An Investigation of Return to Sport Decision Making in Male Professional Football Following Lower Limb Muscle Injury

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A thesis submitted in partial fulfilment of the requirements of Edinburgh Napier University, for the award of Doctor of Philosophy

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Abstract

Background: Return to sport (RTS) following muscle injury represents an on-going challenge for professional male football teams. While published expert consensus have provided guidance to practitioners, it is currently not clear if, and what criteria are being used by teams, nor what decision-making practices look like in reality.

Methods & Results: Study one, a global survey of premier-league professional football teams, found that the RTS practices of surveyed teams closely align with consensus recommendations. The majority of teams (95%) adopted a continuum model. At each phase, a combination of clinical, functional, and psychological criteria was used to inform rehabilitation progression decisions. A shared decision-making approach was used by 80% of teams surveyed. Study two, a scoping review of literature (n=68 studies) regarding the criteria used to inform rehabilitation progression and support RTS decision-making in high-level football-code athletes, found that RTPlay was the most consistently studied rehabilitation phase (94% of studies) with injuries involving the hamstring the primary focus of research (78% of studies). Considerable heterogeneity was found regarding the specific criteria and metrics used. Only 9% of studies reported using psychological criteria to inform RTS decisions. Study three, a prospective two-season investigation of the psychometric properties of the Injury-Psychological Readiness to Return to Sport scale (I-PRRS), found that the instrument demonstrated good structural validity and internal consistency and exhibited good longitudinal measurement invariance in professional male football players.

Conclusion: Professional male football teams follow basic scientific recommendations during RTS, but there remains a lack of standardised specific criteria and metrics in both practice and in research. While decision-making is recognised as needing to be shared, there are several contradictions in the shared decision-making process within teams. Establishing the internal structure of the I-PRRS represents a first step in determining appropriate psychometric properties for use in professional male footballers, however other key psychometric properties are yet to be established to advocate its use in practice.

Publications and Presentations Resulting from this Thesis

Publications

Dunlop, G., Ardern, C.L., Andersen, T.E., Lewin, C., Dupont, G., Ashworth, B., O'Driscoll., G., Rolls, A., Brown, S., & McCall, A. Return to Play Practices Following Hamstring Injury: A Worldwide Survey of 131 Premier League Football Teams. *Sports Med* **50,** 829–840 (2020). https://doi.org/10.1007/s40279-019-01199-2

Presentations

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Author Declaration

This thesis is submitted in partial fulfilment of the of the requirements of Edinburgh Napier University, for the award Doctor of Philosophy.

I, Gordon Dunlop, hereby declare that:

a) I have composed this thesis,
b) This thesis is wholly my own work unless otherwise referenced or acknowledged and
c) This work has not been submitted for anu other degree of professional qualification except as specified

[redacted]

Gordon Dunlop

15th February 2023

Date Submitted

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Abbreviations

ACL	Anterior Cruciate Ligament
ACL-RSI	Anterior Cruciate Ligament Return to Sport After Injury scale
AFC	Asian Football Confederation
AFL	Australian Football League
AROM	Athlete Reported Outcome Measure
BIC	Bayesian Information Criterion
BSEM	Bayesian Structural Equation Modelling
BW	Body Weight
CAF	Confederation of African Football
CFA	Confirmatory Factor Analysis
CHERRIES	Checklist for Reporting Results of Internet E-Surveys
CI	Confidence Interval / Credibility Interval*
CONCACAF	Confederation of North, Central American and Caribbean Association Football
CONMEBOL	South American Football Confederation
COSMIN	COnsensus-based Standards for the selection of health Measurement Instruments
DIC	Deviance Information Criterion
EFA	Exploratory Factor Analysis
FIFA	Fédération Internationale de Football Association
GPS	Global Position Satellite System
H:Q	Hamstring:Quadriceps Ratio
HR	Hazard ratio
IKDC	International Knee Documentation Committee score
I-PRRS	Injury-Psychological Readiness to Return to Sport Scale
IW	Inverse Wishart Distribution
KOOS	Knee Injury and Osteorthritis Outcome Score
MCMC	Markov Chain Monte Carlo
MRI	Magnetic Resonance Imaging
NRCT	Non-Randomised Control Trail
OCEBM	Oxford Centre for Evidence-Based Medicine
OFR	On Field Rehabilitation
OR	Odds Ratio
p	Probability Value
POMS	Profile of Mood States
PPp	Posterior Predictive p Value
PRISMA-ScR	Preferred Reporting Items for Systematic Reviews and Meta-Analyses Extension of Scoping Reviews
PSLR	Passive Straight Leg Raise
RCT	Randomised Control Trail
ROM	Range of Motion
RPE	Rating of Perceived Exertion
RSSIQ	Return to Sport After Serious Injury Questionnaire
RTPerf	Return to Performance
RTPlay	Return to Competitive Play
RTRun	Return to Running
RTS	Return to Sport
RTTrain	Return to Training
SD	Standard Deviation
sRPE	Session Rating of Perceived Exertion
SSCI	State Sport Confidence Inventory
StARRT	Strategic Assessment of Risk and Risk Tolerance
TIP	Team-Sport Injury Prevention
TMD	Total Mood Disturbance
TRIPP	Translating Research into Injury Prevention Practice
TSCI	Trait Sport Confidence Inventory
UEFA	Union of European Football Associations
UEFA-ECIS	UEFA Elite Club Injury Study
VAS	Visual Analog Scale
WHO	World Health Organisation
ω	Omega

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Chapter One

General Introduction

1.1 Research overview

For professional football clubs, the primary objective is to win matches, and ultimately, championships and trophies. Avoiding injury, thereby ensuring high player availability for training and match play, serves not only to be advantageous economically, but may also signify a decisive component in determining a team's success. It has been well documented in professional football that injuries affect performance negatively and that lower injury rates are linked to success in both domestic and international competition (Arnason et al., 2004; Eirale et al., 2013; Hägglund, Waldén, Magnusson, et al., 2013). Of particular concern to medical teams however, is that a previous history of injury has been consistently associated with an increased susceptibility to recurrent as well as subsequent injury, and are therefore faced with the prospect of further time-loss and detrimental injury-reinjury cycles (Bitchell et al., 2020; Hägglund et al., 2006; Hägglund, Walden, et al., 2013; Toohey et al., 2017).

The most common injury type experienced in male professional football players are muscle injuries (López-Valenciano et al., 2020). In fact, the incidence of muscle injuries has not reduced since 2001 in top level European football, neither in training nor in match-play (Ekstrand et al., 2021). Indeed, in the case of some specific muscle injury subtypes (e.g. hamstring injuries), annual increases in injury incidence and injury burden (i.e. lay off days per 1000 hours of exposure) have even been observed. What makes muscle injuries particularly troublesome is that they carry a high rate of re-injury (Ekstrand, Hägglund, et al., 2011; Hägglund et al., 2016) and are often more severe than index injuries (i.e. the initial injury of the same type and location), thereby adding to the total injury burden (Ekstrand, Krutsch, et al., 2020; Hägglund et al., 2016). Furthermore, index injuries to the hamstring, quadriceps, adductors and calves have all been shown to be associated with a greater risk of subsequent injury at a different site following return to sport (RTS) (Hägglund, Waldén, & Ekstrand, 2013; Toohey et al., 2017)

Muscle injuries constitute 40% of all time-loss injuries experienced in top-level European male professional football (Ekstrand et al., 2021). Moreover, they have been found to account for more than a quarter of the overall injury burden (Ekstrand, Hägglund, et al., 2011). These findings have been similarly reflected in epidemiological studies of professional football leagues and football associations conducted outside of Europe (e.g. Aoki et al., 2012; Pedrinelli et al., 2013; Calligeris, Burgess & Lambert, 2015; Reis et al., 2015; Lu et al., 2020). Considered in the context of a typical 25-man playing squad, a professional team can expect 15 muscle injuries each season which collectively can equate to a mean absence of 233 days, resulting in 148 missed training sessions and 37 missed matches (Ekstrand, Hägglund, et al., 2011). The majority (92%) of time-loss muscle injuries are found to affect the major muscle groups of the lower limbs; most notably the hamstrings (37%), adductors (23%), quadriceps (19%) and calves (13%) (Ekstrand, Hägglund, et al., 2011).

Although less frequent than index injuries (1.3 vs 7.0 injuries per 1000 hours of exposure), the rate of re-injury incidence, as described within the epidemiology literature of professional football, is considered high (López-Valenciano et al., 2020). The overall re-injury rate among top-level European clubs has previously been reported as close to 17%, with recurrent injuries involving the major muscle groups of the lower limb accounting for close to half of all reported re-injuries (Hägglund et al., 2016). As a function of frequency and burden, hamstring injuries are by far the most common and time-costly re-injury reported in top-level football (Hägglund et al., 2016). Of particular concern is the finding that the incidence of muscle re-injuries occurring in training following RTS have not significantly reduced in professional football during 18 seasons of observation (2001/2002 – 2018/2019) (Ekstrand et al., 2021). What is more, recurrent muscle injuries appear particularly susceptible to occurring 'early' (i.e. within 2 months) after RTS and by definition in the same location as the index injury; findings which may be symptomatic of insufficient rehabilitation, premature RTS and/or inadequate discharge criteria (Hägglund et al., 2016; Wangensteen et al., 2016). Understandably, this has prompted greater interest in evaluating the effectiveness of current rehabilitation approaches and decision-making practices adopted by professional football teams to guide RTS and specifically following muscle injury.

Following injury, sports medicine practitioners face considerable pressure to return players to training and match play as quickly and safely as possible, whilst simultaneously ensuring they can perform at pre-injury levels and avoid re-injury. From a strict medical perspective and having player welfare and safety in focus, it may be inviting to delay a player's RTS following injury. By allowing sufficient time for tissue healing, rehabilitation, and player recovery (both physically and psychologically) it is advocated that re-injury risk can likely be reduced (Hägglund et al., 2018; Mendiguchia et al., 2017). In a recently published systematic review on RTS after hamstring injury, Hickey et al., (2017) found lower re-injury rates were associated with longer recovery times. However, this study included athletes of professional, collegiate, and recreational standards. Although not specific to lower limb muscle injuries, the recurrence of achilles tendon injuries in elite level European male footballers was shown to be significantly higher in players who were cleared to return to training and matches after their original injury (<10 days) than those who were afforded longer rehabilitation periods (>10 days) (Gajhede-Knudsen et al., 2013).

Across professional football and sport in general, the decision to RTS is notoriously complex and requires consideration of several (often-competing) elements, including medical and non-medical related factors (Creighton et al., 2010; Shrier, 2015). In this respect, it has been argued that aiming for the lowest level of risk of re-injury by intentionally extending RTS timeframes may not always be realistic in practice, especially at the professional level where adherence to recommended timeframes for biological healing may not always be feasible or appropriate (McCall et al., 2017; Pieters et al., 2021). Indeed, in professional football, recurrence proportions are highest in the second half of the competitive season suggesting RTS decisions may be as much context driven, as they are clinically informed (Hägglund et al., 2016). For example, the risks associated with accelerating RTS (e.g. increased re-injury risk and reduced performance) may be more readily accepted if it ensures the availability of a key player for a decisive fixture and thus, provides the team with the best opportunity of success (McCall et al., 2017; Orchard et al., 2005).

In the setting of professional football, each injury must be treated individually whereby the decision to RTS represents a unique judgement based on an assessment of risk. Ideally, this decision should reflect the interests of the player and the team but also be concurrently balanced by sound clinical reasoning to help minimise re-injury risk and optimise performance upon return. To assist practitioners in their clinical decision-making, a multifactorial, criterion-based approach to rehabilitation is widely advocated (Mendiguchia et al., 2017; Mendiguchia & Brughelli, 2011; Schmitt et al., 2012; Serner, Weir, Tol, Thorborg, Lanzinger, et al., 2020; Tol et al., 2014). Composed of quantifiable tests to help identify and address deficits which may increase risk of re-injury, criteria-based programmes have gained popularity across practice by offering a more individualised approach to rehabilitation progression as opposed to relying on predetermined pathophysiological timeframes for muscle healing (Hickey et al., 2017). Unfortunately however, in the absence of valid and standardised criteria to guide the decision about when to return a player to training or competition, or whether pre-injury levels of performance have been reached, a high degree of uncertainty currently surrounds which criteria should in fact inform rehabilitation progression and RTS decision-making (van der Horst et al., 2016). This issue is further hindered by the fact that there appears to be strong reliance placed on subjective assessments and performance tests within the literature to progress rehabilitation and determine RTS clearance (Hickey et al., 2017).

In recent years a number of attempts have been made to establish greater consensus surrounding RTS criteria and decision-making in sport generally (Ardern et al., 2016) and professional football specifically (Delvaux et al., 2014; van der Horst et al., 2017; Zambaldi et al., 2017). Recognising the lack of high-quality evidence to support decision-making in practice, a 2016 expert-led consensus statement on return to sport presented several recommendations to assist practitioners in making optimal RTS decisions and improving rehabilitation outcomes. Among these recommendations it was proposed: (1) RTS should be viewed to occur along a continuum which emphasises a stepwise, criteria-based progression of activity through key stages of the RTS process (i.e. from the point of injury through to a return to participation, return to sport, and return to performance), (2) Objective and clinically practical criteria should be used where possible and complement subjective measures thereby facilitating a more evidence-informed approach to decision-making practices, (3) A multidisciplinary and shared decision-making process should be followed when evaluating a player's readiness to return to sport and appraising the subsequent risks a given decision may carry, (4) As part of an holistic athlete-centred model of care, a players psychological welfare should be taken into consideration during rehabilitation and at the time players are making their transition back to sport.

In support of this approach to RTS, two football-specific Delphi surveys have since attempted to expand on some of these recommendations outlined in the 2016 consensus (van der Horst et al., 2017; Zambaldi et al., 2017). More specifically, each study attempted to achieve consensus on which criteria should be considered as part of a test battery to assess player readiness to return to competitive match-play. In accordance with the multifactorial nature of injury, among the RTS criteria consensually agreed upon, the evaluation of aspects relating to clinical recovery, functional competency, and psychological readiness were perceived to be particularly important across both surveys when returning players to competitive match-play. While it should be recognised that this research has subsequently provided an important reference from which to guide and standardise RTS decision-making within a professional football context, the importance of these recommended criteria in informing RTS decisions and optimising rehabilitation outcomes remains unclear as their utility, validity, reliability, and sensitivity have yet to be established.

It is presently unknown whether the key recommendations from the 2016 consensus and subsequent football-specific Delphi surveys are being implemented within the RTS practices of professional football teams, and if not, what possible barriers could be hindering their implementation. In this respect, if the incidence and subsequent impact of muscle re-injuries are to be addressed within professional football, an important starting point is to determine whether the criteria and decision-making recommendations outlined by research are in fact being translated into practice and to identify if, where, and why gaps exist.

1.2 Thesis aim and objectives

Accordingly, the overall aim of this thesis was to examine the gap between research and current practice with respect to the criteria and practices used to support decision-making in the progression of professional football players through the return to sport process following muscle injury.

To achieve this aim, three key objectives have been identified within this research programme:

1. To explore the current return to sport practices of elite male professional football teams following muscle injury.

2. To scope the existing literature in respect to the criteria used to inform rehabilitation progression and support return to sport decision-making following muscle injury in professional football players

3. To examine psychometric properties of an existing psychological readiness questionnaire related to return to sport following injury in a cohort of male professional football players

Chapter Two

Review of Literature

2.1 Introduction

How best to guide rehabilitation and inform decision-making to ensure a safe and efficient return to sport following injury, presents a significant challenge for medical and performance teams working within elite sport including professional football. The gold standard approach as defined by Coutts (2017) to improving performance outcomes such as the prevention of re-injury is recommended to be one which is evidence-informed, reflecting the integration of the highest-quality research with best current practice. Therefore, the purpose of this chapter is to review the existing literature that underpins and informs current decision-making practices within professional football with respect to guiding a player's return to sport following muscle injury. More specifically, it aims to highlight the impact of injury and in addition, establish the extent of the current muscle injury problem faced within male professional football through review of the relevant epidemiological literature. In consideration of key aetiological factors identified to contribute to the incidence of muscle re-injury, this literature review will subsequently discuss the current evidence-led strategies to guide the rehabilitation and return to sport process. The particular focus of this evaluation of the literature will not only reflect the complexity of decision-making within applied practice, but also highlight existing evidence gaps in conceptual understanding from which to guide and inform return to sport in the setting of professional football. This chapter therefore aims to provide a rationale for undertaking the current body of research and present a detailed context within which the findings of the subsequent chapters may be interpreted.

At this point it should also be outlined that it is beyond the scope of this thesis to critically evaluate and establish the validity (or otherwise) of existing rehabilitation criteria used or reported in the management of muscle injuries. Accordingly, no judgements will be made either supporting or refuting their appropriateness to inform decisions during the RTS process. Rather, this thesis is focused toward determining the extent to which the application of existing evidence around decision-making as a concept and as a strategy is used in the applied setting of professional football. Through this, the thesis intends to establish whether the current rehabilitation practices implemented by professional football teams are evidence-based, and further, what that evidence purports to be both in terms of consistency and in reliability.

To ensure appropriate literature and contemporary expert consensus were included within this thesis a search strategy using Medline and PubMed was developed. This included, but was not limited to, several keywords associated to the topic area - for example: return to play, return to sport, rehabilitation, injury, re-injury, criteria, decision-making, professional football (soccer), and football-code sports. To ensure studies published throughout the course of developing this thesis were included, a monthly search of appropriate peer-reviewed journals was conducted.

2.2 Impact of injuries in professional football

In professional football, the principal objective is to win matches. As a result, the interaction of several performance related variables i.e. technical, tactical, physical, and psychological, are central to achieving this. Avoiding injuries, thereby ensuring high player availability represents a decisive component in determining success. Understandably, a team's prospects of winning will be markedly improved if it has its best players available for selection. Equally, from the perspectives of key non-playing staff such as managers and coaches, higher player availability at training will also enable greater opportunities and time to develop tactical awareness, technical aspects, and team dynamics. From review of the respective literature, there is strong scientific evidence to support this. For example, a number of investigations have demonstrated that low injury rates are positively associated with improved team performance and success in both domestic league competition (Arnason et al., 2004a; Carling et al., 2015; Eirale et al., 2013) and International European cup competition i.e. UEFA Champions League and Europa League, respectively (Hägglund, Waldén, Magnusson, et al., 2013). Furthermore, Bengtsson et al. (2013) highlighted that the odds of losing or drawing a match were greater for teams sustaining two or more injuries during match-play. While Waldén, Hägglund and Ekstrand (2007) had previously found that female football teams eliminated in the group stages of an International European Championship (2004-2005) had a significantly higher match injury incidence compared to the teams which successfully progressed to the latter stages of the tournament.

While the literature cited has encompassed the more immediate impact of injuries on performance outcomes, high-level youth players have also been found to lose large portions of essential seasonal development time due to injury (Jones et al., 2019; Materne et al., 2021). The repercussions of which, as recently demonstrated by Larruskain et al. (2021), can harbour longer-term performance consequences, potentially impeding the development of academy players and decreasing their chances of progressing into 1st team senior-level professional football. This outcome can clearly be potentially very damaging to clubs, especially those whose model is heavily reliant on academy structures producing high-quality homegrown players.

In addition to these performance related outcomes, injuries also present a significant economic burden to professional clubs. Ekstrand has reported that on average the estimated financial cost incurred for a 1st team player being unavailable for a month due to injury equated to ~ €500,000 (Ekstrand, 2013). When extrapolated to incorporate the typical absence observed due to injury across an entire squad, seasonal expenditure can total ~ €20,000,000 (Ekstrand, 2016). Accounting for the substantial transfer fees now required in obtaining the services of the world's top players and the subsequent salaries they command, the financial impact of injury on clubs is now particularly significant. Consequently, as expenditure continues to rise as professional teams endeavor to engineer success on the pitch, they are confronted with a subsequent and equal rise in the economics of injury off it; a reality that has been reflected in a recent audit of the English Premier League. It was revealed that during the 2016-17 and 2017-18 seasons, despite a reduction in the incidence of injury being observed, the overall cost incurred by clubs due to injury had actually increased by 21% from £176.6m to £217 (BBC Sports, 2018). Importantly, also worth considering are the ongoing medical costs connected with injuries to players (e.g. scans, specialist referrals) and the expenses associated with the implementation of new technologies and the acquisition of specialist staff to support the assessment and rehabilitation of injuries. Consequently, the financial costs incurred through injury are likely to be more marked than that reported within the research literature. In accordance with the increasing economic demands of professional football, the incidence of injury and particularly those of a severe nature or high burden due to their frequency of occurrence/reoccurrence can result in a substantial loss of revenue for clubs.

Consideration must also be given to the adverse consequences of injury on player health and welfare. At an individual player level, sustaining a sports-related injury is understood to represent a prominent stressor for athletes/players and can potentially have a significant psychosocial impact leading to the expression of a number of maladaptive psychological and behavioral responses (Hagger et al., 2005; Wiese-Bjornstal, 2010). These can include, for example, emotional and cognitive reactions such as fear, depression, and anxiety as well as reduced self-efficacy and motivation (Ardern et al., 2013; Forsdyke et al., 2016). The consequences of which may impede the speed of RTS, influence rehabilitation adherence and the quality of RTS as well as diminish the chances of successfully returning to pre-injury level sport/competition (Ardern et al., 2013; Ardern, Österberg, et al., 2014; Forsdyke et al., 2016; Ivarsson et al., 2017).

In a cross-sectional analysis of 540 European male professional football players Gouttebarge et al. (2016), found that the number of severe musculoskeletal time-loss injuries (i.e. a time-loss $\geq$ 28 days) experienced during a career was positively associated with symptoms of common mental disorders. More specifically, players sustaining one or more severe joint or muscle injuries during their career were two to nearly four times more likely to report symptoms of common mental disorders than players who had not experienced severe-time loss injury. Outcomes that have since been supported by Kiliç et al. (2018). Such findings, underline the importance of examining injury and RTS through a biopsychosocial lens and providing supportive environments that can fulfil the basic psychological needs (i.e. competency, autonomy, and relatedness) of players returning from injury and help protect against detrimental affective responses (Ardern et al., 2013; Podlog & Eklund, 2007b).

As similarly observed from a performance perspective, injuries may also carry a longer-term psychological impact. This can arise from the fact that injuries can cause premature career termination and increase the risk of developing degenerative physical ailments (e.g. osteoarthritis of lower limb joints); outcomes that may diminish quality of life as a consequence (Drawer, 2002; Freckleton & Pizzari, 2013; Krajnc et al., 2010; Sanders & Stevinson, 2017; Schuring et al., 2017). Safeguarding the psychological and physical welfare of players is becoming increasingly recognised as an important consideration, not only following injury and during the RTS process, but also in assisting players to manage growing social and performance expectations as well as in their transition out of football.

It is clear then, that from the perspectives of performance, economical and psychological wellbeing, the prevention of injury and re-injury is a key priority of science and medicine sport staff working in professional teams. Understandably, exercise-based preventative strategies to reduce risk and minimise their incidence are warranted, and this area of research has received increased attention over recent years. This has prompted the desire for both research and practice based evidence to inform the development of evidence-based prevention practices at primary, secondary and tertiary levels respectively (Blanch & Gabbett, 2016; Drew, Cook & Finch, 2016).

Importantly however, in acknowledgement of the fact that human behaviour represents a key factor in the prevention of injury and re-injury, the attitudes and beliefs of the stakeholders toward preventative strategies are clearly also an integral component in their success (Verhagen & Bolling, 2018). Accordingly, being able to effectively convey the benefits of prevention strategies in a context which engages with key stakeholders such as players (e.g. to reduce injury risk), coaches (e.g. performance outcomes and team success) and board members, (e.g. economically beneficial/prudent approaches) is advantageous when promoting buy-in and maximising compliance and adherence to their adoption (Ekstrand, 2013; McCall, Dupont, et al., 2016).

