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Return-to-play criteria following a hamstring injury in professional football: a scoping review

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ABSTRACT

The present scoping review aims to describe the available criteria to determine Return-To-Play (RTP), propose methodological considerations and new research questions, and provide information to help practitioners in professional football make informed decisions regarding RTP following a hamstring strain injury (HSI) in professional male football. The following electronic databases were searched: PubMed, MEDLINE, web of science and SPORTDiscus using keywords related to HSI in elite football. All types of studies in English reporting at least one RTP criterion for professional football players who sustained an HSI were included. In total, 19 studies met the inclusion criteria. RTP criteria were divided into three categories: clinical, strength and performance criteria. Clinical criteria were also divided into sub-categories: absence of pain, hamstring flexibility, medical staff clearance, psychological readiness, surgeon's opinion and imaging. Practitioners working in professional male football could benefit from using a combination of criteria in their RTP battery of tests.

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Hamstring muscles; football; return to sport; rehabilitation; sports medicine

Introduction

Hamstring strain injuries (HSI) are the most reported injury in professional football (Ekstrand et al., 2023). In European professional clubs, we know that an average of 7 hSI per season or 0.3 to 1.9 hSI every 1000 exposure hours would be expected (Diemer et al., 2021). The majority of HSI affects the biceps femoris (84%), and only a small percentage affects the semitendinosus (11%) and the semimembranosus (5%) (Ekstrand et al., 2012). Over a 21-year study period, the reported hamstring injuries increased from 12% in the 2001/02 season to 24% in the 2021/22 season (Ekstrand et al., 2023). Time loss in professional football is detrimental for the individual athlete and the club because of financial losses and the negative impact on performance (Eliakim et al., 2020; Hägglund et al., 2013).

The other problem practitioners have to face during HSI rehabilitation is the high re-injury rate, which has been consistently reported in elite sports as around 15–20%, with

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a peak of 63% (Pollock et al., 2016). In professional football, about 18% of all reported HSI were re-injuries, most of which occurred within 2 months of Return-to-Play (RTP) (Ekstrand et al., 2023). Practitioners in professional football have to make decisions on RTP with a great deal of external pressure from the athlete, the coaching staff and the stakeholders. Having objective criteria to help in the decision-making process is of primary importance to make informed decisions and mitigate the risk of re-injury. Although several studies have looked at criteria for HSI across several different sports and levels of professionalism (Fournier-Farley et al., 2016; Hickey et al., 2017), few studies have analysed the RTP criteria in professional footballers. This review aimed to analyse the criteria reported in published research to clear professional footballers to return to play football following an HSI, but also to objectively predict lay-off time and help practitioners formulate an RTP plan at the time of the injury. Due to the small percentage of athletes competing at the top level of football, data could often be based on small samples. This review also aimed to analyse the research methods used and find gaps for practitioners to focus their research in the future.

Materials and methods scoping review

The scoping review followed the PRISMA Guidelines 2020 and the "Preferred reporting items for systematic reviews and meta-analysis extension for scoping reviews" (PRISMA-ScR) checklist specific to scoping reviews (Tricco et al., 2018).

Protocol and registration

The scoping review protocol was approved on the Open Science Framework on the 24th of June 2023, with the registration number 10.17605/OSF.IO/HBNAS. The protocol is accessible via the link: https://osf.io/hbnas/.

Eligibility criteria

The scoping review took into consideration studies published in peer-reviewed journals. Studies with the status "in press" or "ahead of print" were also considered. There were no date limitations. Only studies in English were considered. The eligibility criteria were based on the PECOS (Population, exposure, comparator, outcome, study design) approach: (i) population: male participants aged between 17 and 45 years old who play football (soccer) at a professional level. Disabled athletes were excluded and those competing in adapted sports; (ii) exposure: exposed to RTP criteria to assess the ability to return to competition following an acute HSI; (iii) comparator: not exposed to RTP criteria following an acute HSI; (iv) outcome: describe the available and validated criteria to assess RTP following an HSI in professional football; (v) study design: the review included studies that reported at least one RTP criteria used to decide if the subjects were ready to return to participation in football matches. All types of studies were taken into consideration.

Information sources

The following electronic databases were searched: PubMed, MEDLINE, web of science and SPORTDiscus. All databases were searched, and only papers in English were considered. The pre-registration and the research were conducted on the same day. Title and abstracts were checked to decide on the relevancy of inclusion criteria, and if considered eligible, the full text was analysed.

