dupont[7] · Aaron J. Coutts[5] · Tim Meyer[3] · Alan McCall[6,8,9]

1 Performance Department, AS Roma Football Club, Piazzale Dino Viola, 1, 00128 Rome, RM, Italy

2 Department of Neuroscience, Biomedicine and Movement Sciences, University of Verona, Verona, Italy

3 Institute of Sport and Preventive Medicine, Saarland University, Saarbrücken, Germany

4 DFB-Akademie (Deutscher Fußball-Bund), Think Tank, Frankfurt, Germany

5 Faculty of Health, Sport and Exercise Discipline Group, University of Technology Sydney, Sydney, Australia

6 Medical Services Ciutat Esportiva Barcelona, FC Barcelona, Barcelona, Spain

7 Federation de Football Francaise, Paris, France

8 Arsenal Performance and Research Team, Arsenal Football Club, London, UK

9 School of Applied Sciences, Edinburgh Napier University, Edinburgh, UK