In this respect, how research- and practice-based evidence is communicated and disseminated is essential, as undeniably strategies for injury and re-injury prevention will only be capable of reducing injuries if they are accepted, adopted, and complied with by players and other relevant stakeholders whom they are intended to target. To achieve this, the relationship and capacity for engagement and mutual exchange of information between player, coach, practitioner, and researcher appears critical, yet may be the most challenging barrier to implementing evidence-based practice in high-level sporting organisations such as professional football (Bolling et al., 2020; Fullagar et al., 2019)

2.3 Existing models to guide injury prevention efforts

A number of sport injury models have been developed to provide a framework from which to coordinate injury and re-injury prevention research (Finch, 2006; van Mechelen et al., 1992) and advance aetiological theory and understanding within sport (Bahr & Krosshaug, 2005; Bittencourt et al., 2016; Meeuwisse, 1994; Meeuwisse et al., 2007; Windt & Gabbett, 2017). Evident from this review of the literature, approaches directed toward the prevention of injury and re-injury have predominantly used a top-down approach and followed the widely adopted sequence of prevention (Figure 2.1) (van Mechelen et al., 1992).

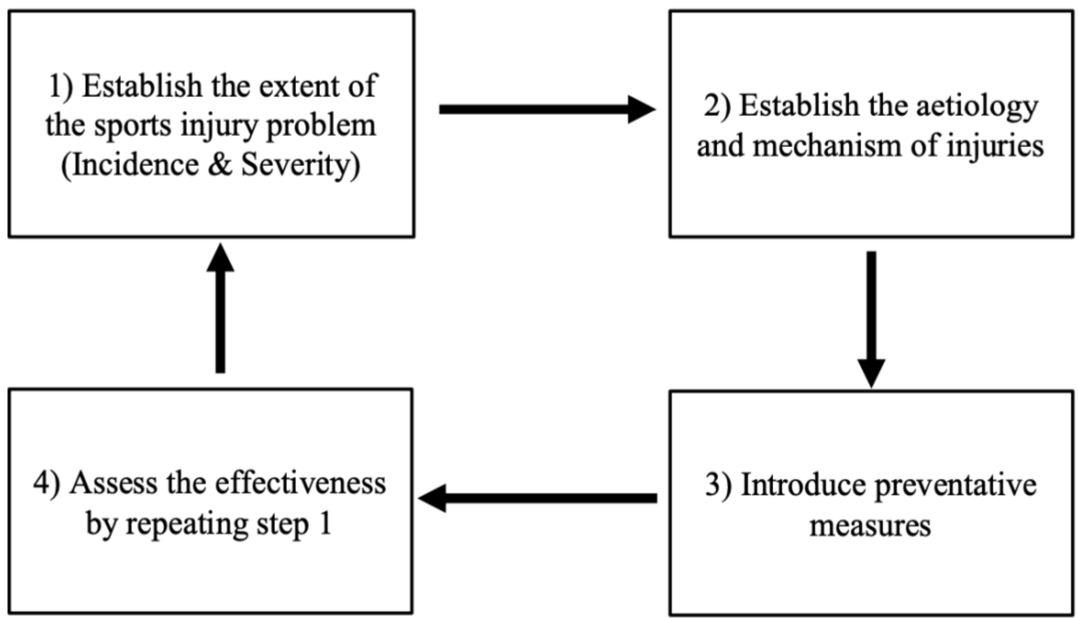

Figure 2.1. The four step ‘sequence of prevention’ of sports injuries (van Mechelen et al., 1992).

Specifically, this four-stage approach outlines that prevention begins with determining the magnitude of the injury problem and is commonly described in terms of injury incidence and severity. The next step in the sequence is to identify possible risk factors and mechanisms associated with injury occurrence. Hereafter, effective preventative measures are developed to mitigate the risk of injury and are subsequently translated into practice. In the final step, the effectiveness of preventative strategies implemented are evaluated by repeating step one. Although van Mechelen's model has been widely adopted to aid the development of an evidence base of efficacious preventive measures, this model has been found to inherently restrict the potential impact an intervention can have in applied 'real-world' settings. This appears to be primarily on account of its failure to take into consideration possible barriers to implementation which can impede the uptake of interventions by practice (Hanson et al., 2012).

Regarded as providing a more practical and meaningful approach to research within the field of sports injury prevention, development of the Translating Research into Injury Prevention Practice (TRIPP) framework can be viewed as an addendum to the original sequence of prevention model (Finch, 2006). Significantly, this model drew attention to the possible translation gap between efficacious interventions suggested by scientific research and their actual implementation in applied practice. Accordingly, the modifications proposed in the TRIPP framework by Finch aimed to reduce this knowledge gap by overcoming the recognised limitations of the former model (Table 2.1).

Table 2.1. The six stages of the Translating Research into Injury Prevention Practice (TRIPP) Framework for research leading to real-world sports injury prevention (Finch, 2006).

Stage	**TRIPP Framework**
1	Injury Surveillance
2	Establish aetiology and mechanisms of injury
3	Develop preventative measures
4	Scientific evaluation under controlled "ideal" conditions
5	Describe intervention context to inform implementation strategies
6	Evaluate effectiveness of preventative measures in implementation context

Specifically, the two steps added, highlighted the need to describe and understand intervention context (e.g. personal, environmental, societal and sports delivery factors) in order to inform implementation strategies (TRIPP stage 5) before evaluating the effectiveness of the intervention when applied to the real-world context of player behaviours and sporting culture (TRIPP stage 6) (Finch, 2006).

A limitation of this framework, however, is that interventions are still designed under 'ideal' conditions prior to outlining and appreciating implementation contexts (Tee et al., 2020). Several peer-reviewed articles have since been published with the aim of addressing a range of limitations identified within injury prevention models such as: the use of linear (Meeuwisse et al., 2007), reductionist (Bittencourt et al.,

2016) or generic approaches (Roe et al., 2017), a lack of operational steps (Padua et al., 2014; Roe et al., 2017) and a failure to incorporate player workloads (Windt & Gabbett, 2017). Interestingly, the necessity to understand and consider both context (Bolling et al., 2018; Tee et al., 2020; Verhagen et al., 2014) and needs of the end users (O 'Brien & Finch, 2016; Jones et al., 2017; Bolling et al., 2019; Fullagar et al., 2019) has more recently been recognised as an important starting point from which to initiate the research process. A viewpoint which has subsequently given rise to new models for injury prevention such as the Team-sport Injury Prevention (TIP) cycle (Figure 2.2) (O'Brien et al., 2019).

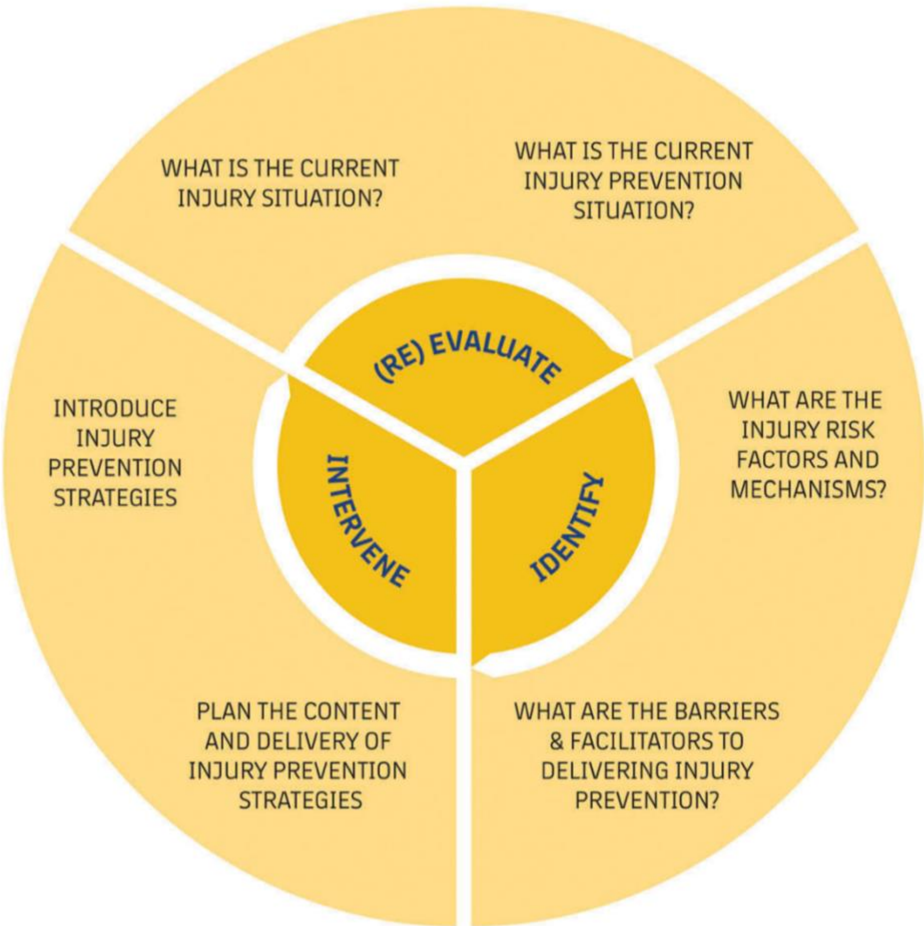

Figure 2.2. The Team-sport Injury Prevention (TIP) cycle (O'Brien et al., 2019).

This framework appears to align more closely to the process-driven, iterative approach which a multidisciplinary staff in team sports will engage in and importantly, allows interventions to continually evolve in response to changing contexts and/or injury situations experienced (O'Brien et al., 2019). Akin to the focus placed on understanding context within the literature cited, the TIP cycle emphasises a bottom-up approach whereby a detailed understanding of all team members perceptions towards injury and re-injury risk in addition to their prevention are prioritised and considered fundamental to informing subsequent phases of the cycle (Hanson et al., 2012; Verhagen et al., 2014; Verhagen & Bolling, 2018).

Through this approach, practitioners can contribute to addressing the research to practice gap by providing much needed practice-based evidence to supplement the existing research-evidence base. Essentially, this information can help guide the design and development of interventions that more closely align to the contextual needs of end-users and provide greater opportunity for the effective embedding of practices which are evidence-based within elite sporting organisations such as professional football teams. To date, as far as can be determined, no published evidence exists currently which has evaluated the application of the TIP cycle within professional football. However, similar iterative multidisciplinary approaches to injury prevention have been shown to be effective in reducing injury risk in other professional team sports (e.g. Rugby Union) (Tee et al., 2018).

Increasingly evident from the review of existing literature, in adopting a predominantly top-down approach to develop injury and re-injury prevention strategies, the main issue appears to be that many of the existing measures and prevention strategies proposed for use in sport general and professional football, are developed and evaluated only from the perspective of the researcher. As a result, knowledge is generated which is still required to be translated into practice. Despite this potentially resulting in a translation gap between research and practice, models such as van Mechelen's sequence of prevention have historically formed the basis of current injury prevention practices within professional football. This may in part explain why, despite concerted prevention efforts, overall training, match, and muscle injury continue to present a significant challenge for medical and science teams operating within professional football (Ekstrand et al., 2013, 2021; Ekstrand, Hagglund, et al., 2011; López-Valenciano et al., 2020).

2.4 Injury epidemiology

Representing the first step in the sequence of prevention, epidemiological research is a fundamental element in the concerted effort to protect professional footballers from injury and subsequent re-injury. The collation of injury data has proved useful in quantifying the extent of the injury problem within professional football and subsequently guiding effective injury prevention by channelling research into injury mechanisms and aetiology to give rise to new preventative approaches and treatment strategies of potential value.

During the period 2000-2020, several injury surveillance research projects have been initiated in male professional football to comprehensively study the type, incidence, severity and patterns of football related injuries and re-injuries at both club and national team levels respectively. Correspondingly, a prominent focus within the literature has also been directed to promoting greater consistency in the definitions and methodologies used to improve the overall reporting standard and quality of epidemiological research undertaken (Bahr et al., 2020; Fuller et al., 2007; Hägglund, Waldén, et al., 2005). The aim of this was to allow for meaningful and valid comparisons to be made (e.g. within teams/leagues, between studies and/or longitudinally across seasons). It is essential that robust study designs with consistent and accurate data capture and thorough analysis be embedded within epidemiological investigations because ultimately, as underpinned by existing injury models, these reflect the building blocks on which sport injury prevention and rehabilitation programmes are currently developed, implemented, and evaluated.

2.4.1 Injury epidemiology in professional football

The collection of injury data is now common practice within professional football. For example, epidemiological studies have been performed in conjunction with a number of major international tournaments (e.g. World Cup, European Cup, Olympic Games and Copa America) (Hägglund et al., 2009; Junge & Dvorak, 2013; Pedrinelli et al., 2013) and elite European, Asian and South American club cup competitions (e.g. UEFA Champions League, AFC Champions League, Copa Libertadores) (Bengtsson et al., 2021; Ekstrand, Hagglund, et al., 2011; Tabben et al., 2022). In addition, they have also been initiated in a host of leagues worldwide, albeit with varying degrees of participation and periods of observation (e.g. England (Jones et al., 2019), France (Carling et al., 2011), Spain (Noya Salces et al., 2014), Italy (Falese et al., 2016), Holland (Stubbe et al., 2015), Norway (Bjørneboe et al., 2014), Sweden (Hägglund et al., 2003), Australia (Lu et al., 2020), Qatar (Mosler et al., 2018), Brazil (Reis et al., 2015), South Africa (Bayne et al., 2018), Hong Kong (Lee et al., 2014), Japan (Aoki et al., 2012), North America (Arundale et al., 2018).

Despite being prominently focused toward male professional football, researchers have also provided important insights into the injury characteristics of other key cohorts within football (e.g. female and high-level youth footballers) (Junge & Dvorak, 2007; Larruskain et al., 2018; Jones et al., 2019). Together, these have assisted in identifying a multitude of non-modifiable and potentially modifiable intrinsic (i.e. player-related) and extrinsic (i.e. environmental-related) risk factors which may influence injury and re-injury rates observed within the professional game (e.g. Hagglund et al., 2006; Hägglund, Waldén & Ekstrand, 2013; Bengtsson et al., 2018; Ekstrand, Lundqvist, Davison, et al., 2018; Ekstrand, Spreco and

Davison, 2018; Ekstrand et al., 2020). While it is out with the scope of this thesis to carry out a detailed evaluation of these risk factors, as per the injury models above, it is important to at least be aware of the multifactorial nature of injury and re-injury risk to support the understanding of the decision-making process for RTS.

Importantly, epidemiology studies and injury surveillance research programmes continue to provide researchers and practitioners with an evolving picture of the current injury landscape within professional football. Perhaps more pertinent to the focus of this thesis however, is that such studies have also provided valuable prognostic information regarding time-loss and the anticipated RTS timelines for a variety of different injury-types (e.g. Gajhede-Knudsen et al., 2013; Lundblad et al., 2013; Hallén and Ekstrand, 2014; Ekstrand et al., 2019; Werner et al., 2019). As discussed previously (section 2.2), owing to the impact which injuries can have on professional teams, RTS decision-making is characterised by complexity with medical and coaching staff facing considerable pressure to accelerate a player's return to training and match-play. Access to detailed information regarding lay-off times for specific-injury types as well as their susceptibility for recurrence can assist in injury management and subsequent planning (i.e. future training and team composition) as well as forecasting financial expenditures. Consequently, ongoing analysis of the severity of injury experienced within professional football continues to be essential in order to provide realistic expectations on estimated timelines for RTS and a best practice approach to rehabilitation (Ekstrand, Krutsch, et al., 2020).

The prevention of injury and re-injury represent a significant challenge for teams: a challenge that is experienced globally throughout professional football. However, the capacity to understand normative rates of injury and re-injury incidence, establish seasonal injury trends or emerging injury patterns within the context of specific leagues and/or continents remains challenging, especially outwith Europe (López-Valenciano et al., 2020). Despite increased calls for greater participation and diversity with respect to the leagues and continents where injury data is being collected (Eirale et al., 2017, 2018), relatively few football confederations have attempted to prospectively study and collate injury and re-injury data in both a centralized and longitudinal manner (Arundale et al., 2018; Eirale et al., 2017; Ekstrand et al., 2021; Lu et al., 2020). Acknowledging that the resources available to teams (e.g. financial, manpower, facilities) across different confederations and leagues is not equal, participation in wider research initiatives may be consequently impaired. It is therefore of concern that the data collated through such studies can lead to the omission of these types of constraints from the models and strategies subsequently being developed and proposed to better support professional practice globally. Thus, despite approaches within research and practice being acknowledged as gold standard, their application in all football settings may not always be feasible. It is therefore important that future research promote greater diversity and inclusion to be able to provide recommendations globally.

Whilst confined to a relatively small cohort of elite European football teams and thereby diminishing general applicability, one database that has helped guide injury related research has been the UEFA Elite Club Injury Study (UEFA-ECIS). Launched in 2001, the UEFA-ECIS represents an on-going injury surveillance research project of European male professional footballers participating in the UEFA Champions League and is perhaps unrivalled as a resource of football injury data.

Having been in place for 19 seasons with, 64 of Europe's top professional teams having participated to date, the UEFA-ECIS database currently has access to over 23,000 injury cases (Ekstrand, Krutsch, et al., 2020; Ekstrand, Spreco, et al., 2020). As evidenced through its extensive publication history, the UEFA-ECIS continues to be a tool used by clubs, football associations and the scientific community, bringing additional valuable knowledge to help prevent, treat, and guide return to play following injury.

Paying particular attention to male European football and the UEFA-ECIS, this review of the injury epidemiology literature aims to offer a systematic and coherent summary of the injury-risk presented by participating in professional football. Providing a comprehensive description of injury incidence as well as highlighting the current injury and re-injury trends observed in professional football, this section will seek to establish the rationale underpinning the specific injury type focus of the subsequent chapters represented within this body of work.

2.4.2 General incidence, severity, and pattern of injury in professional football

Informed by injury data collected from the UEFA-ECIS cohort, the first of two seminal papers in outlining the injury and re-injury landscape in European top level professional football was published in 2009 (Ekstrand, Hagglund, et al., 2011). To this point, while the epidemiology of professional football had been extensively studied, very few published studies had included data collected over two or more consecutive seasons (e.g. Hawkins & Fuller, 1999; Hawkins et al., 2001; Ekstrand, Waldén & Hägglund, 2004; Hägglund, Waldén & Ekstrand, 2006). Consequently, little was known regarding the pattern in injury incidence over time. Further, despite single season injury surveillance studies providing an overview of the injury situation in a specific environment and/or given point in time, the interpretation of injury incidence (i.e. overall, match and/or training) has been deemed relatively superficial due to seasonal variation in injury incidence rates, particularly at an injury-type level (Hägglund et al., 2006; McGregor et al., 2000). Accordingly, more prolonged periods of observation had been advocated to be able to analyse behavioural trends in injury and elicit findings more informative to the effectiveness of preventative efforts (Hägglund et al., 2006). Ekstrand et al. (2009) therefore investigated the injury characteristics in European professional football and described the variations in injury incidence over seven consecutive seasons of observation (2001-2008).

Significantly, the authors found that over seven seasons of observation, total injury incidence as well as training and match injury incidences remained stable, indicating that the risk of injury within this cohort of elite European male professional teams had not changed. This trend has also been observed in other longitudinal injury epidemiology studies performed in single teams (Carling et al., 2010) and also across entire leagues – both within Europe (e.g. Hägglund, Waldén & Ekstrand, 2003; Lundgårdh, Svensson & Alricsson, 2020) and those in other continents (e.g. Aoki et al., 2012; Lu et al., 2020). In contrast, a six-season prospective study of elite Norwegian professional teams noted that the overall risk of match injuries had increased during the observation period (Bjørneboe et al., 2014).

In a subsequent 11-year follow up of the UEFA-ECIS cohort, at this global level of injury analysis and collective reporting, the authors similarly failed to identify any significant changes in training or match injury incidence over time (Ekstrand et al., 2013). Encouragingly however, when seasonal time trends were examined at 18 years (2001-2019) (Ekstrand et al., 2021), 13% and 17% reductions in match and training incidence were reported relative to the earlier initial seven-year follow up (Ekstrand, Hagglund & Walden, 2011). Specifically, in this 2021 study, the authors reported a seasonal decrease in injury incidence by 3% during training and match-play respectively over the 18 year period of the UEFA-ECIS (Ekstrand et al., 2021). In view of the increasing physical demands imposed on professional football players (Barnes et al., 2014; Bengtsson et al., 2018; Bradley et al., 2016), it has been argued that approaches toward injury prevention are more efficient than previously thought and have contributed to the collective stability and ensuing reduction in injury incidence observed (Buchheit et al., 2019).

Reporting injuries in relation to their severity is also important, as the number of days a player will be unable to train or participate competitively provides additional context to the impact an injury will have (e.g. missed matches, financial implications). Of the 4483 time-loss injuries recorded by Ekstrand et al. (2011), ~ 22% were found to prevent players from participating in full training and/or competition for up to 3 days, while injuries categorised as being of mild (4-7 days) and moderate (8-28 days) severity represented ~ 26% and 37% of all time-loss injuries experienced by teams respectively. Severe injuries, causing absence greater than 28 days, equated to ~ 16% of all time-loss injuries. In a recent systematic review and meta-analyses of epidemiological data of time-loss injuries in professional male football, similar trends were reported except that injuries resulting in minimal time-loss were found to be the most common (López-Valenciano et al., 2020).

Data regarding the duration of absence before returning to competitive match-play has also been recently described for the most common injury diagnoses in European professional football (Ekstrand, Krutsch, et al., 2020). Responsible for more than 75% of all injury-related time-loss, the authors found that even though only nine of the 31 most common injuries were of moderate severity, together they accounted for more than 60% of all absence caused among these common injury diagnoses. This finding would appear to attest more to their high frequency of incidence as opposed to the absence they carry. Consistent with previous findings in the professional football epidemiology literature, severe diagnoses were also shown to be particularly uncommon with only two of the 31 most common injury diagnoses causing a median absence of more than 28 days (Ekstrand, Krutsch, et al., 2020). While relatively infrequent (0.8 per 1000 hours of exposure, 95% CI 0.6 to 1.0, I^2=91.63), severe injuries still have the potential to heavily impact teams due to the protracted absences of players (López-Valenciano et al., 2020). Longitudinally, evidence indicates the incidence of severe injuries has not significantly changed in the UEFA-ECIS cohort (Ekstrand et al., 2013, 2021; Ekstrand, Hagglund, et al., 2011) with teams estimated to experience eight severe injury cases per season, with each carrying an average time-loss of 37 days.

A particularly noteworthy finding of the 2020 study conducted by Ekstrand et al. was that across European professional football, the length of a player’s absence following re-injury was significantly longer when compared to the respective index injury for several of the most common injury diagnoses (Ekstrand, Krutsch, et al., 2020). Accordingly, given that a previous history of injury has been found to be strongly associated with an increased susceptibility for injury recurrence, preventing re-injuries should therefore also represent a key priority for teams (Arnason et al., 2004a; Bitchell, Varley-Campbell, et al., 2020; Freckleton & Pizzari, 2013; Hägglund et al., 2006; Hägglund, Waldén, & Ekstrand, 2013; Toohey et al., 2017). A successful programme of rehabilitation is therefore of the utmost importance to ensure that not only do players return efficiently and capable of competing but also do so safely to mitigate re-injury risk and longer term sequalae.