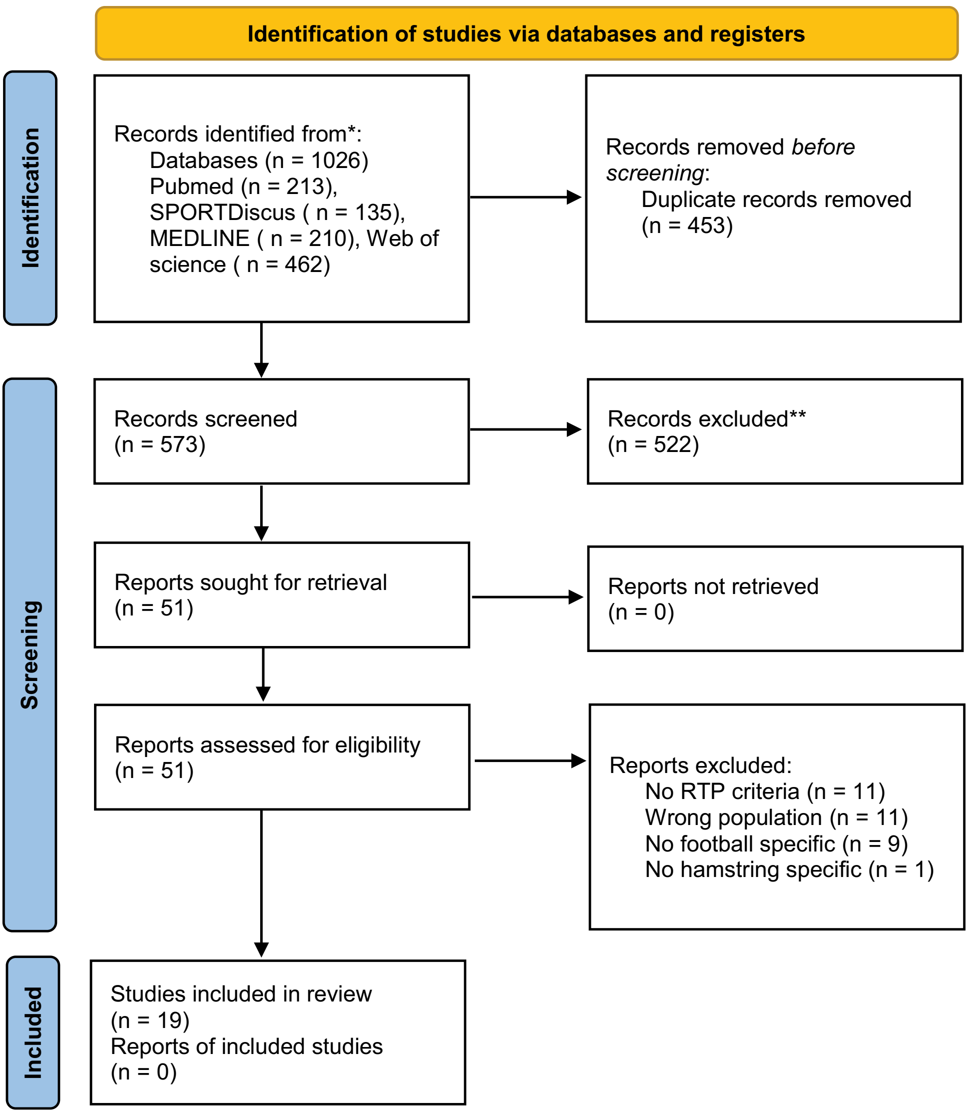

Figure 1. Prisma flowchart.

Search strategy

The search strategy results were managed through the "Rayyan – the intelligent systematic review" web app (www.rayyan.ai). Duplicates were automatically deleted. The keyword search was combined with subject headings (according to MeSH) present in the research field. The results of the search were presented following the PRISMA flowchart (Figure 1). The main search strategy included the Boolean operators AND/OR and was completed as follows:

(Hamstrings OR biceps femoris OR semimembranosus OR semitendinosus OR thigh OR posterior thigh)
AND
(injury OR tear OR strain OR pain OR trauma OR dysfunction)
AND
(football OR soccer)
AND
(return to sport OR return to play OR return to sports OR return to competition OR return to participation OR return to running)

Selection process

Two blinded authors independently screened the articles (PP and MB). In case of disagreement on the study eligibility, this was resolved through a discussion between the two reviewers, and, if necessary, a third reviewer (NG) was asked to intervene until a consensus was obtained. When required, all the authors shared opinions in case of doubts during the selection process.

Data extraction process

The selected studies were stored in a Microsoft Excel datasheet indicating the following variables: year and country of publication, type of journal (sports medicine or not), study design, typology of sample (only professional football), age of the sample, type of hamstring injury, criteria used to RTP. The Excel datasheet is available in the supplementary material.