2.4.3 General incidence, severity, and pattern of re-injury in professional football

Re-injuries have been found to comprise almost one in five (17%) of all injuries experienced within top-level European male football (Hägglund et al., 2016). The overall rate of re-injury incidence described for the UEFA-ECIS cohort (1.0 per 1000 hours of exposure) appears to be in close agreement with that presented in a recent systematic review and meta-analyses of time-loss injuries in professional football (López-Valenciano et al., 2020). Consistent with historical findings throughout the football injury epidemiological literature (e.g. Carling, Le Gall & Orhant, 2011; Noya Salces et al., 2014), players in the UEFA-ECIS study were also at greater risk of recurrence during match-play compared with training situations (3.22 vs. 0.58 re-injuries per 1000 hours of exposure). Despite this, as a proportion of total injury, the frequency of re-injury occurrence during training (17%) and match-play (16%) are relatively comparable within the UEFA-ECIS cohort (Hägglund et al., 2016). A finding within this study that was not similarly observed in a cohort of professional Scandinavian footballers (i.e. teams competing in Sweden's Allsvenskan) or equally reflected in an injury audit of 12 International European Championships between 2006-2008 across a variety of male and female professional age groups (Hägglund et al., 2009). In each of these studies, the frequency of re-injury was higher during training than in match-play, with this being significantly higher in the case of the Scandinavian cohort (539 vs. 255; $p<0.001$) (Hägglund et al., 2016).

Examination of more recent re-injury data published from existing injury surveillance programmes in elite European, Asian, and South American male professional footballers has revealed relatively similar proportions of re-injury between continents among their respective top-level teams (Bengtsson et al., 2021; Ekstrand et al., 2021; Tabben et al., 2022). By comparison, epidemiological studies conducted in domestic leagues of lower ranking have demonstrated higher re-injury rates ranging from 20% to 30% (Bjørneboe et al., 2014; Hägglund et al., 2003, 2006; Lee et al., 2014; Waldén et al., 2005). Consideration of this wide disparity in re-injury rates reported across professional football has given rise to the possibility of an inverse relationship existing between playing standard and the rate of re-injury (Hägglund et al., 2016).

This assumption appears reasonable given top-level teams will invariably benefit from having access to full-time medical and science departments. The availability of such resources and specialised support following injury and during rehabilitation would therefore likely play an important role in minimising re-injury risk. Furthermore, access to larger and higher calibre player rosters, implies top-level teams are perhaps better equipped to tolerate player absences with less impact on team performance and thus, better positioned to permit longer timeframes for the rehabilitation (Hägglund et al., 2016). Evidence from the UEFA-ECIS cohort indicates that a longer time to RTS are in fact afforded following cases of re-injury compared with the respective index injury (Ekstrand, Krutsch, et al., 2020). While this may simply reflect the fact that recurrent injuries can display greater structural damage than index injuries (Koulouris et al., 2007), this has been shown to not always be the case (Wangensteen et al., 2016) Accordingly, the provision of extended periods of rehabilitation may reflect a more conscious decision to protect against additional re-injuries by allowing more time to address modifiable risk factors, potentially contributing to injury or those not addressed during rehabilitation of the initial index injury.

Review of the literature indicates that overall, re-injury rates in the UEFA-ECIS remained relatively stable over the first 11 seasons of observation from 2001-2012 (Ekstrand et al., 2013). Encouragingly, subsequent analysis undertaken in this cohort has exhibited a decreasing trend with respect to incidence of recurrent injuries (Ekstrand et al., 2021; Hägglund et al., 2016). Specifically, in the work of Hägglund and colleagues, a seasonal ~3% decrease in re-injury rate was reported between 2001 and 2015 (Hägglund et al., 2016). While Ekstrand et al., (2021) have since provided additional context by highlighting re-injury incidence has decreased 5% per season across training and match-play during 18 years of observation. Findings that to date, equate to an overall incidence of 0.4 (95% CI 0.4 to 0.4) and 2.2 (95% CI 2.0 to 2.3) re-injuries per 1000 hours of exposure to training and match-play respectively (Ekstrand et al., 2021). Perhaps the most important finding of Ekstrand et al., (2021) research as previsouly touched upon, was that re-injury cases within this cohort are relatively low overall, comprising 10% of all injuries recorded.

Offering added insight to the realities of RTS decision-making within applied practice, a finding of particular interest is that higher recurrence proportions have been observed in the second half of the competitive football season. Specifically, longitudinal evaluation of re-injury patterns as a function of season phase have revealed recurrent injury proportions were significantly lower during pre-season (~11%) than in the first half (~15%) (August – December) and second half (~20%) (January – May) of the competitive season in the UEFA-ECIS cohort (Hägglund et al., 2016). A finding that clearly speaks to the complexity and multifaceted nature of RTS decision-making within football and the possibility that a higher acceptance of re-injury risk is adopted by teams at specific, more decisive points within the competitive season.

Consistent across the epidemiological findings of football injuries (Carling et al., 2011; Ekstrand et al., 2012; Hägglund, Walden, et al., 2005) as well as in other football-code sports (Green et al., 2020; Orchard et al., 2020; Williams et al., 2017), most re-injuries are classified as ‘early recurrences’ and occur within 2 months of being cleared to RTS. Using the UEFA-ECIS study as an example, early recurrences comprise close to 80% of all within season re-injuries (Hägglund et al., 2016). As discussed, this may be explained in part by stakeholders purposely accepting higher risks in response to emerging contextual factors throughout the course of a season. These findings, however, have also been suggested to be symptomatic of insufficient rehabilitation and/or premature RTS as a result of inadequate discharge criteria to guide and inform decision-making (Hägglund et al., 2016; Wangensteen et al., 2016). Presently, valid criteria to inform rehabilitation progression and RTS decision-making are largely lacking and consequently, decisions are being made within practice regarding the physical and psychological readiness of players to RTS without clear guidance (Ardern et al., 2016). Accordingly, developing RTS practices which are evidence-based is clearly warranted to help minimise re-injury risk and avoid further time-loss (Bitchell, Varley-Campbell, et al., 2020; Hägglund et al., 2006; Hägglund, Waldén, & Ekstrand, 2013; Toohey et al., 2017).

From review of the epidemiology literature, particularly noteworthy is the consistent finding that lower limb muscle injuries are especially problematic for professional teams; comprising a large proportion of all time-loss injuries experienced and displaying a high susceptibility for recurrence. Indeed, further examination of this specific injury type is warranted as trend analysis appears to present contradictory evidence to that outlined for the global pattern of football-related injuries described in sections 2.4.3 and 2.4.4. Accordingly, deeper contextual understanding of the injury landscape appears necessary to identify more refined areas of injury and re-injury concern within professional football.

2.4.4 Muscle injury epidemiology in professional football

For clarity, the following section aims to draw the reader’s attention to the challenges presented by lower-limb muscle injuries specifically within professional football settings. Whilst acknowledging this thesis is not intended to be epidemiological in nature, it is argued this area of research helps establish why RTS decision-making within professional football warrants investigation and further, provides a clearer rationale for the subsequent approach taken within this programme of work. Accordingly, the following section aims to provide an overview of some of the relevant muscle injury and re-injury epidemiological data currently available within the research literature.

Subsequent to their previous work from 2009, Ekstrand, Hägglund and Waldén (2011) published the second paper of their seminal work in outlining the injury and re-injury landscape in European top-level professional football. More specifically, their 2011 publication represented an eight season (2001-2009) observational study investigating the incidence and nature of muscle injuries in European male professional footballers. Among the principal findings of this investigation, muscle injuries were found to constitute almost one-third (31%) of all time loss injuries and were responsible for more than a quarter of the total injury absence experienced among teams studied. Moreover, reiterated by this study, was that muscle injuries carry with them a high rate of recurrence (16%) and elicit significantly longer lay-offs compared with index injuries (17.8±25.2 v 13.8±17.0 days, $p<0.001$). Contextualising the consequences of muscle injuries for teams and players, the authors highlighted that a typical elite level professional team containing of 25 players can expect 15 muscle injuries resulting in time-loss each season. A volume of time loss that equated to 148 missed training sessions and 37 missed matches respectively (Ekstrand, Hägglund, et al., 2011). Of note, in a nine season (2001-2010) prospective cohort study of 26 professional teams from 10 European countries, previous injury was identified as a significant risk factor for all major muscle groups of the lower limbs; a finding echoed in the high risk of recurrence (21-30%) observed among hamstring, quadricep, adductor and calf muscle groups following an identical injury in the preceding season (Hägglund, Waldén & Ekstrand, 2013).

Subsequent time-trend analysis of injury characteristics in the UEFA-ECIS cohort has since highlighted that muscle injury rates have not decreased during 11 and 18 seasons of consecutive observation respectively (Ekstrand et al., 2013, 2021). With specific reference to the most recent work of Ekstrand and colleagues conducted in 2021, muscle injuries as a function of incidence, severity, and burden (i.e. the cross product of injury severity and incidence) have not significantly changed in European professional football. In addition, the incidence of muscle re-injuries during training has also not significantly decreased over this time-period (Ekstrand et al., 2021). In fact, as a product of frequency and time-loss that can be attributable to re-injury, recurrences involving the hamstrings, adductors, quadriceps and calves are found to rank highly among specific professional football cohorts studied (Ekstrand, Krutsch, et al., 2020; Hägglund et al., 2016)

As outlined by Ekstrand et al. the majority (92%) of muscle injuries experienced in professional football are found to affect the major muscle groups of the lower limbs, with the hamstrings (37%), adductors (23%), quadriceps (19%) and calves (13%) being the most common injury locations (Ekstrand, Hägglund, et al., 2011). Almost all muscle injury incidences were also found to occur in non-contact situations and were predominantly traumatic in nature with an acute onset. Based on review of the existing literature, an overview of some of the key injury characteristics reported for each main subgroup of muscle injury in professional football will be provided.

2.4.4.1 Hamstring muscle injuries

Hamstring injuries are the single most common time-loss injury type in male professional football (Ekstrand, Hägglund, et al., 2011; López-Valenciano et al., 2020) and have been reported to represent approximately 12% of all injuries (Ekstrand, Hägglund & Waldén, 2011). Particularly alarming are findings from the UEFA-ECIS cohort that between 2001 and 2014, there was an average annual increase of 2.3% in hamstring injury rates and a corresponding 4.1% average annual increase in hamstring injury burden over the 13-year period (Ekstrand, Waldén, et al., 2016). It is therefore not unexpected that the prevalence of hamstring re-injury is also high (16%) (Ekstrand, Hägglund & Waldén, 2011) with a large proportion of these being classified as early recurrences following clearance to RTS (Ekstrand, Hägglund & Waldén, 2011; Ekstrand, Waldén & Hägglund, 2016). In fact hamstring injuries represent the most frequently diagnosed recurrent injury in professional football, generating the largest number of days lost for teams - accounting for around 20% of the total absence due to re-injury (Hägglund, Waldén & Ekstrand, 2016). Furthermore, time-trend analysis has displayed an increasing tendency for hamstring recurrence in the UEFA-ECIS cohort, with an annual seasonal increase of 3% and a total rise of 42% observed over the 13-year study period (Ekstrand, Waldén, et al., 2016). Based on the evidence presented, it is clear that urgent investigation is necessary to understand the reasons underpinning this increase following RTS in order to aid the prevention of hamstring recurrences.

Particularly apparent during this review of the literature was the observation that research on diagnosis, prevention and treatment of muscle injuries primarily concerns the hamstring musculature (Ishøi et al., 2020) and understandably is a predominant area of interest within professional football. Whilst this is merited given the potential consequences they carry as described above, it is important not to undermine the detrimental impact adductor, quadriceps and calf muscle injuries can also have collectively upon professional teams.

2.4.4.2 Adductor muscle injuries

Representing 23% of all muscle injuries and 7% of all time-loss injuries, adductor-related injuries have been reported as the second most common muscle injury in European male professional footballers (Ekstrand, Hägglund, et al., 2011). As a specific diagnosis among hip and groin categorised injures, adductor-related injuries are the most common, totalling 63% of all time-loss injuries among European male professional footballers involved in the UEFA-ECIS (Werner et al., 2019). This finding is in agreement with another recently published 2-season prospective study of time-loss groin injuries in male football players competing in Qatar (Mosler et al., 2018) as well as in previous studies involving European populations (Hölmich et al., 2014; Werner et al., 2009). There is however growing contention within the literature that the use of a time-loss injury definition underestimates the overall groin injury problem in professional football (Esteve et al., 2020; Harøy et al., 2017). Many groin related injuries are the result of overuse and present with a gradual onset of symptoms such as pain and/or functional limitation (Waldén et al., 2015). However, the severity of these symptoms many not necessarily lead to players being withdrawn from training and/or match-play participation. Consequently, this has given rise to the notion that the traditional time-loss approach to injury surveillance might not be appropriate for studying overuse injuries within professional football, resulting in a gross underestimation of the true magnitude of overuse problems experienced (Bahr, 2009).

In contrast to findings reported for hamstring muscle injury, time-trend analysis over 15-seasons (2001-2016) in the UEFA-ECIS cohort has shown a statistically significant seasonal reduction in adductor-related injuries of 3% (Werner et al., 2019). However, it should be acknowledged that the authors did not concurrently observe a decreasing trend in injury burden, implying the impact of adductor-related muscle injuries on teams remains considerable, with each injury on average resulting in ~14 - 15 lay-off days (Ekstrand, Krutsch, et al., 2020; Werner et al., 2009, 2019). Although not entirely reflective of adductor-related injuries, an increasing trend in the incidence in hip and groin injuries over five consecutive seasons was found in Swedish professional male footballers (Lundgårdh et al., 2020). Equally, injury burden resulting from groin injuries in Qatar professional footballers (24.3 days/1000 hours of player exposure) was found to be even higher than the 19.7 days/1000 hours previously reported for hamstring injuries in the UEFA-ECIS (Mosler et al., 2018). In line with the other specific lower limb muscle groups discussed, adductor muscle injuries also display a high propensity for early recurrence following RTS, with re-injury rates reported within the literature ranging from 11% to 18% (Ekstrand, Hägglund, et al., 2011; Hallén & Ekstrand, 2014; Werner et al., 2009, 2019). Further, this rate of re-injury can be as high as 30% when delayed recurrences are accounted for (Hägglund, Waldén, & Ekstrand, 2013). Accordingly, as evidenced by these findings, adductor-related re-injuries also are among the most frequently diagnosed recurrent injuries in professional football and responsible for 8.1% and 11.5% of the total days lost due to re-injury in top level and elite level European teams respectively (Hägglund et al., 2016). As has also been reported for hamstring and quadriceps muscle injuries, adductor-related re-injuries are significantly associated with longer absences than the original injury (Ekstrand, Krutsch, et al., 2020).

2.4.4.3 Quadricep muscle injuries

Over 50% of muscle injuries have been found to affect the thigh musculature, with injury to the quadriceps representing 19% of all muscle injuries and 5% of all time-loss injuries experienced in European male professional football respectively (Ekstrand, Hägglund, et al., 2011). Research relating to the seasonal distribution of lower extremity muscle injuries has highlighted that, at more than in any other period of the football calendar, pre-season is a phase where players appear particularly vulnerable to quadriceps injury, with the rectus femoris muscle being the most common site for muscle strains (Hägglund, Waldén, & Ekstrand, 2013; Hallén & Ekstrand, 2014; Woods et al., 2002). This finding is supported by the fact that the majority (60%) of quadriceps muscle injury affect the dominant leg (i.e. preferred kicking leg) (Ekstrand, Hägglund, et al., 2011). Akin to the hamstring muscle group, quadriceps display a high susceptibility for early recurrence (17%) and are also represented among the top 5 recurring injuries in top-level European football as a function of frequency (6.4% of all re-injuries) and absence (6.5% of total number of days lost for all re-injuries) (Hägglund et al., 2016). As far as can be determined, no time-trend analysis has been performed specifically for quadriceps muscle injury, but the most recent literature (Ekstrand et al., 2019) shows that their overall frequency (5.7%) has remained stable relative to previously published findings (Ekstrand, Hägglund, et al., 2011) and continue to be common within European male professional football. Furthermore, irrespective of injury classification (i.e. structural injury or functional disorder – those with and without macroscopic evidence of muscular tear), recurrences involving the quadriceps remain high (~14 to 16%) (Ekstrand et al., 2019). Avoiding re-injury to the anterior thigh appears especially important since they elicit significantly longer lay-offs than index injuries and can result in several matches being missed (Ekstrand, Krutsch, et al., 2020). In this study, Ekstrand et al. reported a mean difference in time-loss of approximate 5 days (±4.2 days; 95% CI, -8.0 to -0.4) between index and recurrent structural injuries involving the quadriceps (i.e. those with macroscopic evidence of muscular tear).

2.4.4.4 Calf muscle injuries

Of all time-loss injuries affecting the major muscle groups of the lower limbs, calf muscle injuries are the least prevalent (13%) (Ekstrand, Hägglund, et al., 2011). Of those calf muscle injuries, around 13% will reoccur within 2 months of RTS (Ekstrand, Hägglund, et al., 2011) while subsequent analysis inclusive of delayed recurrences (i.e. those occurring > 2 months after RTS) has revealed recurrent proportions as high as 21% (Hägglund, Waldén, & Ekstrand, 2013). In a 16-year follow up of the UEFA-ECIS cohort, structural and functional calf muscle injuries continue to be among the most common index injuries experienced and present a high risk of re-injury (~14-16%) (Ekstrand, Krutsch, et al., 2020). Despite representing one of the most frequently diagnosed recurrent injuries in professional football (Hägglund et al., 2016) and with structural re-injuries involving the calf musculature found to cause significantly longer mean absences (17.4 days vs. 20.8 days) (Ekstrand, Krutsch, et al., 2020), there remains a paucity of evidence examining calf muscle injuries (Ishøi et al., 2020).

2.5 Importance of the rehabilitation process after muscle injury

In view of the substantial performance and financial consequences injuries can impose on professional football teams, the delivery of high-quality rehabilitation is clearly of the utmost importance. The aim of which is to facilitate that a player is returned to match-play and pre-injury levels of performance as fast possible but with minimal risk of re-injury (Erickson & Sherry, 2017; Heiderscheit et al., 2010; Sherry et al., 2015).

Understandably, within the research literature a multifactorial approach to rehabilitation has been advocated, given the range of possible contributing factors to muscle injury risk and athletic performance (Mendiguchia et al., 2017). While restricted to a relatively small sample of semi-professional football players and specific to hamstring injuries only, Mendiguchia et al., (2017) demonstrated that the sequential integration of multiple interventions, as part of a multifactorial rehabilitation approach, could reduce re-injury and improve athletic performance upon RTS.

Characteristically and in line with the literature cited above, the structure of rehabilitation has typically assumed a phased approach where each stage within this process is aimed toward restoring acute deficits in tissue structure and function, as well as mitigating modifiable factors that may have contributed to injury or that potentially place the player at increased risk of subsequent injury or re-injury upon RTS. As the content and complexity of programs are progressed in response to tissue healing as well as the functional capacities/abilities of the player, rehabilitation can be viewed a dynamic process from injury through to RTS. Transition through stages of rehabilitation has typically been informed by predetermined pathophysiological timeframes for healing tissue (Fernandes et al., 2011; Järvinen et al., 2013; Järvinen et al., 2005, 2007; Kujala et al., 1997) or more recently, by criterion-based progressions related to the recovery of key elements defined within the program of rehabilitation (e.g. Heiderscheit, Sherry, Silder, Chummanov, et al., 2010; Mendiguchia & Brughelli, 2011; Schmitt & Mchugh, 2012; Valle et al., 2015).

Offering a more individualized approach to rehabilitation progression, as opposed to relaying on predetermined pathophysiological timeframes for healing alone, criterion-based approaches have gained popularity in professional football to inform RTS decisions for a multitude of different musculoskeletal injuries (Fanchini et al., 2018; Fuller & Walker, 2006; Mendiguchia et al., 2017; Serner, Weir, Tol, Thorborg, Lanzinger, et al., 2020; Tol et al., 2014). Such protocols place an increased emphasis on the programming and sequencing of training load progression as well as performance related factors that are likely essential in preparing players for the unique demands of competitive match play.

Interestingly, greater consideration for biological healing time as part of this approach has however been recently argued (Pieters et al., 2021). Akin to approaches observed in the rehabilitation of other injury types such as anterior cruciate ligament (ACL) injury (Grindem et al., 2016; Kyritsis et al., 2016), the authors of this review advised a combination of time-based and objective discharge criteria should also form part of the RTS clearance assessment following muscle injury (Pieters et al., 2021). Available evidence within athletic populations returning to sport following muscle injury indicate that functional recovery may in fact precede structural recovery of the injured tissue (Silder et al., 2013; Schneider-Kolsky et al., 2006) and thus, greater consideration to biological healing time within current rehabilitation strategies is perhaps warranted. As this recommendation is yet to be examined, future research is required to support or refute the addition of time-based criteria to RTS test batteries in the management of lower limb muscle injury and determine if complete resolution of injury, biologically, is necessary for a safe RTS.

Irrespective of the approach employed, if a period of rehabilitation is warranted, it should always be viewed as a window of opportunity to not only reduce re-injury risk but also optimise performance of the returning player (Gabbett & Whiteley, 2017). In this respect, a safe and effective rehabilitation strategy should always strive for low risk but equally prepare the player for high demand (Blanch & Gabbett, 2016; Mendiguchia & Brughelli, 2011; Stares et al., 2018). Accordingly, sports medicine practitioners are required to remain abreast of current evidence-based practices to guide rehabilitation progression and support decision-making to ensure players are afforded the best opportunity for a full recovery and successful RTS.

Owing to the high incidence of recurrence displayed among the muscle groups of the lower limb, the effectiveness of rehabilitation strategies and RTS decision-making practices currently employed by professional football have come under increasing scrutiny. Indeed, deficits in muscle tissue structure and function can persist in professional football players following clearance to RTS (De Vos et al., 2014; Maniar et al., 2016; Tol et al., 2014). Deficits, it could be postulated, may have possibly contributed to the high incidence of 'early' recurrences observed in muscle injuries following RTS (Hägglund et al., 2016; Wangensteen et al., 2016) or assisted in impairing post-RTS performance capacities (Whiteley et al., 2021). Consequently, such findings have substantiated the opinion that these detrimental outcomes may be symptomatic of insufficient rehabilitation and/or premature RTS (Hägglund et al., 2016; Wangensteen et al., 2016). Moreover, they also give rise to the question, how closely are professional football teams following research-based recommendations for RTS?

A recent editorial has spoken to the difficulty of balancing research evidence with the realities of RTS within professional football when attempting to make high-quality decisions (McCall et al., 2017). As the authors attest, RTS is so multifaceted it cannot simply be read from a 'research recipe book', rather, the challenge is to practise good sports medicine while balancing the interests of player and the team. Returning to sport after injury is evidently complex and subject to influence from a range of different, and sometimes competing, physiological, psychological, and social factors. Accordingly, when arriving at RTS decisions, relevant stakeholders are required to engage in a risk-benefit analysis whereby the risks associated with participation and the extent to which these risks can be tolerated are deliberated (Creighton et al., 2010; Shrier, 2015). Unfortunately, it appears when undertaking this decision-making process, in turning to research, stakeholders are equally presented with limited evidence and ultimately more questions than answers, for example: How should RTS be defined? How can we best determine when a player is ready to RTS? Is physical recovery alone enough for a satisfactory RTS? What constitutes a successful RTS? What are the roles and responsibilities of relevant stakeholders within the team and to the player? What is the specific context surrounding decisions? (Ardern, Bizzini, et al., 2016; Bizzini & Silvers, 2014).

To optimise decision-making processes in high-performance settings, an evidence-based approach is recommended to support teams to make better, more informed decisions (Coutts, 2017). Representing the collated integration of current best practice (i.e. practitioner expertise and athlete preferences) and highest-quality research, the use of evidence-based practice can promote greater confidence when addressing RTS related questions and may subsequently improve rehabilitation outcomes (e.g. minimising the risk of re-injury) (Fullagar et al., 2019). As described by Coutts (2017), the process of developing evidence-based practice in sport is both iterative and cyclical in nature, and involves; identifying relevant research questions, searching and critically evaluating existing research for its validity, impact and applicability, developing strategies to implement best available evidence into contemporary practice and assessing the effectiveness of the new practice(s).

Understandably, to answer these questions and develop practices which are informed and supported by evidence, research is necessary. However, in the absence of scientific evidence or where contradictory evidence permeates the available literature, expert consensus has been shown to represent an appropriate starting point from which to provide guidance for clinical practice and identify research gaps to encourage the advancement of research-based knowledge (Jones & Hunter, 1995).

2.6 A continuum framework for returning to sport

In 2016, an international consensus statement on return to sport was published (Ardern et al., 2016). The purpose of this expert-led consensus was to present and synthesise the existing literature to offer evidence-based recommendations to help understand and guide the RTS process, inform RTS decision-making and outline priorities for future research related to returning athletes to sport. Building upon previous guidelines which were more centred toward framing the team physician's role within the athlete's RTS (Herring et al., 2002). The 2016 consensus statement offers a broader perspective on the RTS process; one which promotes a more collaborative (interdisciplinary and multidisciplinary) and holistic view of rehabilitation, advocating an athlete-centred approach to RTS whilst opposing the position of previous statements which place the team physician as the gatekeeper of the RTS decision (Ardern et al., 2016).

A fundamental component agreed upon within the 2016 consensus was that RTS should not be understood as an isolated decision taken at the conclusion of the recovery and rehabilitation process. Rather, the RTS process should follow a structured approach and occur along a continuum which emphasises a graded, criterion-based progression of activity through distinct elements embedded within an athlete's RTS journey (Ardern et al., 2016). This continuum approach has been subsequently supported within the contemporary literature when returning to sport from a variety of different musculoskeletal injury types, including anterior cruciate ligament injury (Dingenen & Gokeler, 2017; Meredith et al., 2020), lateral ankle sprain injury (Smith et al., 2021; Tassignon et al., 2019; Wikstrom et al., 2020) and lower limb muscle injuries (Bisciotti et al., 2019; Serner, Weir, Tol, Thorborg, Lanzinger, et al., 2020).

According to this phased progression of activity, three elements have been proposed to define the RTS continuum and represent a return to participation, return to sport and a return to performance (Ardern et al., 2016). These distinct phases of progression are intended to act as a framework around which evidence-based decision-making processes can be developed to aid practitioners in guiding an athlete's RTS following injury (Figure 2.3).

Figure 2.3. The three elements of the return to sport continuum framework (Ardern et al., 2016)

Specifically, each phase was described in the 2016 RTS consensus statement and are presented as follows (Ardern et al., 2016):

1. *Return to Participation*: The athlete may be participating in rehabilitation, training, or sport, but at a level lower than their RTS goal. The athlete is physically active, but not yet considered medically, physically and/or psychologically ready to return to sport. It is possible to train to perform, but this does not automatically mean RTS.

2. *Return to Sport*: The athlete has been cleared to return to their defined sport but is not performing at their desired performance level. Dependent upon the athlete (e.g. playing standard, age, previous injury history etc) injury severity and/or rehabilitation outcomes, reaching this stage may be considered a successful RTS.

3. *Return to Performance*: This extends the return to sport phase and signifies the endpoint of the continuum. The athlete has returned to their defined sport and is now performing at pre-injury levels or higher.

While this continuum was designed to be broadly applicable to any sport, injury-type and aligned RTS goals, some authors have subsequently attempted to re-define and/or modify elements of the RTS continuum to make it more appropriate to sport-specific rehabilitation contexts (Buckthorpe, Frizziero, et al., 2019; Meredith et al., 2020; Taberner et al., 2020). This represents a logical and important evolution in our understanding of how the RTS continuum can be feasibly integrated and communicated across specific sporting domains such as professional football. Accordingly, a crucial focus of this thesis will therefore be to develop our understanding and application of this framework to guide RTS within the context of professional football.

Acknowledging that the rehabilitation literature prior to the 2016 consensus has traditionally conceptualised rehabilitation into a dichotomous process representing a period of clinical rehabilitation (i.e. measuring impairment, evaluating tissue healing) followed by a return to sport (e.g. Herrington, 2000; Wright-Carpenter et al., 2004; Askling, Tengvar & Thorstensson, 2013; Reurink et al., 2014), evidence to support practitioners in how to safely progress RTS as part of phased rehabilitation approach has been largely absent. Specifically, despite representing a vital component in determining readiness to RTS, elements encompassing on field rehabilitation (OFR) and the graduated recovery of functional and sport-specific qualities have not been commonly described nor clearly differentiated.

When there is a requirement to prepare athletes for direct re-entry into competitive sport following injury, as is characteristic of professional football, it is necessary that this gap between clinical rehabilitation and returning to sport is addressed (Figure 2.4) (Buckthorpe, Frizziero, et al., 2019). Ultimately, this will provide greater insight in how to monitor and progressively reintegrate players to competitive football who are better prepared to cope with increasing training and competition workload demands.

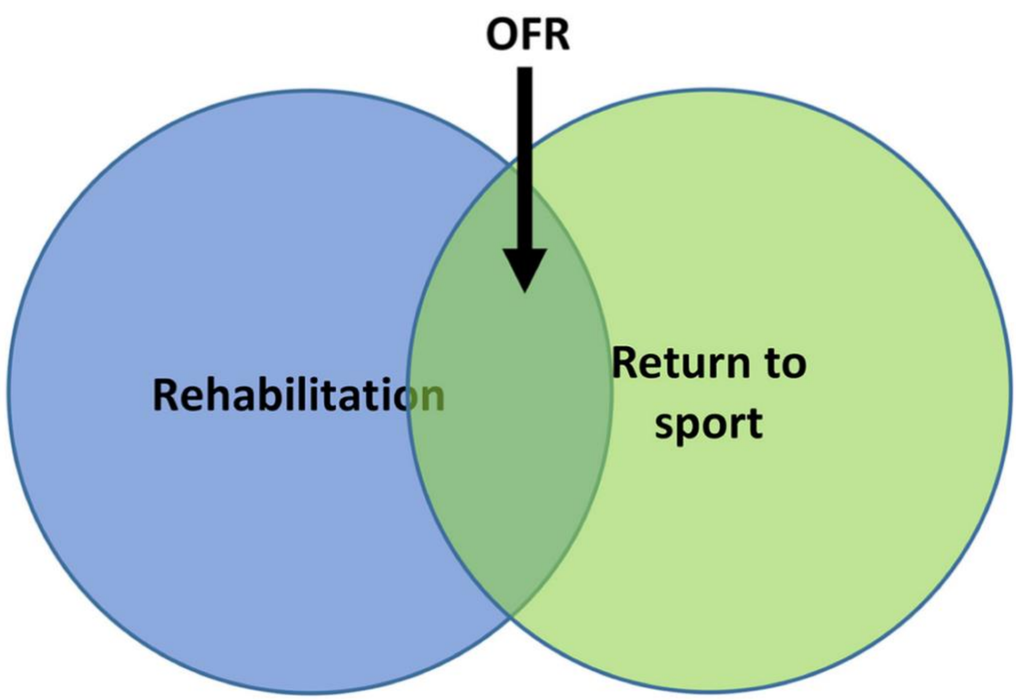

Figure 2.4. A model showing the overcoming of the dichotomous conception of functional recovery with an overlap of clinical rehabilitation and return to sport: the on-field rehabilitation (OFR) (Buckthorpe, Frizziero, et al., 2019).

Ideally, a RTS continuum adapted for use in professional football should therefore more clearly differentiate the on-field elements of a player's RTS as it is anticipated progression between phases will be based on different decision-making criteria. For instance, it is conceivable that greater specificity is perhaps warranted in relation to a player's 'return to participation'. Within a football rehabilitation context, this phase is likely to encompass several key progressions or milestones (e.g. returning to pitch-based running, reintegration to full team training) which may be particularly important to understand in isolation, yet currently not captured by Ardern's continuum model (Ardern et al., 2016).

Drawing on published literature concerning RTS in professional football, it would appear that the structure of a RTS continuum more suitable for use in an applied setting should encompass four principal progressions when re-integrating a player after injury (Bisciotti et al., 2019; Buckthorpe, Frizziero, et al., 2019; Taberner et al., 2020).

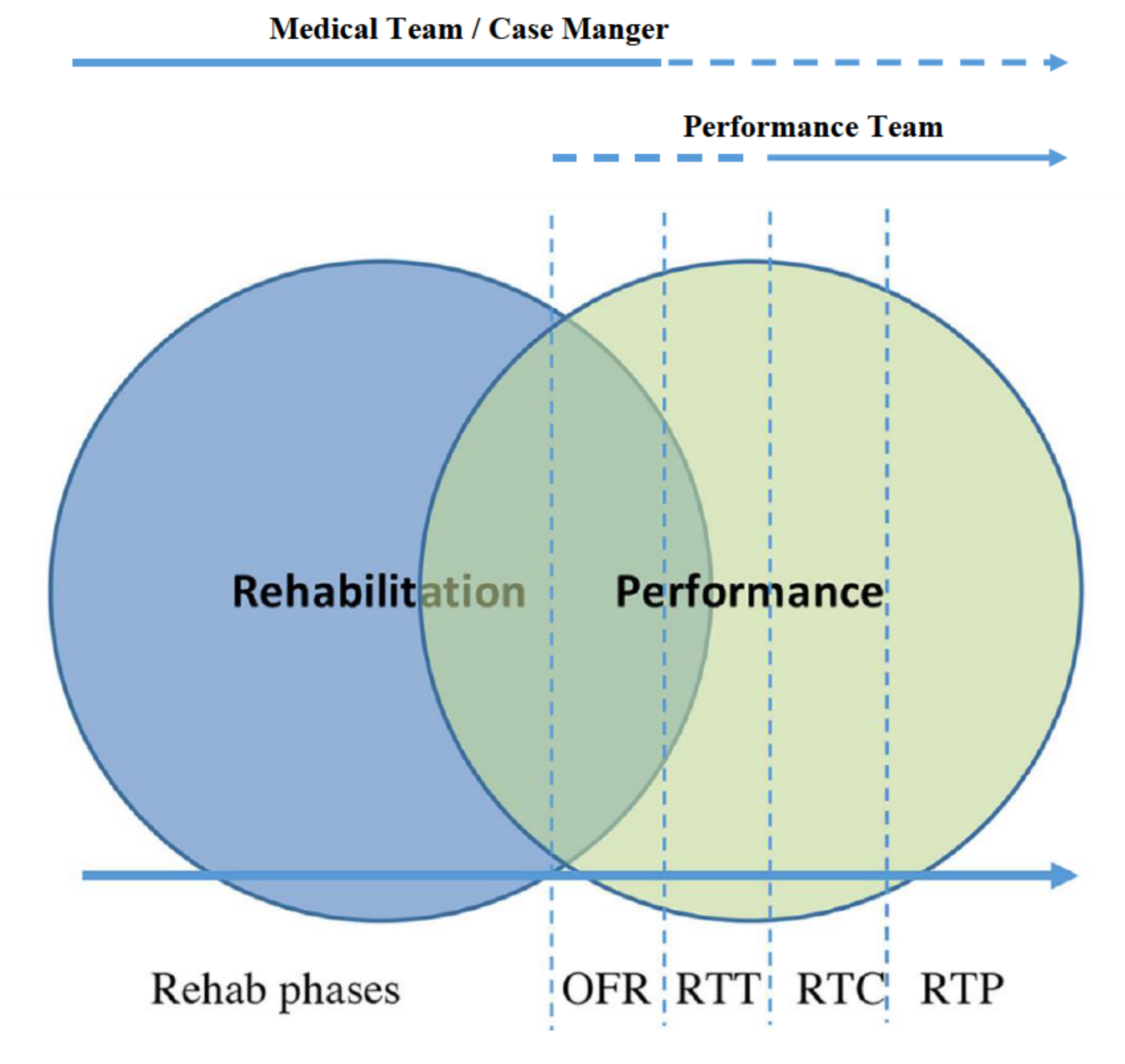

Figure 2.5. A model of functional recovery encompassing a return to sport and performance following injury (Buckthorpe, Frizziero & Roi, 2018).

As illustrated in Figure 2.5, these progressions should describe (at least) the transition back to on-field rehabilitation following injury and subsequent return to full team training (RTT), competition (RTC) and ultimately performance (RTP) (Bisciotti et al., 2019; Buckthorpe, Frizziero, et al., 2019; Taberner et al., 2020). Although not depicted in this model, as discussed within the research literature, progression through specific RTS phases as identified within this model should also ideally reflect a graduated approach, based on the attainment of clearly defined milestones of activity. For a more explicit description regarding these progressions proposed, the reader is referred to the examples presented by Taberner et al., (2020) and Bizzini et al., (2012).

Significantly, the model (Figure 2.5) proposed by Buckthorpe, Frizziero and Roi (2018) recognises the importance of a staged approach to RTS and strengthens the focus of a programme of recovery toward returning to performance as opposed to merely returning to sport. An outcome that is not only imperative to the team but also the returning player, as regaining pre-injury levels of performance is likely to epitomise RTS success (Conti, di Fronso, Pivetti, et al., 2019; Podlog & Eklund, 2009). Despite this model having some notable strengths in helping to support the translation of research into practice, a number of limitations exist that are important to acknowledge.

These limitations primarily relate to how this model sits within the wider context of the RTS process. For example, greater transparency is required regarding the involvement of specific staff within this process and how they contribute to decision-making, as a criticism of this model could be that it depicts somewhat of a disconnect between the medical and performance teams during rehabilitation. Furthermore, an interesting omission from this model was the role and position of the player as an active decision-maker within this process. According to self-determination theory, autonomy supportive rehabilitation environments (i.e. an athlete perceives that their behaviour is self-authored or personally endorsed) are considered to be important in assisting athletes to successfully return to competition following injury (Ardern et al., 2013; Podlog & Eklund, 2007b, 2009). Consequently, now more than ever, decision-making models and ways of practising that are athlete-centred, are being endorsed (Hess et al., 2019).

In this respect, whist acknowledging the model of functional recovery (Figure 2.5) presented within the research literature offers important guidance relating to how a RTS continuum can be contextualised within professional football, further research is warranted to support practitioners in its application. There is a clear need to develop a better understanding of the intricacies embedded within this framework, specifically those related to the practices employed to inform decisions.

The continuum framework as outlined by the 2016 consensus compliments the complexity of the RTS process owing to the multitude of decisions required as a player progresses through rehabilitation following injury. Facilitating the appraisal of player readiness through structured and serial assessments up to and including a return to performance, a multifactorial criterion-based approach to rehabilitation has been recommended which is akin to contemporary practices (Ardern et al., 2016). Allowing collected data to be interpreted in context and thus, providing stakeholders with relevant information regarding structural, functional and/or psychological recovery, criterion-based rehabilitation reinforces the idea that RTS is not an isolated decision taken at the conclusion of rehabilitation, but rather a process that commences concurrently with the initiation of rehabilitation following injury.

As supported in a recent systematic review of criteria-based RTS decision-making following lateral ankle sprain injury, the continuum can play a key role in informing the development of criteria-based return to sport paradigms (Tassignon et al., 2019). However, research is firstly required to establish if a continuum approach is actually being adopted within professional football, and if so, what criteria are being considered at each phase of this framework to guide a player's RTS following muscle injury. To examine the gap between research and practice, this clearly represents a fundamental step from which to direct future RTS research in developing evidence-based practices to sit within this framework, that can support decision-making and ensure the safe transition of football players between phases.

Importantly, drawing on evidence presented within this section, if a continuum is to be incorporated into the rehabilitation setting of professional football, it should be structured in a way that is directly relatable to the real-world context in which it will be applied (i.e. it must be ecologically valid). Accordingly, it should be composed of at least the four distinct and clearly defined stages of progression that fully capture the functional recovery process an injured player would typically follow.

2.7 Criteria used to guide rehabilitation and inform RTS decision-making

A key component within the rehabilitation process and one that can help guide practitioners to progress through the phases of the RTS continuum framework is the assessment and attainment of specified criteria. In line with current consensus, criterion-based approaches are now widely accepted, where a comprehensive battery of tests, mapped to clinical, strength, functional/sport-specific and psychological domains of assessment, are now utilised to inform rehabilitation progression and RTS decision-making (Ardern et al., 2016; Smith et al., 2021). From a decision-making perspective, the purpose of these tests is predominantly two-fold: to determine if it is safe and appropriate to progress the player and to establish a player's functional capability to return to competitive match-play following injury.

The selection of appropriate tests and measurement criteria requires consideration of the musculoskeletal deficits directly resulting from injury, in addition to other potential contributing factors that may have been present prior to the injury (Heiderscheit et al., 2010). It also entails respect of sport-specific performance requirements and an understanding of training and match-play demands (Buckthorpe, Della Villa, et al., 2019a, 2019b). In this regard, to help ensure players are effectively prepared to RTS, feedback pertaining to the restoration of movement quality, physical conditioning, recovery of sport-specific skills and the progressive development of chronic training loads is considered essential. Ideally, as part of this multifaceted and holistic approach, it is advocated that these assessments should be incorporated and monitored across a RTS continuum and complemented by objective and quantifiable discharge criteria that can be used to gauge player recovery and readiness to RTS against specific measurement thresholds (Ardern et al., 2016; Dingenen & Gokeler, 2017; Hickey et al., 2017; Meredith et al., 2020; Smith et al., 2021; Tassignon et al., 2019).

Despite this, very little is presently known about what RTS criteria are best to use to guide progression and determine RTS readiness in professional football. This uncertainty stems from the fact that currently, no single test or battery of tests have been validated to support the decision-making process following lower limb muscle injury (Ardern et al., 2016; van der Horst et al., 2016). Accordingly, existing practices are not supported by strong scientific evidence with little insight offered as to how those criteria being integrated correlate to key outcomes such as a successful RTS, re-injury and/or a return to pre-injury levels of performance - indeed, if at all. Unsurprisingly, a consequence of this and one that further compounds the issue, is the finding that a wide range of tests and discharge criteria are being used to guide progression and determine RTS (Hickey et al., 2017; van der Horst et al., 2016).

In the absence of scientific evidence, the work of Delvaux and colleagues was among the first studies to attempt to elucidate how RTS decisions are actually being formulated within professional football (Delvaux et al., 2014). In this survey of practice, 37 physicians working with French and Belgium professional teams were asked to rank RTS criteria according to the level of importance they assigned to them when determining player readiness to return to competition following hamstring muscle injury (Delvaux et al., 2014). While clinical, strength, psychological and functional criteria were all considered by surveyed physicians to guide a players RTS, interestingly the criteria perceived as most important to decision-making were typically of a subjective nature. This view of practice has also recently been found in a systematic review of the criteria used to progress rehabilitation and determine RTS clearance in various athletic populations following hamstring injury (Hickey et al., 2017). Additional insights provided by Delvaux et al., (2014) highlighted that limited consensus was reflected in the choice of assessment parameters and the specific values and cut-off ranges applied by teams to permit clearance to RTS for a number of criteria. Crucially, if evidence-based decision-making frameworks are to be developed for use in professional football, consensually agreed RTS criteria and assessment parameters are required to be firstly established.

Recognising the need to standardise the RTS decision-making process, attempts have recently been made within professional football to establish agreement on which criteria are most appropriate to support RTS decisions following hamstring muscle injury (van der Horst et al., 2017; Zambaldi et al., 2017). Using the Delphi method to achieve consensus of opinion among expert panels with backgrounds in football medicine and hamstring injury management, each survey recommended several key criteria and relative assessment methods pertaining to clinical, strength, functional, and psychological domains to determine player readiness to RTS (van der Horst et al., 2017; Zambaldi et al., 2017).

Importantly, it has not yet been established if these criteria are being utilised in the decision-making practices of professional teams to inform RTS after hamstring injury. Moreover, acknowledging that these guidelines are only applicable to one muscle group (i.e. hamstring) and one specific phase of the RTS continuum (i.e. returning to competitive match-play), a limitation of these studies is that it remains unclear how measurement criteria change and progress in accordance with the phase of rehabilitation and/or injured muscle group being specifically treated. Finally, and of particular significance, it should be recognised that the RTS criteria recommended in each Delphi survey reflect expert opinion and are currently not supported by high-quality scientific evidence. Accordingly, their appropriateness to facilitate the management of hamstring injuries with respect to guiding progression and supporting a successful RTS is not clear.

The application of more rigorous methods for the development and validation of athlete-monitoring measures and performance tests has been previously outlined (Impellizzeri & Marcora, 2009; Robertson et al., 2017). Currently, despite an evidence-based approach to rehabilitation progression and RTS decision-making being recommended, the measurement properties of many existing assessment criteria advocated for use in professional football remain largely unknown with empirical evidence to confirm their validity lacking (Ardern et al., 2016; Bisciotti et al., 2019; van der Horst et al., 2016; Zambaldi et al., 2017). As re-injury can result in longer absences (Ekstrand, Krutsch, et al., 2020) as well as posing marked competitive and economic consequences for players as well as teams (Ekstrand, 2013; Hägglund, Waldén, Magnusson, et al., 2013), ensuring the criteria within RTS protocols are valid, reliable, and responsive to change, represents an important aspect of decision-making. Establishing greater confidence in the data that is perceived as being important to informing decisions across a RTS continuum may help to protect players against premature RTS and subsequently re-injury and performance impairments.

2.8 Arriving at RTS decisions within professional football

Return to sport decisions following injury are complex. Not only are they recognised as being specific to the individual athlete and type of sport performed, but they also can be subject to influence from decision modification factors (Creighton et al., 2010). Accordingly, it therefore seems unreasonable to think the responsibility of decision-making and determination of an accepted level for risk tolerance can lie solely within a single domain of professional practice, yet this has traditionally been the case (Herring et al., 2012; Matheson et al., 2011). In the highly-pressured environment of elite professional sport, there is now growing recognition that RTS decisions will be better understood and accepted if all relevant stakeholders are properly informed and their views considered (e.g. Dijkstra et al., 2016; Mooney et al., 2017; Gabbett et al., 2018; King et al., 2018; Sporer & Windt, 2018). This notion lends itself to '*The Wisdom of Crowds'* doctrine in that a collective judgement utilising information acquired from several sources (e.g. objective, subjective and contextual) and areas of expertise will improve the accuracy and quality of decisions made and, ultimately, lead to better outcomes (Coles, 2017).

In accordance with the paradigm shift from biomedical toward biopsychosocial models of sports injury rehabilitation, the way in which player care is conceptualised to occur in practice following injury has shifted toward a team-based approach. Adapted from practices used in the general healthcare domain, Hess, Gnacinski and Meyer (2018) recently outlined three different team-based approaches (i.e. multidisciplinary, interdisciplinary and transdisciplinary) to sport injury rehabilitation and subsequently described how each of these might be applied in elite sport environments. For further detail regarding the main distinguishing features between these different team-based decision-making approaches, the reader is referred to Hess et al., (2018).

While the benefits of embedding such approaches into the injury rehabilitation process seem somewhat intuitive, there remains very little empirical evidence to establish the efficacy and effectiveness of team-based approaches in improving RTS outcomes within the domain of elite sport, let alone professional football (Hess et al., 2018). Drawing on preliminary evidence available from professional rugby, the appropriate synergy of various perspectives from within a multidisciplinary team has been shown to improve injury related outcomes (Tee et al., 2018). Acting on epidemiological data collected over a five season period, Tee and colleagues highlighted how, as part of an iterative and responsive process to preventing injury and re-injury, the utilisation of the diverse expertise and knowledge within a multidisciplinary support staff can help reduce seasonal injury burden (Tee et al., 2018).