Assessment of risk of bias

The study selection of the present scoping review included a variety of study typologies. The review aims to describe all the studies published on the specific topic, including case reports and opinion papers. Therefore, due to the descriptive nature of this paper and the heterogeneity of the articles, no assessment tools were utilized to evaluate the internal validity of the included studies as described in previous scoping reviews (Rambaud et al., 2018).

Results

Study identification and selection

The electronic database search yielded 1026 records (Figure 1). The data were imported to the "Rayyan – the intelligent systematic review" web app (www.rayyan.ai). Duplicates ($n = 453$) were removed automatically. The remaining 573 titles and abstracts were screened for their relevance. Fifty-two studies were included for full-text review. Following the full-text inspection, 33 articles were removed for one of the following reasons: RTP criteria were not described ($n = 11$), the participants were not professional male football players aged 17 to 45 ($n = 11$), RTP criteria were not football specific ($n = 9$), no hamstring specific ($n = 1$). Nineteen studies were included in the final scoping review.

RTP criteria

The studies and the RTP criteria included in this scoping review are summarized in Table 1. Due to the differences between the criteria, we proposed to group the criteria into three categories: clinical, strength and performance. Table 2 shows the criteria grouped into these three categories.

Clinical criteria

Absence of pain

Absence of pain was utilized in seven studies as an RTP criterion (Delvaux et al., 2013; Dunlop et al., 2020; Garcia et al., 2022; Taberner et al., 2020, 2022; van der Horst et al., 2017; Zambaldi et al., 2017). Delvaux et al. (2013) used a bespoke questionnaire to interview 37 sports medicine physicians from French and Belgian male professional football clubs about the most important RTP criteria after an HSI. Complete absence of pain was indicated as the most important criterion because the pain would indicate "incomplete injury healing". Dunlop et al. (2020) used an online survey to interview practitioners responsible for the RTP programme from 131 professional football clubs. The majority (57%) identified the absence of pain during clinical evaluation (e.g., on palpation, during strength and flexibility tests) and/or following functional performance testing (e.g., running mechanic drills, low-moderate speed running) as the most important criterion for return to high-speed running within the RTP continuum described in the study (return-to-high-speed running, return-to-train, return-to-play, return-to-performance). The definitions of the RTP continuum phases are summarized in Table 3. Similar results were presented by van der Horst et al. (2017) in their Delphi study. Fifty-eight experts from 28 FIFA Medical Centres of Excellence worldwide identified the absence of pain on palpation of the hamstrings, on strength and flexibility testing and on functional performance as important criterion for RTRun. In the case study presented by Taberner et al. (2022), the professional football player was deemed ready to return to on-field rehabilitation following a semimembranosus proximal-free tendon injury once pain was absent. In a case study of a professional football player with a semimembranosus proximal tendon

Table 1. Summary of studies on RTP criteria following a hamstring injury in professional football.

Studies	Year	Country of publication	Study design	Typology of sample	Type of hamstring injury	RTP criteria
Baldock et al.	2021	England	Case study	3 Premier league football players	Proximal LHBF LHBF and the SHBF at the conjoint T-junction Proximal LHBF MTJ	Resolution of a tendon injury on MRI
Cohen et al.	2011	USA	Descriptive epidemiology study	38 professional football players	LHBF, SHBF, semimembranosus, semitendinosus proximal, middle and distal injuries	MRI scan: Multiple-muscle/tendon involvement Percentage of muscle involvement Sagittal plane signal Presence of retraction
Crema et al.	2017	USA	Retrospective cohort study	22 professional football players	Grade 1 hamstring injuries	MRI-detected oedema
Delvaux et al.	2013	Belgium	Letter to editor	37 sports medicine physicians from French (League 1 and 2) and Belgian (1st division) male professional football clubs	Not reported	Complete pain relief Muscle strength performance Subjective feeling reported by the player Muscle flexibility
Dunlop et al.	2020	UK	Online survey	Practitioners responsible for the RTP programme from 131 professional football clubs	Not reported	Absence of pain Hamstring strength Hamstring flexibility Functional performance/assessment Staff subjective appraisal Psychological readiness Training load monitoring
Ekstrand et al.	2011	Sweden	Prospective cohort study	207 hamstring injuries from professional football clubs	27 Grade 0 118 Grade 1 56 Grade 2 6 Grade 3 151 Biceps femoris 20 Semimembranosus 9 Semitendinosus	MRI to prognosticate lay-off time
Ekstrand et al.	2016	Sweden	Prospective cohort study	255 hamstring injuries from professional football clubs	173 Grade 1 82 Grade 2 212 Biceps femoris 30 Semimembranosus 11 Semitendinosus	MRI to prognosticate lay-off time

(*Continued*)

Table 1. (Continued).

Studies	Year	Country of publication	Study design	Typology of sample	Type of hamstring injury	RTP criteria
Garcia et al.	2022	Brazil/Spain	Narrative review	N/A	N/A	Similar hamstrings flexibility and muscle strength compared with preinjury level (when registered data available) or contralateral (uninjured) side (~10–15%) Absence of pain on palpation and activities Psychological readiness Functional performance test Including position-specific Global positioning system (GPS) targeted Match-specific rehabilitation Repeated sprint ability test Single leg bridge Deceleration drills Equivalent strength endurance tests.
Hallén et al.	2014	Sweden	Retrospective cohort study	283 hamstring injuries from professional football clubs	34 Grade 0 164 Grade 1 77 Grade 2 8 Grade 3 207 Biceps femoris 29 Semimembranosus 13 Semitendinosus	MRI to prognosticate lay-off time
McCauley et al.	2022	UK	Retrospective cohort study	35 hamstring injuries in one Premier League football club	17 Biceps Femoris (Long Head) 1 Biceps Femoris (Short Head) 5 Semitendinosus 3 Semimembranosus 9 Multiple muscles (inc. tendon injury)	Injury grade (using BAMIC classification), and whether a player was removed from play to predict time to RTP
Víctor Moreno-Pérez et al.	2020	Spain	Cross-sectional study	20 male professional footballers	N/A	Nordic hamstring eccentric 90:20 isometric posterior-chain strength Isometric 15 knee flexion
Shamji et al.	2021	UK	Retrospective cohort study	61 hamstring injuries in one Premier League football club	4 Grade 0a 4 Grade 0b 6 Grade 1a 15 Grade 1b 3 Grade 2a 16 Grade 2b 10 Grade 2c 3 Grade 3c 40 Biceps femoris 10 Semimembranosus 7 Semitendinosus	Injury grade (using BAMIC classification) to predict time to RTP

(*Continued*)

Table 1. (Continued).

Studies	Year	Country of publication	Study design	Typology of sample	Type of hamstring injury	RTP criteria
Taberner et al.	2022	UK	Case study	1 Premier League football player	Semimembranosus proximal free tendon	Absence of pain Psychological readiness Isometric posterior chain test The "control-chaos continuum" framework completion Training load monitoring and management
Taberner et al.	2020	UK	Case study	1 Premier League football player	Semimembranosus proximal tendon	MRI follow-up results Surgeons' opinion Absence of pain Isometric posterior chain test Countermovement jump test The "control-chaos continuum" framework completion Training load monitoring and management
Tears et al.	2022	UK	Retrospective cohort study	39 hamstring injuries in one Premier League football club	1 Grade 0a 1 Grade 0b 4 Grade 1a 3 Grade 1b 3 Grade 2a 18 Grade 2b 4 Grade 2c 0 Grade 3a 3 Grade 3b 2 Grade 3c 26 Biceps femoris 6 Semimembranosus 2 Semitendinosus 1 All hamstring muscles 3 Biceps femoris and Semitendinosus	Injury grade (using BAMIC classification) to predict time to RTP
Tol et al.	2014	Qatar	Randomized control trial	52 professional football players	27 Grade 1 25 Grade 2	Isokinetic strength test: Hamstring concentric 60°/s Hamstring concentric 300°/s Hamstring eccentric

(*Continued*)

Table 1. (Continued).

Studies	Year	Country of publication	Study design	Typology of sample	Type of hamstring injury	RTP criteria
Valle et al.	2022	Spain	Retrospective cohort study	76 hamstring injuries at FCB (senior A and B and the two U-19 teams)	1 Grade 0 3 Grade 1 17 Grade 2 5 Grade 3 50 Grade 3 r 54 Biceps Femoris (Long Head) 1 Biceps Femoris (Short Head) 9 Semitendinosus 12 Semimembranosus	Injury grade (using MRI-based MLG-R classification) to predict time to RTP
Van der Horst et al.	2017	Netherlands	Delphi study	58 hamstring injury experts	N/A	Medical staff clearance Similar hamstring flexibility Performance on field testing Psychological readiness Absence of pain on palpation Strength testing Flexibility testing and/or functional testing
Zambaldi et al.	2017	Italy	Delphi study	20 hamstring injury experts	N/A	Complete pain relief Muscle strength performance Subjective feeling reported by the player Muscle flexibility Specific soccer test performance

BAMIC = British Athletics Muscle Injury Classification.
FCB = Football Club Barcelona.
GPS = Global positioning system.
LHBF = Long Head Biceps Femoris.
MRI = Magnetic resonance imaging.
MTJ = myotendinous junction.
RTP = Return to Play.
SHBF = Short Head Biceps femoris.

Table 2. Return to play criteria divided into clinical, strength and performance.