Appreciating this study was confined to the practices of a single professional rugby union team, it was still interesting to note that although the club's rehabilitation and RTS processes were examined and discussed as part of this integrated approach, the authors did not indicate if and how the injured player was involved in this process specifically. Player input and involvement as part of a multidisciplinary team is considered essential to this process and when fully competent, it is accepted that the player should be able to make an informed decision about their readiness and desire to RTS (Dijkstra et al., 2017; King et al., 2019). However, as previously recognised (section 2.6), how players are explicitly involved in RTS processes is not always clear.

Modelled on a structure of shared decision-making, current research recommendations for RTS advocate the use of an athlete-centred approach to collectively deliberate the range of potential physical, psychological, social and contextual factors capable of influencing rehabilitation outcomes (Ardern et al., 2016). Guided by this approach, the rehabilitation team aim to foster athlete autonomy and ensure that their voice, perspectives and experiences remain at the forefront of decision-making process (Rollo et al., 2021). Drawing on the experiences of those involved in professional football, a number of key elements have been proposed to underpin an athlete-centred RTS approach (King et al., 2019). As described by the authors, this approach is characterised by player empowerment and engagement. In this respect, educating the player about their injury and recovery, empowering them to take ownership over aspects of the rehabilitation process (e.g. nutritional) as well as ensuring their involvement in rehabilitation planning and decision-making are important habits to incorporate. Importantly, these elements should also be complemented by the delivery of regular feedback and transparent communication about progress (or lack of progress) toward identified goals that may result in the reformation or revision of the existing rehabilitation plan.

The incorporation of these elements align with the principles of shared decision-making whereby the existing choices and treatment options available should be conveyed; with the player subsequently supported to make an informed decision based on an understanding of the risks associated (Elwyn et al., 2012). Positioning the player at the centre of this process, their immediate and future needs are collaboratively defined with all members of the rehabilitation team subsequently required to contribute their own expertise to collectively manage and address the needs identified in order to best support the player and promote optimal rehabilitation outcomes following injury (Hess et al., 2018).

Appreciating that the integration of perspectives from diverse disciplines is very complex and can give rise to misunderstanding, especially when opinions regarding a players RTS may not necessarily align among stakeholders or coincide with complete recovery (i.e. physically and/or psychologically) and healing of the injured tissue. A clearly defined process that outlines the roles and responsibilities of the decision-making team and that also formally resolves disputes is essential to minimise conflicts and protect players from coercion when dissimilar thresholds of risk tolerance exist among stakeholders (Ardern et al., 2016).

An overall decision-based model has been developed to assist practitioners in capturing key elements to be considered and discussed in RTS decisions. Introduced in 2015 by Shrier and colleagues, the Strategic Assessment of Risk and Risk Tolerance framework (StARRT) encourages RTS decisions to be viewed through the lens of complexity (Shrier, 2015). In agreement with a player centred care approach, the StARRT framework does not focus solely on the injured body tissue; rather it draws attention to the interaction among many intrinsic and extrinsic variables across the rehabilitation process and thus, places focus on the individual, its subsystems and interactions with the environment as part of holistic decision-making approach (Tassignon et al., 2019).

The strength of this framework ultimately lies in its simplicity. The StAART framework outlines clearly how and where stakeholders considered relevant to RTS decisions can contribute meaningfully to this process. Moreover, it can be applied to any injury or stage within the rehabilitation process and was designed to work uniformly with any RTS definition (Figure 2.6). Accordingly, the model is widely recognised as being a particularly useful tool in promoting interdisciplinary dialogue and helping support stakeholders synthesise all relevant information to make optimal decisions at each stage of a RTS continuum (Ardern et al., 2016).

At its foundation, the StARRT framework considers that the basis of decisions reflect a risk assessment for different short and long term outcomes associated with RTS (Shrier, 2015). If the assessment of risk is greater than the risk tolerance threshold, the player cannot be permitted to progress within rehabilitation or RTS (and vice versa). To achieve this, the StARRT framework follows a three-step approach which aims to consolidate key information from varying perspectives to establish an injury risk profile for the given player. The overarching goal of which is to improve transparency and consistency in the process of how decisions are reached.

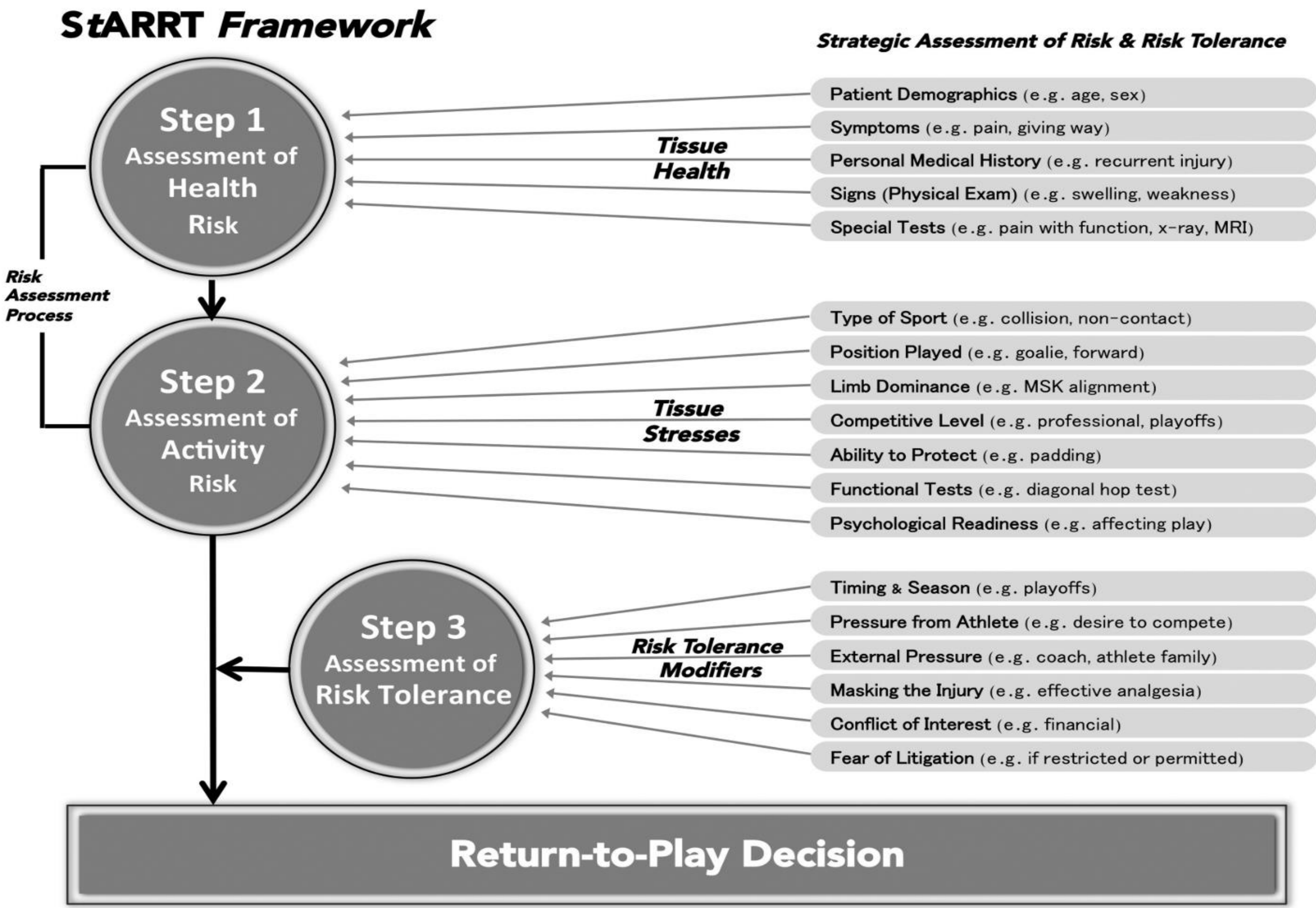
StARRT Framework
Strategic Assessment of Risk & Risk Tolerance
Step 1
Assessment of Health Risk
Risk Assessment Process
Step 2
Assessment of Activity Risk
Step 3
Assessment of Risk Tolerance
Tissue Health
Tissue Stresses
Risk Tolerance Modifiers
Patient Demographics (e.g. age, sex)
Symptoms (e.g. pain, giving way)
Personal Medical History (e.g. recurrent injury)
Signs (Physical Exam) (e.g. swelling, weakness)
Special Tests (e.g. pain with function, x-ray, MRI)
Type of Sport (e.g. collision, non-contact)
Position Played (e.g. goalie, forward)
Limb Dominance (e.g. MSK alignment)
Competitive Level (e.g. professional, playoffs)
Ability to Protect (e.g. padding)
Functional Tests (e.g. diagonal hop test)
Psychological Readiness (e.g. affecting play)
Timing & Season (e.g. playoffs)
Pressure from Athlete (e.g. desire to compete)
External Pressure (e.g. coach, athlete family)
Masking the Injury (e.g. effective analgesia)
Conflict of Interest (e.g. financial)
Fear of Litigation (e.g. if restricted or permitted)
Return-to-Play Decision

Figure 2.6. The Strategic Assessment of Risk and Risk Tolerance (StARRT) framework for return to sport decision-making (Shrier, 2015).

Closer examination of this framework highlights how available information pertaining to tissue health, tissue stress and the prevailing circumstances surrounding a player rehabilitation can be sequentially integrated to promote interdisciplinary dialogue and a more collective decision regarding RTS progression. The first step in this process involves assessing the amount of load (stress) that a tissue can absorb before becoming damaged, to establish the current health status of the tissue. The assessment of tissue damage is typically judged according to the presence of signs and symptoms of injury such as pain, swelling and/or through diagnostic tests. Accordingly, for the same level of activity, the propensity for re-injury rises with increasing damage to the tissue. Following this, decision-makers then are required to contemplate the expected cumulative load (stress) which will be applied to the tissue if the athlete were to be cleared to progress. Tissue stress is directly related to the planned activity and therefore this second step of the framework is considered an assessment of activity related risks (e.g. playing position, level of competition etc). In the StARRT decision-making framework, these two steps collectively represent the risk assessment process. The third step involves stakeholders establishing an agreed threshold for acceptable risk (risk tolerance) when arriving at RTS decisions (i.e. what level of re-injury risk is tolerable to RTS). During this stage, information relevant to any contextual factors which surround the player/team and may consequently modify the threshold of acceptable risk are considered and discussed. In this respect, a higher risk tolerance for RTS may be more readily accepted under specific circumstances (e.g. ensuring the availability of a key player for a decisive fixture opposed to a friendly match). Arriving at a threshold of acceptable risk is typically subjective and shaped by societal values as well as how a given outcome may affect the overall health or well-being of the player under a specific context (Shrier, 2015).

In following expert consensus and electing to incorporate the StARRT model within a RTS continuum to guide decision-making following muscle injury, it is important to recognise that the model itself will not resolve the decision of whether a player's RTS should be delayed or progressed (Ardern et al., 2016). Rather, it serves as a general framework to operationalise RTS decision-making within practice, enabling decisions to be viewed through an evidence-based practice lens (Ardern, Bizzini, et al., 2016). Integrating information relevant to practitioner expertise, the player and available research to assess risk, an evidence-based rationale for RTS decisions can be formulated.

Despite a variety of theoretical approaches being outlined and endorsed within research to help guide RTS decision-making, such models ultimately remain untested in applied settings and specifically professional football. Accordingly their value to practitioners and how they can be successfully implemented to promote more integrated and collective approaches to RTS decision-making remains unclear. Indeed, of concern are the recent findings from within professional football highlighting that poor interdisciplinary communication across teams is correlated to higher injury rates and lower training and match availability of players (Ekstrand et al., 2018; Ekstrand, Lundqvist, et al., 2019). These findings point to a possible disconnect between research and practice and attest to the challenges outlined in taking the best available evidence and applying it within the real world setting of professional football to arrive at high-quality RTS decisions (McCall et al., 2017). Consequently, with no clear description or insight to the decision-making paradigms being used within practice, uncertainty exists surrounding the emphasis that is currently being placed on collective decision-making and shared responsibility within the RTS practices of professional football teams.

Some guidance has since been provided to practitioners working in professional football that was intended to support them in incorporating a shared decision-making approach as part of their RTS strategy. Presented in 2017, an expert panel of injury management specialists from 28 Fédération Internationale de Football Association (FIFA) Medical Centres of Excellence identified and agreed upon a number of key figures who should ideally contribute to a shared decision and regularly exchange information to optimally guide a players RTS (Figure 2.7) (van der Horst et al., 2017).

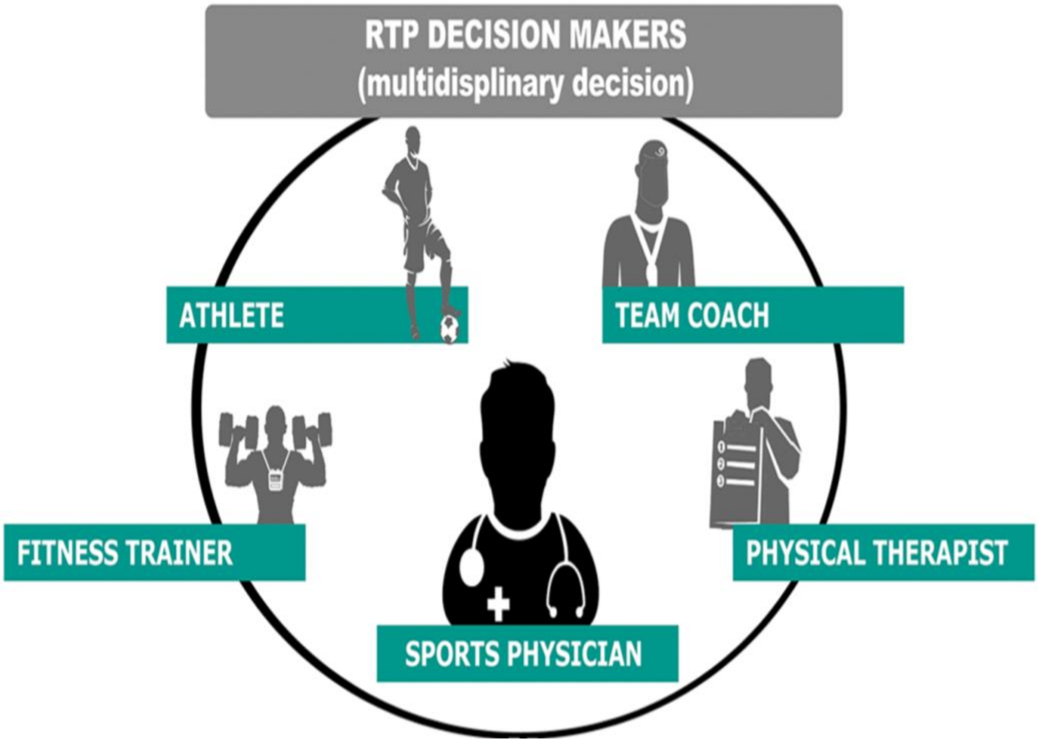

Figure 2.7. Proposed stakeholders to be considered as part of a multidisciplinary return to sport decision-making approach within professional football (van der Horst et al., 2017).

Respectful of the multifaceted nature of RTS decision-making, the expert panel acknowledge that decision-making cannot lie within a single domain of professional practice. Rather, to navigate the steps defined within the StARRT framework, it is considered that drawing on the collective perspectives of these stakeholders is likely important to informing this process within a football specific RTS context. Principally however, it remains to be clarified if, and indeed how, shared decision-making approaches are being adopted in the RTS practices of professional football teams. Equally, it is currently not known if all the key stakeholders outlined are in fact being consulted concerning RTS and if they are being given the opportunity to contribute to decisions that either permit or oppose progression within rehabilitation or clearance to return to competitive match-play.

Attention should however also be drawn to the fact that the authors of this Delphi survey focused exclusively on the decision to return to competitive match-play. As a result, it is not yet clear how shared decision-making evolves over an entire RTS continuum (e.g. level of engagement and specific dynamics of communication between relevant stakeholders). Recognising that within applied practice RTS does not exist in isolation, but rather, functions in accordance with the wider demands of the team, ascertaining how the everchanging socio-ecological context of high-performance environments influences this process represents an important area of future enquiry.

Drawing on the aforementioned work of Ekstrand and colleagues and their observations of poor interdisplinary communication across teams, it is perhaps reasonable to assume that at specific time points within a player's recovery from injury (e.g. early-stage rehabilitation) the responsibility of progressing RTS is being delegated to specialist staff. Although a multi-disciplinary, shared-decision making is advocated, pragmatically it must be acknowledged that competing obligations (e.g. preparing the active squad for an upcoming fixture) are likely to impinge on this approach which will understandably occupy the attention of certain stakeholders (e.g. coaches and managers).

Importantly, to help bridge the gap between the way that RTS decision-making is conceptualised in theory and the way it is approached in professional practice, research is urgently required to describe the decision-making practices of professional football teams and establish how team-based, athlete-centred approaches to injury rehabilitation are being utilised.

2.9 Existing limitations in this area of professional football research

In respect of the overall aim of this research project, a necessary step is to reflect upon some of the limitations that have emerged from review the of existing literature that may impede with this process. Consideration of these limitations in the design and conduct of the studies that will underpin this body of work can help ensure intended research objectives are addressed. This knowledge subsequently can contribute to the wider goal of examining the research practice gap relating to existing RTS decision-making practices within male professional football following lower limb muscle injury.

To being with, it is evident having reviewed the published literature that a significant proportion of studies have focused on elite European football. This is important to acknowledge because observed geographical (e.g. Yoon, Chai & Shin, 2004; Hägglund, Waldén & Ekstrand, 2005; Walden et al., 2011; Waldén et al., 2013; Tabben et al., 2020) and cultural/religious differences (e.g. Chamari et al., 2012; Ekstrand, Spreco & Davison, 2018) within the football injury epidemiology literature infer findings from prevention programmes may not necessarily extrapolate when prescribed elsewhere. In addition, a major limitation of the available literature is that many studies only report findings from the perspective of a single club or use data only collected from a few teams. Drawing on available evidence, it is recognised that factors such as elected leadership styles (Ekstrand et al., 2018), communication quality (Ekstrand, Lundqvist, et al., 2019), fixture congestion (Bengtsson, Ekstrand, & Hägglund, 2013), playing styles (Bradley et al., 2011), decision-making practices (Bengtsson et al., 2020) (to name a few) are likely to vary widely between clubs and may impact the incidence of injury and re-injury differently. Accordingly, the transferability of information into a league setting or wider context is markedly reduced.

To enhance the external validity of published findings, increasing study participation appears crucial. An aspect, professional football has itself acknowledged. It was recently promoted that in order to address important questions arising from within the game, it is necessary that more teams start '*thinking bigger and working together'* (Buchheit, 2017; Ekstrand, 2016). Indeed, well-designed studies involving multiple teams and stakeholders have been recognised to illustrate several advantages over single team studies (Impellizzeri, 2017). In consideration of the overall aim of this thesis, undertaking multi-club and multi-league studies is likely to represent a key component of this process and one that should ideally look to extend research findings beyond that of elite European football teams. Undertaking research of this nature is however not without its own challenges and complexities. It is clearly important therefore that these must be deliberated and accounted for.

Despite sharing a common goal of wanting to reduce the detrimental impact of injury and re-injury, professional football has traditionally held a reputation of being secretive, insular, and averse to sharing (Rolls & McCall, 2017). Accordingly, a resistance to collaboration and unwillingness to participate in multi-team research through possible fear of conceding a competitive advantage has also likely contributed to the research-practice gap. As established, developing approaches that are evidence-led requires a combination of both research evidence and practical experience. However, this cannot be achieved without an openness from teams to share, allow others to learn from their own experiences (i.e. successes and mistakes) and review current practice and intuition. While research undoubtedly holds an important role in helping guide and enhance practice, it has been estimated that it can take up to one to two decades for original research to translate into routine clinical practice (Morris et al., 2011). Consequently, as practices continue to evolve and move forward within the fast-working environment of contemporary football (Coutts, 2016; McCall, Davison, et al., 2016), the delay in the translation of research means it may not always be considered cutting edge, innovative or relevant. Accessibility to practice-based evidence is therefore crucial to establish current thinking and optimise decision-making across professional football.

As a means to successfully connect research with practice, the use of qualitative methods (e.g. surveys, interviews, focus groups) are becoming more prevalent in sport medicine and professional football research specifically (e.g. McCall, Dupont & Ekstrand, 2016; Reeves et al., 2018; Weston, 2018; Roberts et al., 2020). It has recently been recommended that when answering particular research questions, qualitative methods lend themselves to a number of potential uses both in isolation, but also as part of a mixed method approach (Harper & McCunn, 2017). Eliciting a deeper understanding of existing practices as well as offering a contextual perspective to the challenges faced and barriers inhibiting the adoption of best practice recommendations, qualitative methods can direct follow-up investigations that help address the specific needs of practitioners.

As with quantitative research, it is imperative that validated and robust methods of analysis are used to enhance the credibility of findings derived from qualitative approaches (Patton, 2002). Moreover, given the multi-cultural world of professional football, to encourage participation and enhance the reliability of data collected, consideration must also be given to evident language and cultural differences between leagues and teams (Beaton *et al.*, 2000; World Health Organisation (WHO), 2017). In view of the anticipated global outreach of this research project and strong reliance on practitioner and player engagement, these are important considerations that will need to be reflected upon to be able to answer research questions that will emerge over the course of this research project.

As outlined, understanding context is a critical aspect of being able to successfully implement, improve, and increase the adoption of research-based recommendations and strategies within applied practice. Eliciting a deeper understanding of existing practices (e.g. 'what', 'how' and 'why' certain strategies are adopted) as well as offering a contextual perspective to the challenges faced, qualitative research methods (e.g. surveys, interviews) have been shown to help guide the conduct of meaningful and relevant research that can impact practice. As evidenced by McCall and colleagues and their extensive work in professional football regarding the prevention of non-contact injuries, establishing the perceptions and practices of applied practitioners can represent an important basis from which to examine the gap between research and practice and subsequently assist in guiding the development of context-driven scientific investigation that can address identified knowledge gaps (McCall et al., 2014; McCall, Carling, et al., 2015).

Given that behaviour ultimately represents a key factor in the prevention and injury and re-injury, the attitudes and beliefs of end-users must therefore represent an integral component in any preventative strategy (Verhagen & Bolling, 2018). Accordingly, to provide answers to the 'real world' problems and challenges encountered within professional football (e.g. reducing muscle injury recurrences), it is advocated that we need to look beyond our common arsenal of controlled methodological approaches and re-assess the way in which evidence is built (Bolling et al., 2018; Verhagen & Bolling, 2018). In this respect, if we are to establish why football-based practitioners involved in rehabilitation and RTS decision-making behave as they do, and what barriers may be influencing this behaviour, it is important that their voice is heard, and their personal experiences considered.

The translation of research into the practical setting has great potential to develop and deliver new information which can enhance RTS practices (Lippi, 2011; Lippi et al., 2007). Conversely, there is also clear need to better support the translation of evidence from practice into research. Practice-based evidence accepts that real-world implementation is complex and can provide a deeper understanding of the challenges faced by those delivering interventions and/or attempting to adopt recommendations. It is therefore of great interest to establish if current recommendations for RTS proposed within research (i.e. expert-led consensus) are aligned to the practices being implemented within professional football and identify if, where and why gaps exist. In addition, gaining insight to professional practice can serve to enhance existing RTS recommendations and, importantly, direct future research.

2.10 Summary

In summary, it is clear from review of the literature that the process of returning to sport following injury has evolved substantially in recent years. This evolution in current thinking (i.e. how we view and approach RTS) appears to have been shaped significantly by the publication of an expert-led international consensus statement in 2016. Drawing on current evidence across an array of topics relevant to RTS, Ardern et al., (2016) presented a number of recommendations that were intended to help practitioners better understand and guide this process and make optimal decisions.