Clinical	Strength	Performance
Absence of pain	Muscle strength performance	Specific soccer test performance
Muscle flexibility	Similar muscle strength compared with preinjury level (when registered data available) or contralateral (uninjured) side	Functional performance/ assessment
Medical staff clearance	Single leg bridge	Training load monitoring and management
Psychological readiness	Equivalent strength endurance tests	Including position-specific training
MRI: Resolution of a tendon injury Multiple-muscle/tendon involvement Percentage of muscle involvement Sagittal plane signal Presence of retraction Detected oedema Muscle injury severity Injury grade (using BAMIC classification)	Nordic hamstring eccentric	GPS targeted on-field rehabilitation
Player removed from the field	90:20 isometric posterior-chain strength	Match-specific rehabilitation
Surgeon's opinion	Isometric 15 knee flexion	Repeated sprint ability test
	Isometric posterior chain test	Complete deceleration drills
	Isokinetic strength test: Hamstring concentric 60°/s Hamstring concentric 300°/s Hamstring eccentric	The "control-chaos continuum" framework completion

BAMIC: British Athletics Muscle Injury Classification.
GPS: Global positioning system.
MRI: Magnetic resonance imaging.

Table 3. Criteria definition.

Criteria	Definition
Return-to-high-speed running	The period between hamstring injury occurring and the player being cleared to run on-field and progresses to high-speed running
Return-to-train	When the player is allowed to return to on-field unrestricted training
Return-to-play	When the player is cleared to return to competitive match-play with the team (whether selected or not)
Return-to-performance	When the player returned to pre-injury levels of performance (or higher)

surgical repair described by Taberner et al. (2020), absence of pain was used 18 weeks post-surgery to clear the player to return to unrestricted team training.

Hamstring flexibility

Hamstring flexibility was utilized in five studies as an RTP criterion (Delvaux et al., 2013; Dunlop et al., 2020; Garcia et al., 2022; van der Horst et al., 2017; Zambaldi et al., 2017). In their survey, Delvaux et al. (2013) reported that Hamstring muscle flexibility represented the fourth most relevant RTP criterion on a list of 12 criteria. Dunlop et al. (2020) reported that hamstring flexibility was the third most appropriate test to clear a player for return to running following an HSI. van der Horst et al. (2017) reported that a consensus about using hamstring flexibility as an RTP criterion was reached. The experts agreed that a 0%–

10% difference between injured and uninjured leg or compared with preinjury data is required. They also reached consensus that hamstring flexibility should be assessed by means of both the active and the passive straight leg raise test. Zambaldi et al. (2017) reported that all the Delphi study participants agreed that full hamstring flexibility is necessary for a safe RTP, but the best method to assess it has not been specified.

Medical staff clearance

Medical staff clearance was described in two studies (Dunlop et al., 2020; van der Horst et al., 2017). Although Dunlop et al. (2020) reported that 80% of Premier League teams surveyed used a shared decision-making approach, others have shown that responsibility belongs to the medical staff. Ninety-six teams (73%) reported that medical staff were responsible for the RTP clearance. In addition, the teams revealed that ≥87% of the time across the different stages of RTP at least one medical practitioner was consulted. Similarly, in the Delphi study conducted by van der Horst et al. (2017) the experts' panel reached an agreement on medical staff clearance as a criterion for RTP.

Psychological readiness

Psychological readiness was included in seven studies (Delvaux et al., 2013; Dunlop et al., 2020; Garcia et al., 2022; Taberner et al., 2020, 2022; van der Horst et al., 2017; Zambaldi et al., 2017). The physicians questioned in the Delvaux et al. (2013) study ranked the subjective feeling reported by the player as the third criterion out of the list of 12 options. Psychological criteria were considered for RTP by the experts in the survey by Dunlop et al. (2020) and the Delphi studies by van der Horst et al. (2017) and Zambaldi et al. (2017). All three studies highlighted the importance of psychological readiness for RTP, suggesting that factors such as fear of pain, fear of reinjury and higher motivation could impact the outcome. However, in professional football, there are no validated tools to measure psychological readiness following a hamstring injury (van der Horst et al., 2017). In the two case studies (Taberner et al., 2020, 2022), the authors reported that subjective feedback from the player was part of the criteria used alongside a combination of clinical, strength and performance criteria.

Surgeon's opinion

The surgeon's opinion was only included in one study (Taberner et al., 2020). In this case, study on rehabilitating a surgically managed semimembranosus injury, the authors utilized the surgeon's opinion as a criterion to clear the player to return to team training.

Imaging as RTP criterion

Imaging was included as an RTP criterion in three studies (Baldock et al., 2021; Taberner et al., 2020, 2022). Baldock et al. (2021) presented three cases of HSI with intramuscular tendon involvement. They concluded that the healing of those injuries can be accurately seen on Magnetic Resonance Imaging (MRI) scans and that this information should be used as a criterion for RTP. Taberner et al. (2020) utilized healing and maturation on MRI scans as one of the criteria to return the player to team training. Finally, Taberner et al. (2022) used additional imaging (ultrasound) to clear the player's transition into the football-specific phases of the control-to-chaos continuum framework (Taberner et al., 2019).

Strength criteria

Strength criteria were reported in nine studies (Delvaux et al., 2013; Dunlop et al., 2020; Garcia et al., 2022; Moreno-Pérez et al., 2020; Taberner et al., 2020, 2022; Tol et al., 2014; van der Horst et al., 2017; Zambaldi et al., 2017). Delvaux et al. (2013), Dunlop et al. (2020) and Zambaldi et al. (2017) all agreed that strength objective measures should be used as an RTP criterion. However, none of the studies reported which tests should be used. Conversely, the experts in the Delphi study by van der Horst et al. (2017) did not reach a consensus on the use of eccentric strength as a criterion to support the RTP decision, but a consensus was reached that other contraction modalities should not be included as a criterion to support the RTP decision. In the van der Horst et al. (2017) study, single leg bridge was identified as a performance test to assess readiness to RTP.

Moreno-Pérez et al. (2020) studied the correlation between an eccentric hamstring test (Nordic hamstring) and two isometric hamstring tests (15° knee flexion and 90:20). The results showed a poor association between the tests due to the different contractile activity, but each test showed good validity. The authors concluded that despite the low correlation, these tests could be used during the rehabilitation process. The isometric testing might be preferable during the initial stages of rehabilitation as a screening tool, while the Nordic hamstring might be more applicable for the late stages of rehabilitation, to assess hamstring weakness and asymmetry to help with the decision to RTP.

Two case studies (Taberner et al., 2020, 2022) used an isometric posterior-chain hamstring test to inform clinical reasoning and decision-making regarding RTP. Tol et al. (2014) used the 300°/s hamstring concentric and eccentric tests to help with the decision regarding RTP. Regarding strength asymmetries, 67% of hamstring-injured professional football players showed at least one hamstring isokinetic testing deficit of more than 10% at the moment of RTP. The normalization of isokinetic strength did not seem to be required for successful RTP.

Performance criteria

Performance criteria were reported in six studies (Dunlop et al., 2020; Garcia et al., 2022; Taberner et al., 2020, 2022; van der Horst et al., 2017; Zambaldi et al., 2017). Two case studies (Taberner et al., 2020, 2022) used the completion of gradual and progressive on-field exposure to load as a criterion for RTP. Both studies used the "control-chaos continuum" framework for on-pitch rehabilitation (Taberner et al., 2019). The progression from one phase to the following one is determined by the ability of the player to tolerate and transition from high-control sessions to more unrestricted and unpredictable sessions.

In the Dunlop et al. (2020) study, the interviewed experts suggested that functional and on-field sport-specific criteria are important during all the phases of the RTP continuum; however, no specific criteria were reported. van der Horst et al. (2017) reported that the interviewed experts gave great importance to performance testing. Consensus was reached on the following tests to support the RTP decision: repeated sprint ability test, deceleration drills and position-specific physical load using a global positioning system (GPS) to perform match-specific rehabilitation drills. Zambaldi et al. (2017) reported that consensus was reached in their Delphi study about the following performance criteria to RTP: the ability to perform maximal sprints and reach maximal linear velocity, completion of a progressive running plan with total high-speed running distance equivalent to match requirements, return of full aerobic and anaerobic fitness (pre-injury, based on previous data) and achievement of match-based targets of external load.