While the potential value in embedding these recommendations proposed remains subject to further empirical scrutiny, they appear to have been widely accepted by the research community. Conversely, whether the practices being employed by professional football teams reflect this multifaceted and multidisciplinary approach to RTS decision-making remains to be established.

From the perspective of the applied practitioner, the translation of research into practice can be challenging, particularly when recommendations outlined are not contextualised to sport-specific settings or situations. Accordingly, while it is advocated that RTS should occur along a continuum that emphasises a graded, criterion-based progression of activity through key recovery milestones, existing research gaps impede our understanding of how best to integrate this framework within professional practice. This is substantiated by the fact that currently, RTS criteria are not supported by high-level scientific evidence, lack standardisation and are primarily of a subjective nature. Inevitably, a high degree of ambiguity surrounds decision-making, with limited guidance available to support practitioners in selecting appropriate criteria to inform progression through the phases outlined within this framework.

Returning to sport following injury is a complex and multifactorial process and calls for a player-centred, biopsychosocial approach to help support decision-making. The multifaceted nature of injury necessitates the contribution of expertise from a variety of disciplines is required to assess the broad range of physiological, psychological, social, and contextual factors capable of affecting player wellbeing and potentially influencing RTS outcomes. As such, the regular and transparent exchange of information between members of the rehabilitation team is considered essential during the RTS process. Despite this shared decision-making approach being supported within the RTS literature, there remains limited evidence to indicate how this practice should actually be implemented and what in fact this actually looks across a continuum framework within the context of professional football. Given that the quality of interdisciplinary communication represents an area of particular concern within professional football, understanding how to effectively apply team-based decision-making strategies over an entire RTS continuum is an important avenue through which to support future practice.

As depicted within the research literature, the continuum framework has the potential to play a key role in informing the development of criteria-based RTS paradigms and structuring decision-making processes. However, there is a clear need to firstly develop a better understanding of the intricacies and practices embedded within this framework and how they are being used to inform RTS decisions. As it stands, the research literature currently available to us does not appear to provide the answers that are necessary to achieve this. Accordingly, establishing the perceptions and practices of practitioners working within professional football who are involved in the RTS process, represents a logical basis from which to acquire important insights that can be subsequently used to direct relevant and meaningful research that best supports the current decision-making practices of professional teams.

Chapter Three

Study One – Return to sport practices following hamstring muscle injury: A worldwide survey of 131 premier league professional male football teams

3.1 Introduction

Despite an evidence-led approach being recommended as gold-standard to optimise high-performance outcomes (Coutts, 2017), a disconnect between research and practice is often cited by professional football teams (Bahr et al., 2015; McCall, Carling, et al., 2015). A finding that has also similarly been observed among other football populations including semi-professional, amateur and female cohorts (Harøy et al., 2019; Lindblom et al., 2018; van der Horst et al., 2018).

The suboptimal uptake of scientifically supported interventions and recommendations by teams has been accredited to a failure of research evidence to consider implementation contexts and understand end-user needs (Tee et al., 2020). For example, strategies or treatments found to be efficacious under carefully controlled experimental conditions are inherently hindered by low external validity and consequently may not readily transfer into applied practice or demonstrate similar effectiveness. Accordingly, research in the field of sports medicine is now being increasingly challenged to replicate results from controlled studies in real-world athletic contexts (Finch, 2006). To support the translation of research into practice and ensure compliance and adherence to recommendations outlined, understanding what is purported to work or be of potential benefit is insufficient.

Rather, to address this translation gap, it is necessary to understand what works in which context and why (Tee et al., 2020).

To reduce injuries within professional football, a top-down approach toward the development of evidence-based recommendations has traditionally been adopted as demonstrated by the coordinated approaches of football organisations such as UEFA when undertaking injury surveillance and prevention research (Hägglund, Waldén, et al., 2005). While this approach is of value and has contributed to existing knowledge within the field, providing a basis through which specific screening tests and preventative-based exercises have been developed and promoted, it is not without its limitations. The tendency of top-down research to collate information and prescribe recommendations in a unidirectional way (i.e. from research to practice) has resulted in less emphasis being placed on context and may inadvertently have contributed to the misalignment between research and practice observed within professional football concerning injury prevention and specifically muscle injury prevention. As Hanson et al., (2012) have alluded to, context is both the source of the research-practice gap and the pathway to bridging it. With that in mind, to better support practitioners to arrive at RTS decisions, research evidence which is rich in context would clearly be advantageous.

As established in the review of the literature (Chapter Two), return to sport is a topic of much discussion and debate in professional football due to its complexity and consistently poor rehabilitation outcomes. Owing to this complexity and recognising the need for greater consideration of context, adopting a top-down approach to facilitate the translation of research into practice as part of an evidence-based approach to RTS may be unsuitable. Accordingly, adopting a strategy in research that promotes a clearer understanding of both the realities of current practice and needs of practitioners involved in the rehabilitation process, is perhaps a more appropriate starting point from which to connect research in the area of RTS with professional football.

Return to sport related research is increasing rapidly. In particular and previously outlined, the publication of a 2016 expert-led consensus statement (Ardern et al., 2016) and two subsequent Delphi surveys specifically aimed at professional football and RTS from hamstring muscle injury (van der Horst et al., 2017; Zambaldi et al., 2017) have provided some key recommendations to assist decision-making practices and improve RTS outcomes. Specifically, the 2016 RTS consensus statement (Ardern et al., 2016) recommended that:

1) Returning to sport should be viewed as a continuum rather than an isolated event taking place at the conclusion of the rehabilitation process. The continuum framework is proposed to reflect a stepwise, criteria-based progression of activity up to and including a player's 'return to performance'

2) Where possible, objective makers should be used within this framework to quantify rehabilitation progression and guide RTS

3) Practitioners should follow a shared decision-making process including key stakeholders (e.g. science and medical staff, coaches, players).

4) With emphasis toward a holistic athlete-centred model of care, a player’s psychological welfare should be taken into consideration alongside physical markers of recovery during rehabilitation and at the time players are making their transition back to sport.

It should however be acknowledged that the recommendations outlined within the 2016 consensus were framed as general guidelines for RTS in sport and did not consider specific implementation contexts. It is therefore unclear if, and indeed how, these recommendations are being followed by professional football teams, and if not, what barriers could be preventing their adoption. Additionally, while a criterion-based progression of activity was advocated to represent best-practice, the consensus statement did not specify the tests and criteria to be used and how these should develop overtime to inform progression through phases of a RTS continuum. While, this aspect has since been considered for some specific injury types within the research literature (e.g. Dingenen & Gokeler, 2017; Tassignon et al., 2019), it has yet to be studied within a football specific rehabilitation context or when returning to play from lower limb muscle injury; a common and particularly challenging injury type within this population (Chapter Two).

As previously outlined, without direction in the form of high-quality scientific evidence, it is particularly challenging for practitioners to determine which criteria actually best inform a player’s RTS following muscle injury. Consequently, we find that a wide array of criteria are used and RTS decisions inherently lack standardisation (van der Horst et al., 2016). More recently, attempts have however been made to established agreement as to which criteria may be appropriate to assess in order to better support decision-making following hamstring muscle injury. Employing expert panels with backgrounds in football medicine and hamstring injury management, two RTS Delphi surveys, published in 2017, were designed and developed specifically for use by practitioners working in professional football (van der Horst et al., 2017; Zambaldi et al., 2017).

The adoption of the Delphi method to develop guidelines for best practice is now common within sports medicine research (e.g. McCall et al., 2020; Mendonça et al., 2022; Smith et al., 2021). Notably, this technique offers a practical means through which experts within the field can collectively arrive at justifiable, valid and credible solutions to areas of interest (and/or concern) based on best available evidence and their own experiential expertise. Gravitation toward the Delphi method as suggested by Fink-Hafner et al., (2019), may be attributed to the fact that this approach offers anonymity which encourages creativity, honesty (i.e. the expression of individual opinion) and a more balanced consideration of the topic under investigation while mitigating the risk of group dynamics negatively influencing outcomes (e.g. confirmation of the most dominant view). Equally, on account of its iterative approach (i.e. multiple rounds of adaptive questioning based on responses provided), participants within the Delphi procedure have the opportunity to re-evaluate their own position on the given topic in the wake of differing and evolving opinions and rationales. This process of repeated feedback and appraisal to arrive at consensus ultimately serves to enhance the validity of the data collected.

In the case of both football-specific Delphi surveys, a number of key criteria and objective markers were consensually proposed and included clinical tests to assess tissue healing (e.g. pain, flexibility, strength), measures of training-load (e.g. global position satellite (GPS) systems), functional sport-specific performance tests (e.g. repeated-sprint ability, maximal sprints, acceleration/deceleration) and psychological status which may be important in determining player readiness to RTS from hamstring injury (van der Horst et al., 2017; Zambaldi et al., 2017).

It is, however, important to acknowledge that a number of limitations also exist within this research that may inhibit the translation of the recommendations prescribed. Specifically, only one survey utilised full-time practitioners working in professional football teams and unfortunately, the response rate was low and limited to the practices and perceptions of one country (i.e. 18 out of 92 English professional teams invited completed all 3 Delphi survey rounds) (Zambaldi et al., 2017). Equally, while football specific, it is important to note that the Delphi survey of van der Horst and colleagues only involved experts affiliated to the FIFA Medical Centres of Excellence (van der Horst et al., 2017). It was not established by the authors how many, if any, worked full-time in professional football and were faced with the day-to-day context that is imperative to further our understanding in this specific population.

The selection of panel members represents an inherent limitation of the Delphi method and as illustrated, can engender difficulties when attempting to generalise findings to the wider population (i.e. in this case male professional football). This challenge is further compounded by the fact that the concept of consensus remains vaguely defined within the literature and there is little agreement among researchers as to the statistical determination of group consensus (Sandrey, M. A. & Bulger, 2008). In fact, critics of the Delphi method have argued that consensus attained may be undermined by the limited scope of this process to foster in-depth discussion and provide participants with the opportunity to expand on their opinions and ideas. Accordingly, valid yet dissenting viewpoints within the panel, are often overlooked and underreported (Shrier, 2021). A consequence of which is studies run the risk of overstating the significance of their findings.

Such methodological limitations and discrepancies may, in fact, account for the observed differences in football-specific Delphi surveys as evidenced by the different RTS criteria recommended. While each Delphi survey attempted to provide a reference to support decision-making, as previously acknowledged, only discharge criteria for the return to play phase of the RTS continuum were consensually agreed upon. If a continuum framework is indeed adopted within professional football, the specific criteria considered important to informing progression at other phases of this process following hamstring muscle injury have yet to be established.

The translation of research into the practical setting has great potential to develop and deliver new information which can enhance RTS practices (Lippi, 2011; Lippi et al., 2007). However, in consideration of the limitations highlighted to underpin the 2016 RTS consensus (Ardern et al., 2016) and subsequent expert-led Delphi surveys (van der Horst et al., 2017; Zambaldi et al., 2017), many unknowns relating to these recommendations within a football-specific rehabilitation context evidently remain. Accordingly, an appropriate starting point for this programme of work would therefore be to examine whether the RTS practices of professional football teams actually align with current research recommendations and identify if, where and why gaps exist.

3.1.1 Study aims

To determine if current research recommendations are being translated into practice, and if not, where, and why gaps potentially exist, the aims of this study were:

i) To determine if premier-league football teams worldwide follow a RTS continuum.

ii) To identify what RTS criteria are used and considered important to inform progression through a RTS continuum.

iii) To understand how RTS decision-making occurs in applied practice.

3.2 Methods

3.2.1 Participants

In total 310 professional football teams from 34 premier leagues worldwide were approached to participate in this structured online survey during the 2017-18 season. Between the 24th of October 2017 and the 20th of March 2018 (2017-18 season), an invitation was emailed to respective Heads of Medicine and/or Sport Science of premier league teams which described the purpose and procedure of the survey. Access to the survey was provided via a web-link attached to the invitation email. It was requested that the survey be completed by the person/s of the science and sports medicine team responsible for the design and implementation of the RTS programme. Only one survey response per team was accepted. Institutional ethical review board approval was granted by Edinburgh Napier University (SAS/00014). Confidentiality and anonymity were detailed to all teams before consenting to participate.

A maximum of three email reminders were sent over a six-week period from the first email invitation. If no response was received, then a classification of 'no response' was assigned to that specific team. A follow-up email was also sent to respondents in instances where data was missing. If the question(s) remained unanswered, the specific items excluded from the analysis. Owing to the explorative nature of this survey, strict inclusion criteria was not applied in this study. Accordingly, a judgement on whether partially completed survey responses should be included or excluded from analysis entirely was based on the proportion of items completed by respondents. For clarity, the proportion of completed responses (%) included for analysis is outlined in the results section where appropriate.

3.2.2 Development of the RTS survey

The design and construction of the survey followed recommendations as outlined by Rattray and Jones (2007). To establish content validity of generated items and assure useability of the survey, three rounds of piloting were undertaken with 12 experienced applied researchers/practitioners working in professional football – none of whom were affiliated to any team invited to participate in the study. Twelve modifications resulted: four items were deleted and eight items either adapted or added.

Among the key modifications made, it was decided that to provide a more comprehensive picture of current practice, in addition to identifying the criteria considered most important to informing rehabilitation progression, a more general question around the types of criteria used at each continuum phase was added. Similarly, instead of asking practitioners to reflect more generally on the challenges faced to meet criteria during the RTS process, this item was embedded into each phase. Prior to the 2016 consensus statement, reporting guidelines commonly defined RTS as a "return to full participation in team training and availability for match section" (Fuller et al., 2006). It would therefore have been presumptuous to expect all teams to monitor up to and including a players return to performance. Accordingly, it was decided that initially asking if respondents considered this phase within their practice was appropriate. While the focus of this survey was on RTS following hamstring injury, the decision was taken to provide the respondent with an opportunity to detail how they would adapt the criteria and tools used when rehabilitating adductor, quadricep and calf muscle injuries. While important, it was decided to remove items relating to injury severity, the criteria respondents would like to use under ‘ideal’ circumstances and what barriers were currently preventing these specific criteria from being implemented.

The survey was administered online (Novi Survey, http://novisurvey.net) and is presented as a supplementary appendix (Appendix A). Respondents were asked to consider their RTS practices during the previous season for a typical football-related hamstring muscle injury (time-loss 18 days) (Ekstrand, Lee, et al., 2016) when answering all questions in the survey. Although the primary focus of this survey was directed toward determining perceptions and practices following hamstring muscle injury, respondents were also given the opportunity to elaborate on anything which they did differently when addressing adductor, quadricep or calf related muscle injuries respectively.

The survey comprised of 29 questions (10 closed, 19 open) organised into four sections, which were adapted for use in football and refined through the piloting process but were based on a RTS continuum model (Ardern et al., 2016), a structure which subsequent published research has also adopted when examining sport-specific rehabilitation contexts (Buckthorpe, Frizziero, et al., 2019; Meredith et al., 2020; Taberner et al., 2020). The four sections were as follows:

1. Return to high-speed running (RTRun) – the period between hamstring injury occurring and the player being cleared to run on-field and progresses to high-speed running

2. Return to train (RTTrain) – when the player was allowed to return to on-field unrestricted training with the first team

3. Return to play (RTPlay) – when the player was cleared to return to competitive match-play with the first team (whether selected or not)

4. Return to performance (RTPerf) – when the player has been deemed to return to pre-injury levels of performance (or higher).

Each section comprised four parts *(except RTPerf, which only considered parts 1 and 2):

1. Use of RTS continuum and criteria used to progress each phase (5 closed and 7 open questions)

2. Achieving desired criteria before moving to next phase (3 open questions)

3. Decision-making process to progress each phase (3 closed questions)

4. Challenges (i.e. barriers) faced when progressing from one phase to the next (3 open questions)

3.2.3 Cross-cultural adaptation of RTS Survey

Originally developed in English, once a finalised version of the RTS survey had been agreed upon it was translated into French, Spanish, German, Italian, Portuguese, Brazilian-Portuguese, and Japanese using a cross-cultural adaptation process recommended by the WHO (World Health Organisation, 2017). This process consists of five stages:

Stage 1 – Forward Translation: The survey was translated from English into each of the seven target languages. Each forward translation was performed by a bilingual translator (i.e. fluent in English) whose native language was that of the target tongue. All translators were experienced applied researchers/practitioners working in professional football and were familiar with the concepts being examined in the survey being translated. None of the translators were included as respondents for the final survey.

Stage 2 – Translation Synthesis: In conjunction with the original version of the survey, each translated version was presented to an expert committee which comprised of one physician, one physiotherapist and four sport scientists all of whom had applied experience and/or research expertise in the field of return to play. Any issues which had arisen from the forward translation process were presented to, and discussed by the committee, until a consensus was achieved. The outcome of this stage was the development of a first test version of the survey in each target language.

Stage 3 – Back Translation: Each translated version of the survey was then back translated to English. The Back translation was performed to highlight any grammatical inconsistencies or conceptual errors in the translation process. As a check on the validity, this procedure confirmed translation consistency and ensured that the translated version of the survey reflected the same item content as the original version (Beaton et al., 2000). Each translated version of the survey was back translated using a translator whose first language was English and had not been involved in the forward translation process. Importantly, all translators were blind to the original version of the survey and the objectives of the study.

Stage 4 – Expert Committee Review: The expert committee then convened to review and evaluate all versions of the translated surveys to develop a compatible version of the survey in each target language. At this stage, the committee along with all translators involved in the process were required to ensure that equivalence between the original and target versions of the survey was reflected in semantic and conceptual meaning, in addition to experimental correspondence and idiomatic expression.

Stage 5 – Pretesting of Prefinal Version: Since my target population were also involved in the forward and backward translation process of the survey, I took the decision not to undertake this stage of the translation and cross-cultural process. My underlying rationale being that firstly, I felt this stage had already been undertaken in the previous stages of this process and further piloting would not bring to the fore any significant changes to the survey. Secondly, my existing contact network in each of the translated languages was primarily limited to premier-league teams and therefore I did not want to diminish potential responses by approaching teams I intended to survey.

3.2.4 Survey analyses

Reflective of the staggered approach through which leagues were invited to participate in the study and to accommodate the late inclusion of the Japanese premier league, the survey was closed on 31st of April 2018. Responses received after this cut-off date were discarded and not included in the analysis. Raw data was exported to Microsoft Excel. To ensure the accuracy of content analysis, native speakers skilled in translation verified, where necessary, the translation accuracy of answers to open-ended questions. A cross-sectional design was used and the results were analysed descriptively according to the checklist for reporting results of internet e-surveys (CHERRIES) (Eysenbach, 2004). To evaluate the importance of specific criteria, and the corresponding test or tool used to inform clearance to the next RTS phase, a method used in previous survey research was implemented to assign rankings (Akenhead & Nassis, 2016; McCall et al., 2014; McCall, Davison, et al., 2015; McCall, Dupont, et al., 2016). For each continuum phase, respondents specified and ranked in order of importance (1st to 3rd) the criteria they considered to determine RTS progression. For each phase, criteria ranked in 1st, 2nd and 3rd position were reported as a frequency (%) of total responses.

To analyse the open-ended questions, I used inductive content analysis (Patton, 2002) following a three-stage process (Chesterfield et al., 2010; Côté et al., 1993; Nelson et al., 2013). I treated survey answers as standalone meaning units, unless they contained more than one self-definable point, in which case, each meaning unit was considered and separated. As outlined, responses with insufficient information were excluded. For each section of the survey, meaning units generated from responses pertaining to each question were listed, before being compared for similarities and organized into raw data themes. Raw data themes were grouped for each question into larger and more general themes/categories in a higher order concept (Côté et al., 1993). The data were continually refined until theoretical saturation (Corbin & Strauss, 2008).

To enhance confidence in interpreting the data, two independent authors (GD and AM) read the lists of meaning units at least twice (Thomas, 2006). They discussed meaning units, categories, and themes at each stage to reach a consensus regarding data accuracy and clarity. Sample data sets were re-examined by a third independent researcher, blind to the research aims, to audit the assigned categories and themes to ensure they accurately reflected the standalone meaning units (Krane et al., 1997).

3.3 Results

3.3.1 Survey response rate and respondent demographics

Of the 308 who responded to the initial email invitation, 304 teams subsequently consented to participate in the study. However, 101 (33% of 304) teams failed to respond having initially consented to participate. A further 72 (24%) teams were also excluded based on survey responses being incomplete and considered to be of insufficient detail to warrant inclusion. In total, 131 (43%) teams completed the survey and were included in analysis. Figure 3.1 provides a full list of participating confederations with affiliated countries and premier leagues. A more detailed breakdown of responses from each specific premier league surveyed is presented in Table 3.1. The position held by respondents were as follows: club doctor (61 teams); physiotherapist (33 teams); strength and conditioning coach (26 teams); sports scientist (9 teams) and manual therapist (2 teams).

3.3.2 Return to sport continuum in professional football

In total, 124 of 131 premier league teams surveyed (95%) reported to following a return to play continuum model. Of these 124 teams, 27 (21%) did not report to continuing to monitor a player through to the phase of returning to performance (RTPerf) once cleared to RTPlay.

Figure 3.1. World map representing the premier leagues responding to the return to play survey.

Table 3.1 Details of the response rate among invited premier leagues by confederation and country.

Football Confederation	Union of European Football Associations (UEFA)	Asian Football Confederation (AFC)	South American Football Confederation (CONMEBOL)	Confederation of North, Central American and Caribbean Association Football (CONCACAF)	Confederation of African Football (CAF)	Anonymous
Survey Response Breakdown (Invited / Responded / Included)	**(225 / 129 / 86)**	**(50 / 40 / 25)**	**(9 / 9 / 9)**	**(23 / 12 / 7)**	**(3 / 3 / 3)**	**(N/A / 115 / 1)**
Associated Premier Leagues Surveyed	Austria (2 / 1 / 1)	Australia (10 / 10 / 7)	Argentina (3 / 3 / 3)	America (20 / 9 / 5)	South Africa (3 / 3 / 3)	(Unknown / 115 / 1)
	Belgium (8 / 5 / 3)	China (5 / 3 / 0)	Brazil (3 / 3 / 3)	Mexico (3 / 3 / 2)		
	Croatia (7 / 1 / 0)	India (1 / 1 / 0)	Uruguay (3 / 3 / 3)			
	Denmark (10 / 9 / 6)	Iran (1 / 1 / 0)				
	England (20 / 20 / 13)	Japan (18 / 11 / 9)				
	France (21 / 11 / 8)	Qatar (12 / 12 / 8)				
	Germany (14 / 5 / 2)	UAE (2 / 2 /1)				
	Holland (13 / 7 / 2)	Saudi Arabia (1 /0 / 0)				
	Israel (1 / 1 / 1)					
	Italy (20 / 17 / 13)					
	Norway (16 / 13 / 6)					
	Portugal (18 / 8 / 8)					
	Russia (4 / 2 / 1)					
	Scotland (12 / 8 / 7)					
	Spain (17 / 10 / 8)					
	Sweden (14 /1 / 0)					
	Switzerland (8 / 4 / 2)					
	Turkey (10 / 6 / 4)					
	Poland (1 / 0 / 0)					
	Greece (9 / 0 / 0)					

3.3.3 Criteria used during the RTS process from hamstring muscle injury

Across all phases, criteria from clinical, functional, and psychological assessment domains were used in the rehabilitation of hamstring muscle injuries. Specifically, for both RTRun and RTTrain phases, all teams reported to using a criterion-based approach to inform the progression. At RTPlay seven (5% of 131) teams reported that they did not use specific criteria to determine a player's clearance, and this increased to 27 (21%) teams at RTPerf (Figure 3.2). Table 3.2 provides an overview of the specific criteria used by teams and the level of importance given to guide progression at each phase of the continuum.

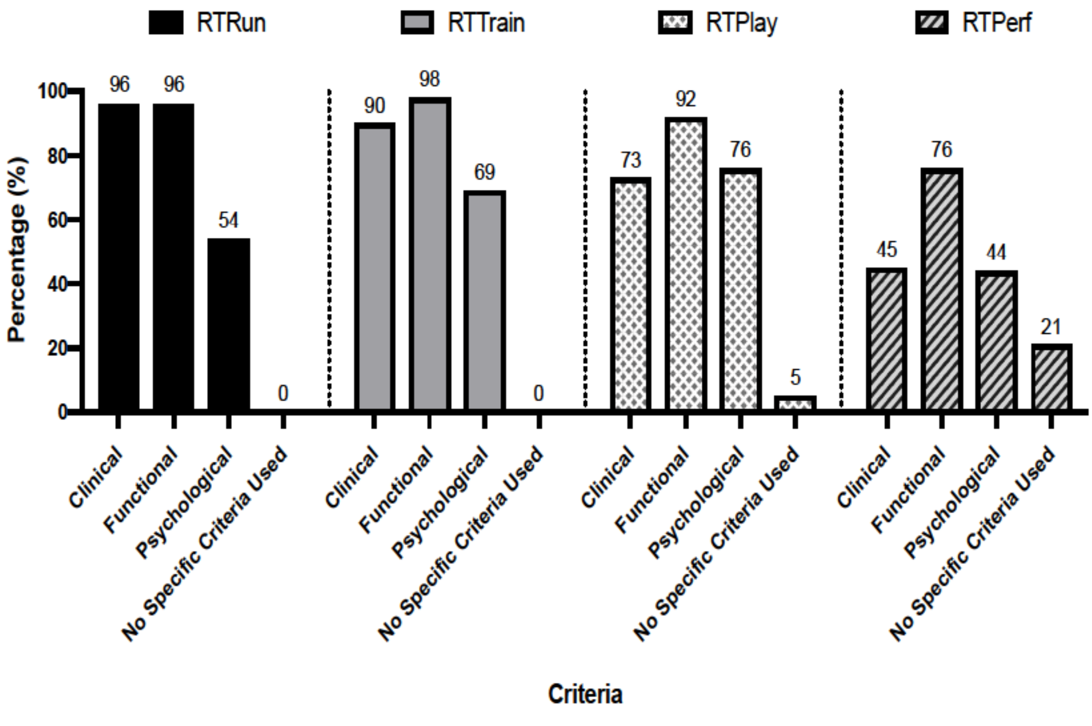

Figure 3.2. Criteria used by teams at each phase of the return to sport continuum to guide progression.

Table 3.2. The frequency (%) of reporting top three criteria across the return to sport continuum.

Continuum Phase	RTRun			RTTrain			RTPlay			RTPerf		
Criteria	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd
Absence of Pain	57*	21	27*	12	8	4	7	5	4	2	2	2
Hamstring Strength	17	40*	24	22	29*	18	3	6	5	8	8	0
Hamstring Flexibility	8	21	15	2	1	3	1	1	2	1	2	0
Functional Performance / Assessment	5	6	8	11	18	19	24	18	14*	6	5	7
Staff Subjective Appraisal	3	3	6	8	3	5	7	4	5	11	14	15*
Psychological Readiness	5	3	9	2	2	8	6	7	13	11	14	11
Training Load Monitoring	1	2	3	39*	25	20*	41*	38*	14*	33*	21*	15
Other (e.g. medical imaging, time)	5	5	5	2	5	2	0	1	2	0	0	1
Total (%)	100	100	97	98	92	80	89	79	58	72	64	50

* The most frequently reported criteria for that RTS phase. Please note that in phases and/or individual ranking positions where totals do not reach 100% - the remaining % represents the proportion of blank responses.

3.3.4 Criteria used for other lower limb muscle injuries

In this section within the survey, participants were asked to reflect on how their RTS practices could change at specific phases within the continuum when rehabilitating different lower limb muscle groups, namely the adductors, quadriceps, and calves. During analysis nine different categories of criteria were identified and these align closely with those presented for hamstring muscle injury. However, a low response rate limited the opportunity to provide detailed analysis. Table 3.3 provides a breakdown of responses for each muscle group and outlines additional and/or modified criteria cited by survey respondents across continuum phases.

Adductors: Of those surveyed, 77 teams (59%) outlined additional criteria which they would consider when returning a player to running following an adductor injury. This was contrasted by 13 (10%) teams indicting that their criteria did not change when dealing with a different muscle injury type, while 41 (31%) teams failed to provide a response. As players were cleared to RTTrain (73%) and RTPlay (92%), the combined frequency of teams reporting to either use similar discharge criteria or failing to provide a response for adductor muscle injuries increased.

Quadricep: Additional criteria were presented by teams 62 (47%) that they would consider when progressing a player to RTRun following a quadricep injury. In comparison, at this phase 21 (16%) teams indicated they did not change their criteria from those adopted for hamstring muscle injury when managing this muscle injury type. In total 48 teams (37%) failed to provide a response to this question. As observed with adductor injuries, as player progressed to RTTrain (75%) and RTPlay (91%) respectively, the combined frequency of teams reporting to use similar discharge criteria or failing to provide a response for quadricep muscle injuries increased.

Calf: Of those surveyed, 62 teams (47%) specified criteria which would be considered when returning a player to running following a calf muscle injury. In contrast 20 teams (15%) suggested that criteria used to inform decision-making at this phase would not change from that used when managing hamstring muscle injury. However, 49 teams (37%) failed to respond to this question. The number of teams either subsequently indicating that they used similar discharge criteria or elected not to respond to this question increased for RTTrain (79%) and RTPlay (94%) phases respectively.

Table 3.3. The frequency (n) of different criteria reported when progressing different lower limb muscle groups across the return to sport continuum.

Continuum Phase	RTRun			RTTrain			RTPlay		
Criteria	Adductor	Quadricep	Calf	Adductor	Quadricep	Calf	Adductor	Quadricep	Calf
Absence of Pain	16	12	9	4	6	3	3	2	2
Strength Assessment	44	32	35	10	9	7	4	2	2
Flexibility Assessment	10	13	13	2	0	0	0	0	0
Functional Performance Assessment	26	25	34	26	27	19	6	9	4
Clinical Assessment	14	10	11	4	6	7	0	0	0
Staff Subjective Appraisal	1	2	1	1	0	0	3	5	4
Psychological Readiness	1	1	1	2	2	2	0	0	0
Training Load Monitoring	0	2	1	5	4	5	5	7	4
Other (e.g. medical imaging, time)	3	5	14	0	1	3	1	0	2
Similar Criteria Used	13	21	20	26	28	30	33	32	33
Non-Response	41	48	49	69	70	74	87	87	90

3.3.5 Frequency with which criteria were met before permitting player progression

In total, 378 (96%) responses out of a possible 393 (i.e. 131 responses x 3 main RTS phases) were included for analysis. Across each phase, the response rate of teams was 130/131 (99%); 128/131 (98%) and 120/131 (92%) for RTRun, RTTrain and RTPlay respectively. When returning to RTRun, a frequency of 100% was reported by 68 (52%) teams (i.e. all intended criteria were met before the player was cleared to progress by 68 teams). In comparison, 55 premier league teams at RTTrain and 36 at RTPlay reported with 100% frequency in always successfully meeting the criteria set. Figure 3.3 displays the frequency range (%) with which teams successfully reported achieving all their intended criteria at each phase of the continuum following hamstring muscle injury.

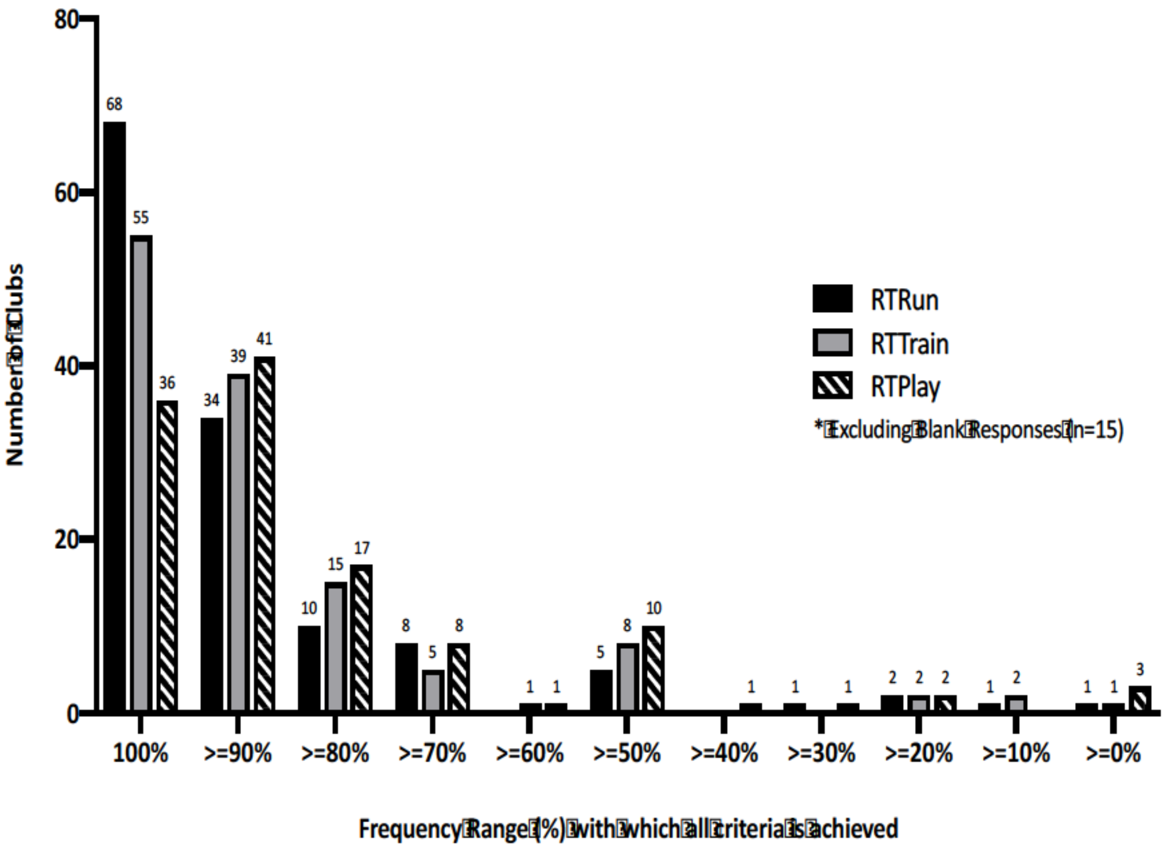

Figure 3.3. The frequency which teams reported achieving all the criteria they set across each phase of the return to sport continuum.

3.3.6 The RTS decision-making process

When examining how teams arrived at decisions, 389 out of a possible 393 (99%) responses were analyzed. Contextualized per phase, 131/131 (100%) teams responded for both RTRun and RTTrain phases while 127/131 (97%) answered at RTPlay. Overall, 105 (80%) teams use a shared decision-making approach involving at least 2 people throughout the RTS process. Table 3.4 represents the contribution of key staff members to decision-making based on the position (i.e. medical or science) of the practitioner who completed the survey.

3.3.7 Challenges influencing decision-making

Table 3.5 presents the main challenges perceived by practitioners which cause a player to be progressed or cleared prior to meeting all criteria set. Both globally and for each individual phase, the challenges cited were grouped into seven main categories. Challenges relating to team hierarchy (e.g. pressure from management) were regarded the most likely to influence the decision making of practitioners (24% of the total challenges cited; n=446). As a player transitioned to RTPlay, match related factors were also found to became more prominent. During the analysis, a further 130 responses were excluded; 94 due to non-response and 36 due to an error which was discovered in the cross-cultural adaption of the survey into Spanish. Presumably this error was not detected during the translation procedure and, as a result, I could not rule out that the question could have been misinterpreted by respondents. In the case of 13 teams (16 responses), challenges were explicitly considered non-applicable as it was stated that every player must have met all criteria outlined prior to being cleared to progress.

Table 3.4. The contribution of key staff members to decision making across the phases of the return to sport continuum based on the perspective and position held by the responding practitioner.

Stakeholder/s involved in the decision-making process to inform progression	**Stakeholder involvement when reported by Medical Team (n=96)**			**Stakeholder involvement when reported by Science Team (n=35)**			**Difference in response between Medical Team *versus* Science Team responses**		
	RTRun (n)	**RTTrain (n)**	**RTPlay (n)**	**RTRun (n)**	**RTTrain (n)**	**RTPlay (n)**	**RTRun (%)**	**RTTrain (%)**	**RTPlay (%)**
Medical staff	**94**	**94**	**83**	**35**	**34**	**31**	**98 *vs* 100**	**98 *vs* 97**	**87 *vs* 89**
Club doctor	74	79	68	27	27	25	77 *vs* 77	82 *vs* 77	71 *vs* 71
Physiotherapist	78	75	58	33	28	25	81 *vs* 94	78 *vs* 80	60 *vs* 71
Science staff	**39**	**53**	**53**	**30**	**34**	**31**	**41 *vs* 86**	**55 *vs* 97**	**55 vs 89**
Strength & conditioning coach	33	45	44	28	32	30	34 *vs* 80	47 *vs* 91	46 *vs* 86
Sport scientist	16	27	28	12	15	16	17 *vs* 34	28 *vs* 43	29 *vs* 46
Sport psychologist	1	1	1	0	1	0	1 *vs* 0	1 *vs* 3	1 *vs* 0
Coaches & management	**11**	**30**	**73**	**8**	**19**	**30**	**11 *vs* 23**	**31 *vs* 54**	**76 *vs* 86**
Manager	8	17	40	2	6	12	8 *vs* 6	18 *vs* 17	42 *vs* 34
Coach (technical staff)	4	19	52	7	14	26	4 *vs* 20	20 *vs* 40	54 *vs* 74
Player	**48**	**51**	**51**	**18**	**23**	**24**	**50 *vs* 51**	**53 *vs* 66**	**53 *vs* 69**

Table 3.5. The challenges faced when helping a player return to sport

Challenge	**RTRun**	**RTTrain**	**RTPlay**	**Total**
Hierarchical	29	38	42	**109**
Match-related	28	30	39	**97**
Player-related	32	29	24	**85**
Team-related	18	13	26	**57**
Rehabilitation programme	12	19	9	**40**
Other challenges	4	6	2	**12**
External factors	2	3	4	**9**
No challenges encountered	6	7	8	**21**
All criteria must be met	8	5	3	**16**

Hierarchical challenges e.g. pressure from management/internal staff agreement; Match-related challenges e.g. importance of upcoming fixture(s)/phase of season; Player-related challenges e.g. compliance to progress, pressure to progress/return; Team-related challenges e.g. existing squad depth/other injuries; Rehabilitation programme-related challenges e.g. time constraints, isolated decision making; External factors, e.g. media, sponsors, agents; Other challenges e.g. language barriers, limited resources/facilities

3.4 Discussion

3.4.1 Summary of findings

Through means of a structured survey, the aim of this study was to establish if current recommendations presented in research are being translated into the RTS practices of premier-league football teams during the rehabilitation of lower limb muscle injuries. With a specific interest toward hamstring muscle injuries, this study sought to: determine if teams were following a RTS continuum framework, identify what criteria were being used and perceived as important to inform progression through a continuum and elicit a better understanding how decision-making actually takes place in professional practice.

The study revealed that the majority of premier-league teams surveyed (124: 95%) adopted a continuum approach to guide RTS following hamstring injury using a combination of clinical, functional and psychological criteria. Clinical criteria were most common at RTRun and RTTrain, while functional criteria were consistently assessed across all phases of the RTS continuum. In contrast, greater emphasis was placed on the assessment of psychological readiness as players entered the later phases of the continuum. Of teams surveyed, 80% adopted a shared decision-making process with at least two people involved at any one phase. Despite a myriad of challenges being perceived to influence decision-making, teams reported to often meeting the discharge criteria that they set to progress through the RTS continuum.

3.4.2 Adoption of RTS continuum in premier league football teams

Based on the sample premier league teams surveyed, the majority (124: 95%) followed a continuum to guide RTS following hamstring injury. Of 124 teams, 102 (78%) reported to assessing criteria at each of the four specified phases; RTRun, RTTrain, RTPlay and RTPerf. Of the remaining 29 teams, 22 implemented a criteria-based approach at RTRun, RTTrain and RTPlay, but not RTPerf. Unfortunately, the teams did not provide sufficient detail from which to confidently report why this was the case. However, of the minimal feedback received, it was specified that they believed the RTPlay phase should be where the player is also considered to be back to full performance. Although not specifically addressed in this survey, it would have been interesting to establish if these teams, despite not recognising RTPerf as a distinct phase, implemented any ongoing monitoring or tertiary prevention strategies aimed at mitigating re-injury risk once a player had been cleared to RTPlay. Indeed, a number of clinical symptoms and deficits have been recognised to persist in athletes following RTPlay after hamstring injury and may be associated with a higher-risk of re-injury (De Vos et al., 2014). Of the seven (5%) teams that did not follow a RTS continuum, they did not explain why.

These findings provide preliminary support, at least in this sample, that general research recommendations and practice align in that team practitioners view RTS from the point of injury until at least returning to play and most through until returning to desired performance. As outlined in the methods and discussed within the review of the literature, the RTS continuum adopted in this study differs from the one specified in the 2016 consensus statement. The notable amendment being that an additional phase early in rehabilitation (RTRun) was specified; an approach which has been subsequently supported within the literature (Buckthorpe, Frizziero, et al., 2019; Meredith et al., 2020; Taberner et al., 2020). It is important that future research continues to take this into consideration. Football, and sport in general, as well as research are constantly evolving, and the application of a continuum framework within and between sports may need to be adapted to the specific needs of those monitoring and controlling the overall RTS process. As a result, models such as the RTS continuum may need to be adaptable to suit these requirements and specific implementation contexts.

Significantly, having established that surveyed teams tend to follow a continuum, the next step is to identify what criteria are considered important by practitioners to inform progression through a RTS continuum and to determine how these criteria develop overtime after muscle injury. In the endeavor to develop RTS decision-making practices which are evidence-based, knowledge acquired through practice-based evidence can help direct future research when selecting criteria to investigate.

3.4.3 Criteria widely used to guide RTS but highly varied across premier league teams

Team practitioners used a combination of clinical, functional, and psychological criteria to guide RTS following a hamstring muscle injury. Multifactorial and criteria-based rehabilitation programmes are advocated in research to support RTS decision-making (Mendiguchia et al., 2017; Mendiguchia & Brughelli, 2011; Tol et al., 2014). Such criteria-based decision approaches provide practitioners with an individualized approach to RTS which integrates quantifiable assessment, objective and subjective, to systematically progress rehabilitation. Criteria-based approaches may reduce re-injury risk, and improve player performance and availability of footballers (Fanchini et al., 2018; Mendiguchia et al., 2017). In this survey, respondents were asked to specify their top three most important criteria used at each of the RTS phases (Table 3.2) with the aim of uncovering some consistently used criteria, metrics and thresholds which could inform current practice and guide future research.

3.4.3.1 Criteria to progress to return to running

While eight different criteria were represented at this phase, absence of pain and hamstring strength were the two most frequently reported top three criteria used to inform progression to RTRun following hamstring muscle injury by premier-league professional football teams. The observed weighting assigned to the absence of pain by survey practitioners (reported frequency; 1^{st}– 57%, 2^{nd} – 21%, 3^{rd} – 27%) is in line with perceptions previously presented in the research literature (Delvaux et al., 2014; van der Horst et al., 2017; Zambaldi et al., 2017). Based on the findings of this survey, emphasis appeared to be placed on the absence of pain during clinical evaluation (e.g. on palpation, or strength and flexibility tests) and/or following functional performance testing (e.g. low-level running mechanic drills, low-moderate speed running) which is similar to the RTS Delphi survey of football experts by van der Horst and colleagues (van der Horst et al., 2017).

In a recent systematic review of criteria used to inform rehabilitation progression and RTS clearance following hamstring muscle injury, it was highlighted that progression was typically only permitted within pain free limits (Hickey et al., 2017). The avoidance of pain during rehabilitation is consistent with conventional guidelines for the treatment of acute muscle injuries (Tero A.H. Järvinen et al., 2005) and aligns with the notion that the presence of pain during rehabilitation activities may indicate incomplete tissue healing (Bisciotti et al., 2019; Delvaux et al., 2014; van der Horst et al., 2017). Indeed, the presence of localized discomfort on palpation following RTS has been proposed to be associated with an increased risk of hamstring re-injury in football players and strengthens the notion that progression should only be granted on complete resolution of presenting symptoms (De Vos et al., 2014).

However, remaining pain free during rehabilitation has also equally been challenged. Silder et al., (2013) indicated that even in the absence of pain, muscle tissue healing is likely to be incomplete at RTS as evidenced by the fact no participant with an acute hamstring injury had complete resolution of oedema on MRI assessment. A finding reinforced by Reurink et al., (2014) who reported that 89% and 39% of clinically recovered acute hamstring injuries still demonstrated hyperintensity (oedema) and/or fibrosis respectively, on MRI at RTS. More recently, Whiteley and colleagues have questioned the value in using an athlete's subjective appraisal of pain to inform the progression of loading during rehabilitation following hamstring injury (Whiteley et al., 2018). In this study, the subjective rating of daily pain was found to track poorly with progress during rehabilitation as by the time 30-40% of the program of rehabilitation had been completed, athletes typically reported to experiencing 'no pain at all' (i.e. 0 on numeric rating scale). More pragmatically, remaining pain-free during rehabilitation may unnecessarily prolong rehabilitation, thereby increasing the injury burden experienced (Hickey et al., 2017). Consequently, there does not appear to be any clear and confident recommendations on the role of ‘absence of pain’ prior to RTRun or in general throughout RTS process.

Relative to other recorded criteria, hamstring strength was also more frequently reported by practitioners as a top three criteria at RTRun (reported frequency; 1st – 17%, 2nd 40% and 3rd – 24%). There is an important consideration with strength however, that was identified in the Delphi surveys of van der Horst et al., (2017) and Zambaldi, Beasley and Rushton (2017), in that ‘strength’ can encompass a variety of contraction types (e.g. eccentric, isometric) and evaluations (e.g. imbalance between legs and within legs). Yet which specific components of strength should inform RTS progression remain unclear.

In the consensus of Zambaldi, Beasley and Rushton (2017), it was agreed that full hamstring strength is essential to for a safe RTS. However, in contrast, the experts in the Delphi survey of van der Horst and colleagues did not reach consensus: experts unable to agree if eccentric strength should be used as a criterion (van der Horst et al., 2017). Although they did agree that other contraction types should not be used as criteria for RTS. Unfortunately, the respondents for this survey did not provide sufficient information on the types of hamstring strength they tested as criteria. Tol et al., (2014) have previously indicated that the normalisation of isokinetic strength following hamstring injury was not necessary for successful RTS in professional footballers, while a 2017 systematic review recommended the opposite; that the assessment of isokinetic hamstring strength could be a useful criteria to adopt during the RTS process (Hickey et al., 2017). However, the systematic review was not specific to professional football only and specificity of population is arguably necessary. Since then, scientific studies (e.g. cohort studies) are beginning to question the utility of hamstring strength and specifically isokinetic cut-off values as progression criteria for hamstring RTS (van Dyk et al., 2016, 2017, 2019). It should be noted however, that these studies are concerned with the RTPlay phase and to our knowledge no studies have investigated the role of strength prior to returning to high-speed running.