Predictors of time loss

Imaging

Imaging was included as an RTP predictor in eight studies (Crema et al., 2018; Ekstrand et al., 2012; Hallén & Ekstrand, 2014; McAuley et al., 2022; Shamji et al., 2021; Tears et al., 2022; Valle et al., 2022). Cohen et al. conducted an epidemiological study on 38 professional football players. They concluded that factors such as the percentage of muscle/tendon involvement, the number of muscles involved and the amount of retraction seen on MRI scans were significant predictors of time to RTP. In their retrospective cohort study, Crema et al. (2018) analysed the MRI scans of 22 grade 1 hSI. The authors concluded that there was no correlation between oedema-like changes in grade 1 acute HSI and the time needed to RTP. Ekstrand et al. (2012) in a prospective cohort study analysed the MRI scans of 207 hamstring injuries from professional football clubs to evaluate the use of MRI as a prognostic factor for lay-off time after HSI in professional football players. The authors concluded that there was a clear association between injury grades and absence days from training sessions and match-play. Similar results were presented by Hallén and Ekstrand (2014) on a cohort of 283 hSI from professional football clubs. McAuley et al. (2022) also analysed retrospectively the MRI scans of a cohort of 35 HSI in one English Premier League football club. In discordance with Ekstrand et al. (2012) and Hallén and Ekstrand (2014), the authors reported no correlation between injury grades and RTP, while they found a correlation between the British Athletics Muscle Injury Classification (BAMIC) and time to RTP. The results indicated that RTP increased by 3 days for every increase in BAMIC grading, with an upper confidence limit of 4 days. Similarly, Tears et al. (2022) reported a significant correlation between the BAMIC system and RTP and a weak correlation between both oedema length and cross-sectional area and RTP. Also, Shamji et al. (2021) analysed the correlation between the BAMIC classification and RTP and found that intramuscular injuries ("c" according to the BAMIC system) are associated with an increased time to return to full training and reinjury rate. Valle et al. (2022) aimed to assess the ability of the muscle injury classification MLG-R in the prognosis of RTP. This classification system is based on the initials MLG-R, which refers to the mechanism of injury (M), location of injury (L), grading of severity (G) and number of muscle re-injuries (R) and was first proposed by an evidence-informed and expert consensus-based study (Valle et al., 2017). Valle et al. (2022) found that the injury grade was the most important prognostic factor for RTP, followed by an injury at the myotendinous junction (MTJ) location.

Player removed from the field

Only one study reported a player removed from the field as a predictor of RTP following a hamstring injury (McAuley et al., 2022). The authors reported that the athlete being removed from the activity significantly predicted time to RTP, adding an average of 11 days to RTP.

Discussion

RTP criteria

The literature search highlighted heterogeneity in the type of RTP criteria used and the definition of the different stages of RTP. Therefore, a division of the criteria into clinical, strength and performance was proposed. The clinical criteria are used primarily in the first phases of rehabilitation to assess players' ability to return to perform functional and physically demanding activities. The role of the clubs' medical departments is central in diagnosing and assessing clinically the progression of the injury (Delvaux et al., 2013; Dunlop et al., 2020). When the HSI is managed surgically, the surgeon's opinion should be considered to guide progression (Taberner et al., 2020). The most frequently utilized clinical criterion in this scoping review was the absence of pain. The included studies described the absence of pain on palpation during strength testing and functional activities, but none of them described specifically how to assess them. Absence of pain is described as a valid criterion in the literature in studies on RTS following hamstring injuries among a variety of sports (Hickey et al., 2017; Martin et al., 2022; van der Horst et al., 2016). Although, Hickey et al. (2020) compared a pain-threshold rehabilitation protocol with a standard rehabilitation programme for HSI in their randomized control trial. The authors concluded that the pain-threshold protocol offered a greater recovery of isometric strength and better maintenance of fascicle length, despite a similar time to RTP (Hickey et al., 2020).

Hamstring flexibility was also described as a useful tool to assess RTP (Delvaux et al., 2013; Dunlop et al., 2020; van der Horst et al., 2017; Zambaldi et al., 2017). van der Horst et al. (2017) reported that the expert panel agreed that hamstring flexibility should be assessed utilizing both the active and passive straight leg raise tests. The Askling H-test was considered to determine hamstring active flexibility and athlete's apprehension, but the experts did not reach a consensus on the inclusion, despite promising results in the literature (Askling et al., 2010, 2013). Zambaldi et al. (2017) reported that hamstring flexibility is an important RTP criterion, but the experts did not specify which test to use. The Askling H-test was mentioned by Zambaldi et al. (2017), but this test did not reach a consensus, similarly to van der Horst et al. (2017).

It is well known that the most common hamstring mechanism of injury occurs during the late swing phase of a sprinting action when the hamstring muscles have to produce high eccentric forces (Danielsson et al., 2020; Gronwald et al., 2022; Klein et al., 2021). Therefore, many authors have highlighted the importance of eccentric strength training during HSI rehabilitation (Breed et al., 2022; Hickey et al., 2022; Martin et al., 2022; Mendiguchia et al., 2017; Tyler et al., 2017) and the role of hamstring eccentric training in injury prevention (Al Attar et al., 2017; Beato et al., 2021; Martin et al., 2022; Shadle & Cacolice, 2017). Despite the aforementioned role of eccentric strength, there is limited and conflicting evidence regarding the use of eccentric strength measures as an RTP criterion in this review. Moreno-Pérez et al. (2020) suggested using the Nordic hamstring test in the late stages of rehabilitation.

Tol et al. (2014) used an isokinetic eccentric muscle test as RTP criterion, but the majority of the players tested (67%) had a significant strength deficit at the moment of RTP. In contrast, the experts in the van der Horst et al. (2017) study did not reach a consensus on the use of eccentric strength as an RTP criterion. Other studies supported using strength criteria for RTP but did not specify which tests to use (Delvaux et al., 2013; Dunlop et al., 2020; Zambaldi et al., 2017).

Predictors of time loss

MRI is the gold standard diagnostic tool for muscle injury detection (Lee et al., 2012), but there is no consensus on the best method to classify hamstring muscle injuries. In this review, some studies utilized the BAMIC classification (McAuley et al., 2022; Shamji et al., 2021; Tears et al., 2022), Cohen et al. used the traditional classification method (Shelly et al., 2009), Crema et al. (2018), Ekstrand et al. (2012) and Hallén and Ekstrand (2014) used the Peetrons classification (Peetrons, 2002), and Valle et al. (2022) used the MLG-R classification. Despite the different methodologies used, most studies supported using MRI as a predictor of time loss. Only Crema et al. (2018) found no correlation between the extent of grade one HSI and prognosis. The explanation for these results might be that grade one HSI does not affect the MTJ or the tendons. The association between HSI with tendon involvement and prolonged time to return to training was first described in elite track and field athletes using the BAMIC classification (Pollock et al., 2016). In professional football, McAuley et al. (2022), Shamji et al. (2021) and Tears et al. (2022) found differences in time to RTP between myofascial and intratendinous HSI based on the BAMIC classification. Although the conclusions were similar, there was high variability in lay-off times reported between these three studies (Tears et al., 2022). Valle et al. (2022) also reported that an important determinant for time to RTP is if the HSI affects the tendon.

Methodological considerations

Although RTP is an important and often discussed topic, there is a paucity of studies in professional football resulting in limited information available on RTP criteria specific to the elite population. This had, as a consequence, the need for some authors to conduct surveys or Delphi studies (Delvaux et al., 2013; Dunlop et al., 2020; van der Horst et al., 2017; Zambaldi et al., 2017) to interview experts in the field and practitioners working in professional football clubs to understand how they clear players to RTP, and for other authors to conduct retrospective studies to analyse and identify good practice (Crema et al., 2018; Ekstrand et al., 2012, 2016; Hallén & Ekstrand, 2014; McAuley et al., 2022; Shamji et al., 2021; Tears et al., 2022). This scoping review includes case studies (Baldock et al., 2021; Taberner et al., 2020, 2022) because of the need to describe research based on professional football experience, which can provide practitioners with applied RTP progression and criteria. One of them described the role of MRI as an RTP criterion (Baldock et al., 2021), while the other two case studies described the rehabilitation process with the RTP criteria, one used along the rehabilitation of an HSI managed conservatively (Taberner et al., 2022) and one which underwent surgical repair (Taberner et al., 2020). This scoping review highlights the paucity of observational and intervention studies since only one cross-sectional study (Moreno-Pérez et al., 2020) and one randomized control trial (Tol et al., 2014) were included, which suggests the need for more high-quality research and more studies to validate RTP criteria in professional football.

Limitations of the study

This scoping review included papers based on their definition and timing of RTP. The rehabilitation process goes through phases of progression until the return to playing competitive matches. Therefore, RTP criteria can be used at different stages to monitor and indicate the ability to progress to the next phase. The review also included different management (conservative and surgical) and rehabilitation protocols that can increase the variability among the evidence. To be included in this review, studies had to be published in English and peer-reviewed, which could have limited the access to tests and criteria used in non-English-speaking countries. HSI are common in sports that involve high-speed running, jumping, kicking and explosive activities such as track and field, football, Australian rules football, American football and rugby (Martin et al., 2022). Therefore, there is a plethora of research on HSI across numerous sports, but this review constrained the research to professional football, limiting the inclusion of RTP criteria studied and validated in other sports that are potentially used in practice but not reported here. Finally, this scoping review (because of its characteristics) does not provide guidelines for clinical practice (Munn et al., 2018), in particular, it was beyond the scope of this review to assess the validity of RTP tests and their optimal application specific to the type of injury and stage of rehabilitation. Future research is needed to investigate in more detail these topics in professional football.

Conclusions

This scoping review reports the available criteria to assess RTP following an HSI in professional football. It proposes methodological considerations, new research questions and new RTP criteria for future investigations. Moreover, it provides information to help practitioners in professional football make informed decisions regarding RTP following an HSI. Practitioners should consider including in their RTP battery of tests a combination of clinical, strength and performance criteria. Because of the variety and heterogeneity of those tests, there is a need to involve more professionals with different expertise in the RTP decision-making. Final decisions regarding RTP clearing should be based on a collective effort to analyse all the aspects of the process/case. This approach could reduce the risk of failure associated with the RTP decisions, particularly considering that HSI has a high recurrence rate.

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