3.4.3.2 Criteria to progress from returning to running to returning to training

To inform progression to RTTrain, despite a variety of top three criteria being reported, training load (reported frequency; 1st – 39%, 2nd – 25% and 3rd – 20%) and hamstring strength (1st - 22%, 2nd - 29%, and 3rd - 18%), were the most frequently reported criteria by practitioners. Hamstring strength has been discussed in the previous section. The higher reported frequency of training load monitoring is consistent with the perceptions of medical practitioners in UEFA Champions League (McCall, Dupont, et al., 2016) and FIFA national teams (McCall, Davison, et al., 2015) where training load was highlighted as one of the top criteria for injury prevention. This shift in focus of criteria from RTRun likely represents a shift from prioritizing clinically focused criteria towards a greater reliance on tools to appraise functional performance and capabilities. However, it is currently unclear how training load relates to re-injury risk and specifically muscle/hamstring re-injury, if at all. While only expert opinion, it has been recommended to maintain ‘high control’ over running loads and speeds during this rehabilitation phase with particular consideration given to the progression of speed and player characteristics e.g. position, style of play (Taberner et al., 2019).

3.4.3.3 Criteria to progress from return to training to returning to play

To inform RTPlay decision-making, training load was again the criterion most frequently considered by practitioners (1st – 41%, 2nd – 38% and 3rd – 14%). Existing RTS recommendations advocate achieving GPS benchmarks based on player/position-specific match metrics (e.g. max speed, high-speed running distance, sprint number) are important to ensuring readiness to RTPlay (van der Horst et al., 2017; Zambaldi et al., 2017). Stares and colleagues recently reported that longer RTPlay timeframes, to progressively develop greater weekly and total training loads, were associated with reduced risk of re-injury in Australian rules footballers (Stares et al., 2018). This has since been supported within professional football, whereby it was found that the propensity for muscle re-injury on return to competitive match-play was reduced with each additional training session completed by players since being cleared to RTPlay (Bengtsson et al., 2020). The authors suggested that following muscle injury, players should ideally complete at least six training sessions between returning to play and subsequently being exposed to competitive match-play. Interestingly, within the study of Stares et al., (2018) achieving running loads above peak values prior to the injury resulted in an extra ~ 10 days missed (31.6 ± 10.8 days vs. 21.6 ± 2.5 days). Return to play decision-making is complex and balancing research evidence with the demands of professional practice is particularly challenging (McCall et al., 2017). While these more recent findings offer some guidance for practitioners to help them make well informed decisions regarding a player's readiness to return to match-play, the time taken to progress through RTS phases represents an ongoing risk assessment. An additional 10-day absence or the requirement to complete six training sessions equates to two to three matches being missed in elite professional football and potentially up to nine points.

It was not surprising that performance/sport specific field testing was one of the more frequently reported criteria at this phase (1st – 24%, 2nd – 18% and 3rd – 14%). This criterion should theoretically allow practitioners to assess a player's readiness to load the injured muscle as required during progression to activities with higher demands as seen at RTTrain and RTPlay. Performance during on-field testing was considered to be a 'vital' criteria in determining RTS clearance by the football experts (van der Horst et al., 2017). A carefully planned RTS program that addresses all aspects of the game may be important for restoring functional performance levels while minimizing the risk of re-injury (Bizzini & Silvers, 2014; Mendiguchia et al., 2017). However, further prospective research is required to validate functional tests to guide RTPlay decisions.

3.4.3.4 Criteria to determine when players have returned to performance

While the majority of premier league teams followed a four phase RTS continuum, RTPerf was the one phase that 21% teams highlighted that they did not follow with anecdotal feedback suggesting that they believed players should be back to desired performance levels upon RTPlay. Defining what represents the desired level of performance remains an important knowledge gap in the current understanding and one which has not yet been achieved in the research literature. As suggested in the 2016 consensus statement (Ardern et al., 2016), this phase may be categorized by personal best performance or expected growth because it relates to performance and therefore criteria within this domain may be important. In the professional football setting this is likely to refer to match-related metrics related to physical, technical, tactical, and cognitive qualities.

As with RTTrain and RTPlay, training load was one of the most frequently reported criteria (1st –33%, 2nd -21%, 3rd -15%), yet little is currently known about training load and RTPerf. Given that the majority of a starting player's in-season loading is derived from match play (i.e. typically 2 games/ week), the inability to maintain training load throughout rehabilitation has been suggested as a risk factor for re-injury and may contribute to the high rate of 'early' recurrences (< 2months) observed following RTPlay (Blanch & Gabbett, 2016; Hägglund et al., 2016). Normalization of training loads comparable to the team were not achieved until after RTPlay in Australian rules football (Ritchie et al., 2017), while footballers returning to play were at increased risk of subsequent injury for up to 12-weeks (Stares et al., 2019). Accordingly, extending player monitoring and observation beyond RTPlay may represent an interesting aspect to assess during the RTPerf phase to not only ensure pre-injury performance benchmarks are being achieved but also as a tertiary-level injury prevention strategy (Stares et al., 2019). In a recent case report involving the rehabilitation of a surgically repaired intramuscular hamstring tendon in an English premier-league professional footballer, the authors highlighted that a high-speed running drill comprising of acceleration, speed maintenance and deceleration phases was used as an optional top-up within the training week to ensure high-speed exposure in the continually remodeling tendon was maintained after RTS (Murphy & Rennie, 2018). Ongoing monitoring of this nature may be important in instances whereby players may not necessarily retain their position upon returning to the team or where the player may not be deemed a first team regular and therefore does not acquire sufficient high-speed exposure through the addition of regular match-play.

3.4.3.5 Other considerations regarding criteria

Psychological criteria were highlighted in the global criteria used by team practitioners (Figure 3.2) and specified as important to consider in the research literature (Ardern et al., 2013; Forsdyke et al., 2017; Lentz et al., 2018; Podlog & Eklund, 2007b) as well as the previous Delphi surveys conducted in elite football (van der Horst et al., 2017; Zambaldi et al., 2017). However, psychological readiness was infrequently reported by practitioners.

In view of the modifiable nature of psychological factors/traits, it has been recommended in research that psychological factors should be assessed from the time of injury (Glazer, 2009). While limited in football, expression of positive psychological responses across rehabilitation (e.g. higher motivation, low fear of re-injury) have been associated with successful return to sport (i.e. RTPlay in our study) outcomes within a variety of different athletic populations (Ardern et al., 2012, 2013; Sonesson et al., 2017). Few practitioners specified which psychological inventories they used, if indeed, they used any formal evaluation. It could be postulated that this may be due to a lack of well validated instruments to measure this concept of 'psychological readiness' following muscle injury and may therefore explain the relatively low accumulated points. Research is urgently needed to validate and evaluate the effectiveness of psychological readiness questionnaires for professional footballers.

3.4.4 Criteria to guide RTS following injury to other lower limb muscle groups

In consideration of the different types of criteria reported by respondents, practices to guide RTS for quadricep, adductor and calf muscle injures appear to closely mimic those used for hamstring injury. This finding is not surprising given they are all soft tissue injuries of the lower limb and the criteria classified appear to be broadly applicable to the rehabilitation of several muscle injury types (e.g. Bisciotti et al., 2019). However, a more detailed interpretation of how these RTS criteria are specifically adapted by professional football teams when presented with another lower limb muscle injury is much less clear. This is likely a consequence of how this question was interpreted. Specifically, respondents were asked to consider if there was anything they would change or add with respect to the criteria, tools and/or tests implemented when dealing with an adductor, quadricep or calf muscle injury to inform progression to RTRun, RTTrain and RTPlay.

As summarised in Table 3.3, some respondents outlined that they used the same criteria to those applied for hamstring injury. In the absence of context, such responses could only be interpreted at a global level and were viewed as implying the recovery of similar properties (e.g. strength, range of motion, sport specific function) were being assessed. Conversely, a significant number of respondents chose not to provide any additional information and for clarity, these were categorized as non-responses. However, given the open nature of the question asked, these could equally be construed as respondents choosing not to answer as they perceived their RTS practices to be comparable with those used in the rehabilitation of hamstring injuries. Among those electing to offer additional information, akin to items relating to the hamstrings, the level of detail provided varied widely. Accordingly, analysis was restricted to more generalized categorization of criteria to ensure poor judgements and/or wrong interpretation of responses was avoided. Notably however, from the findings presented, any adaption to the criteria used to inform RTS progression for these other injuries continued to demonstrate significant crossover with those practices adopted for hamstring injuries.

Muscle injuries involving the other major muscle groups of the lower limb are prevalent in male professional football and recurrences are common (Ekstrand, Hägglund & Waldén, 2011). At this point, as highlighted by Ishøi et al., (2019), research in sport relating to the diagnosis, prevention and treatment of muscle injuries, primarily concerns hamstring muscle injuries with only limited research available for quadriceps, adductor and calf muscle injuries. However, this study only included articles that investigated the effect of a rehabilitation treatment on re-injury risk and/or time to return to sport and therefore studies not directed toward these rehabilitation outcomes were not considered. Consequently, studies documenting criterion-based approaches that may offer insight as to how rehabilitation is progressed for these lesser researched muscle injuries have yet to be explored and represent an important avenue for future research to help better support practice.

While defending the original decision to add this line of enquiry into the RTS survey, how this open-ended type of question was possibly constructed made interpretation of responses challenging. As a result, the level and depth of information obtained for these other muscle groups was not as expected or hoped. Better practice would have been to follow the line of questioning similarly used for hamstring muscle injury. However, this approach presented its challenges and would have additionally contributed significantly to response fatigue (i.e. an additional 72 items) and a deterioration in the quality of data captured. Pragmatically, the conduct of qualitative research in this area should look to examine each muscle injury independently to establish a more comprehensive picture of the assessment criteria currently adopted by professional teams to guide progression through a RTS continuum.

3.4.5 What does RTS decision-making look like in practice?

A shared decision-making approach was used by 80% of premier league teams surveyed. This is an encouraging finding as low quality internal communication may be associated with injury and re-injury rates and reduced player availability (Ekstrand, Lundqvist, et al., 2019; Gabbett & Whiteley, 2017; McCall, Dupont, et al., 2016). Only 8 (6%) teams reported using isolated decision-making across all continuum phases while eighteen (14%) teams used a combination of isolated and shared approaches to guide rehabilitation progression.

Whilst appreciating the interpretation of these findings is confined to a relatively superficial level on account of the lines of enquiry used within the survey (see Appendix A.1.), the propensity for teams to adopt shared decision-making practices would appear to align with calls within the literature for a more biopsychosocial approach to sports injury rehabilitation (Ardern, Bizzini, et al., 2016; Hess et al., 2018). Although empirical evidence is still required to establish the efficacy of shared decision-making as a mechanism to improve RTS outcomes within professional sport, an interdisciplinary approach, at least in principle, possesses a number of benefits which may contribute to the overall quality of decisions being made within practice.

Drawing on the work of Karol (2014), a hallmark of this approach is the increased interdependence and coordinated strategy of members within the rehabilitation team to address the needs (i.e. physical, social, psychological), goals and progress of the injured athlete. With emphasis placed on delivering athlete-centred care, rather than targeted objectives and challenges being assigned to single disciplines and practitioners, all treatment decisions are underpinned by the collective expertise and experiences of the rehabilitation team and always made in consideration of the athletes immediate and future needs. Owing to this problem-focused, shared approach, no single discipline retains the exclusive responsibility of clearing an athlete to RTS. It is envisaged that this will elicit increased empowerment, engagement and motivation for rehabilitating athletes, whereby the anticipated outcome of this process is a confident athlete who is prepared socially, physically and mentally to return to competition (Hess et al., 2018).

Deeper exploration of survey responses revealed that medical staff (club doctors and physiotherapists) were most frequently consulted throughout the decision-making process. Traditionally regarded as the gatekeepers of the RTS decision, medical staff clearly hold a prominent role within the decision-making practices of clubs. In fact, in 96 teams (73%), medical staff were recognised as being the lead practitioner responsible for the RTS programme. Across each phase of the RTS continuum, ≥ 87% of teams consulted with at least one medical practitioner (Table 3.4).

Interestingly, while the involvement of medical staff in decision-making across all phases of the continuum was reported by both medical and science practitioners surveyed (Table 3.4), their perceptions of how other key stakeholder groups are involved in the decision-making process differed. Specifically, medical staff reported less involvement of science and coaching staff across all phases of the continuum compared to when science staff answered the survey. In addition, less emphasis was also placed on the contribution of players by medical staff to inform RTTrain and RTPlay decisions respectively. It is not clear as to why this is, as any potential bias of responding staff types to place greater emphasis on their own involvement should have then also been evident in the responses of science staff, yet this was not the case. It could be postulated that this finding perhaps attests to the fact that as yet, practitioners do not have access to clear, empirically supported decision-making frameworks. As a result, a degree of uncertainty continues to surround the specific shared decision-making practices of teams within a RTS context.

The results ascertained raise important questions about how key stakeholder groups are actually involved in RTS continuum process. Despite an initial encouraging finding that RTS decisions are being shared within teams, inconsistency in the composition of stakeholders used to inform decision-making throughout this process brings into question the specific dynamics of communication among football staff. For example, within a shared decision-making model, the inclusion of players and coaching staff is considered important as it is perceived they are best positioned to evaluate the non-medical factors that can influence RTS and equally affect the overall well-being of the injured player (Shrier et al., 2014). In fact, the work of Podlog and Eklund (2007a, 2009) points to the possible benefits of integrating these stakeholders groups within the rehabilitation and RTS process. Based on the current findings however, it can be interpreted that engagement by teams with these stakeholder groups appears to be suboptimal and may insinuate existing decision-making practices are not yet wholly player centred. Accordingly, subsequent research should look to not only establish the perspectives of other stakeholder groups involved in this process (e.g. players, coaches), but also how they are involved and contribute to the decision-making process.

3.4.6 Achieving discharge criteria set across the RTS continuum

Premature RTS has been suggested as a possible risk factor for re-injury (de Visser et al., 2012; Hägglund et al., 2016; Opar et al., 2012; Wangensteen et al., 2016). Throughout the RTS continuum, surveyed practitioners highlighted encountering various challenges capable of influencing their decision-making (Table 3.5). When progressing through the RTS continuum following hamstring injury, team practitioners reported that there were occasions when the player did not meet all of criteria set (Figure 3.3). However, these occasions were not common. Typically, teams met the criteria they set ≥90% of the time yet observed variations in reporting demonstrate the reality of the practical setting where it is not possible to achieve this all of the time.

Each injury case must be assessed individually, based on a risk assessment. So while the evidence for biological time frames for muscle tissue must be respected (Järvinen et al., 2013; Pieters et al., 2021), individual psycho-social influences, team culture, and coaching philosophies should also be taken into consideration (Coles, 2018). Accordingly, the risk associated with accelerating a player's RTS to ensure availability for a decisive fixture may be more readily accepted in the case of the key 1st team player as opposed to the promising youth team prospect – who might be afforded a longer RTS timeframe to reduce reinjury risk. In this respect, while acknowledging that medical and science staff should take responsibility of a player's health and well-being in all their recommendations regarding RTS decisions, ultimately, the player, coaching staff as well as the medical and science teams have to work together to create a shared responsibility for the injury management strategy implemented, and an accepted level of risk in each individual case (Coles, 2018). Importantly it must be recognised that while surveyed teams predominantly displayed a high degree of success in achieving criteria, this finding reflects only one muscle-group (hamstring). Therefore, it is not yet clear if this is representative of rehabilitation across other muscle-groups or injury types.

3.4.7 Limitations

An inherent limitation of survey-based research is its lack of external validity owing to low response rates. One hundred and thirty-one (42%) of 310 invited teams completed the survey. Accordingly, caution should be exercised when interpreting or generalising these results, as the extent to which they characterise the perceptions and practices of the non-responding teams is unclear. Furthermore, how these findings extend to other levels of competition (professional vs. amateur), gender, different age groups (senior-level vs. academy-level) and other injury-types is also unknown and warrants consideration in future research.

Limited insight was provided by respondents as to how rehabilitation practices were adapted to manage adductor, quadricep and calf injuries. As previously discussed, it is not entirely clear why items relating to other muscle groups were poorly answered. Given the repetitive nature of the survey and prominent use of open questions, respondent fatigue cannot be ruled out. On account of this, research is urgently required to identify the criteria and specific tests considered important within this population to inform progression through a RTS continuum. This is especially important as injury and re-injury involving these other lower limb muscle groups also represents a significant problem for male professional football teams. Critically, to continue to develop research in this area, further investigation is warranted using techniques capable of facilitating a more comprehensive picture of how specific metrics and thresholds affiliated to the RTS criteria used by teams inform decision-making following muscle injury.

Representing current opinion (level 5 evidence) it should be acknowledged that the findings presented within this survey may change with emerging evidence and paradigm shifts. Therefore, the perceptions and practices of practitioners should be re-evaluated in the future based on the emergence of new recommendations presented within research. While sampled teams appear to display a high degree of success in meeting their outlined criteria, a perceived limitation (although not a specific focus of this survey) could be that practitioners were not asked to elaborate on instances where RTS was accelerated without achieving criteria. It is not known if, in these instances, re-injury occurrences predominantly occurred.

It is also acknowledged that survey responses correspond only to the perceptions and practices of science and medical practitioners responsible for the return to sport program. It is possible that responses could vary according to the position of the stakeholder surveyed while the perceptions of other key stakeholders' groups involved in decision-making (e.g. managers, players) were not considered. In addition, cultural differences could not be compared as participating teams from different confederations and leagues were not equally represented. Given a large proportion of survey responses represented the practices of teams competing in European premier-leagues, the development of strategies in research to better engage with practitioners and teams working across professional leagues in other continents is needed. It cannot be assumed that research recommendations will similarly translate into practice in these countries and continents. Differences in cultures and financial resources will mean that much research, while considered potentially the gold standard, cannot necessarily be applied in all football settings. Future multi-centre research should aim to include this diversity to provide recommendations globally.

3.5 Conclusion

Premier League professional football teams were found to assess a range of clinical, functional, and psychological criteria to support decision-making on whether to progress or delay a player's transition through key phases (i.e. RTRun, RTTrain, RTPlay and RTPerf) of the RTS process. Although within the continuum framework a wide variety of RTS criteria were adopted by teams, the criteria most frequently reported to progress to high-speed running were absence of pain and hamstring strength. When returning to full team training, assessment of hamstring strength and monitoring of training load were more frequently reported than any other criteria. To transition to full match-play, teams place particular importance on training load and functional performance/sport-specific assessment criteria to guide their decision-making. Correspondingly, in determining a player's return to performance, training load was also the most frequently reported criteria adopted by teams. Importantly however, insufficient information regarding the specific metrics and thresholds used for these RTS criteria highlight that the lack of clear guidelines within research also appears to be an issue in the practice of professional football teams.

Encouragingly, professional football teams predominantly reported using a shared decision-making process throughout the entire RTS process. However, the proportion of those involved at each phase was only consistent for medical staff (club doctors and physiotherapists). The specific involvement of science staff, management and coaches as well as players was less clear and should be explored in more detail. While there were instances where respondents reported progressing players without meeting all the criteria they set, these instances were not overly frequent. Accordingly, practitioners responsible for the design and implementation of the RTS programme within teams can be encouraged by the fact that despite facing a number of challenges (including but not limited to, hierarchical, match and player related), they can still meet the criteria they set a large proportion of the time.

Chapter Four

Study Two – What criteria are used to inform progression through a return to sport continuum framework following lower limb muscle injury in high-level football code team sports: A scoping review

4.1 Introduction

As highlighted previously, to optimise rehabilitation outcomes current recommendations outline that RTS should be viewed as a continuum rather than an isolated event taking place at the conclusion of the rehabilitation process (Ardern et al., 2016). As such, the emphasis of the first study within this thesis sought to explore if, and indeed how, this evidence-based recommendation is being applied in male professional football.

Specifically, when applying a RTS continuum, a criterion-based approach is advocated to assist practitioners in making decisions regarding the progression of rehabilitation or when determining clearance to RTS (Ardern et al., 2016; Meredith et al., 2020). While the landmark 2016 consensus outlined that these criteria should reflect quantifiable assessments (objective and subjective) evaluating aspects of clinical recovery, functional competency, and psychological readiness to RTS, the specific criteria that should be incorporated into this framework were not outlined. For applied practitioners, deciding on the criteria that should be incorporated into this framework to inform their own rehabilitation strategies can be particularly challenging owing to a lack standardisation and consistency in criteria used within the literature (van der Horst et al., 2016), a reliance toward assessments of a subjective nature (Hickey et al., 2017), limited agreement on testable thresholds against which RTS decisions should be made (Wikstrom et al., 2020), and presently, no validated criteria to determine when it is to safe progress rehabilitation or permit RTS (Webster & Hewett, 2019). Accordingly, establishing the criteria that should guide the RTS process and mitigate the risk of re-injury represents a current key priority.

Interest has grown across research and practice with respect to what criteria may be appropriate to appraise athlete readiness, both physically and psychologically, and help inform decisions related to progression through key recovery milestones embedded within the rehabilitation process (e.g. RTRun, RTTrain, RTPlay) as well as identifying if, and when, athletes have returned to performance (RTPerf). Accordingly, a variety of literature reviews have since been conducted to examine the criteria based RTS decision-making processes for some specific injury types such as anterior cruciate ligament reconstruction (Dingenen & Gokeler, 2017) and lateral ankle sprain (Tassignon et al., 2019). Presently however, knowledge of the RTS criteria used to inform decision-making and how these criteria develop over time within a RTS continuum for other common injuries such as lower limb muscle strains are lacking. A synthesis of scientific evidence to establish how RTS testing is being approached in research may be of particular interest to practitioners involved in football-code team sports such as football (soccer) rugby, Australian football, and American Football given muscle injuries to the hamstring, adductor, quadricep and calf are common and have been found to display a high susceptibly for recurrence across these specific team-sport populations (Feeley et al., 2008; Green et al., 2020; Hägglund et al., 2016; Orchard et al., 2013; Williams et al., 2017).

Recently, a call was made for insights into scientific evidence that can help guide the progression of rehabilitation following muscle injuries (Ishøi et al., 2020). To date, what general guidance does exist within the published literature appears to be either directed toward RTPlay decision-making (Orchard et al., 2005; van der Horst et al., 2016) and/or centred primarily on hamstring muscle injuries (Erickson & Sherry, 2017; Heiderscheit et al., 2010; Hickey et al., 2017; van der Horst et al., 2016, 2017; Zambaldi et al., 2017). Moreover, much of the guidance published represents the consolidation of research evidence that predates the conceptualisation of the RTS continuum framework (Heiderscheit et al., 2010; Sherry et al., 2015). In this respect, it is important to acknowledge while a continuum has been proposed to represent best practice (Ardern et al., 2016), it is not clear if, and how, this is being supported within the research literature to help practitioners operating within football code sports rehabilitate lower limb muscle injuries.

Through qualitative examination of the current practices and opinions of medical and science practitioners working with injured footballers (Study One), it was found that after muscle injury, professional football teams do indeed consider and largely follow a RTS continuum. As part of this approach, teams appear to utilise a variety of specific criteria related to clinical, strength, functional, and psychological assessments of recovery to progress players to RTRun, RTTrain, RTPlay and determine RTPerf. While this survey provided some novel insights into how criteria are being developed across a RTS continuum and what criteria are considered most important by practitioners in determining progression across specific phases of this framework after hamstring muscle injury, a number of knowledge gaps remain which need to be addressed if practitioners rehabilitating injured athletes are to be better supported.

Firstly, out with identifying the global RTS domains and specific assessment items used to inform decision-making across a RTS continuum, a deeper understanding of how these measures were actually being evaluated in practice failed to be determined in this survey. For example, while training loading monitoring was consistently identified as a prominent measure used to inform progression to RTTrain, RTPlay, and determine a player's RTPerf, a lack of insight and consensus amongst respondents meant clear comprehension of how this tool was being used could not be determined. Similar outcomes have equally been reported in previous qualitative investigations involving professional football teams (Delvaux et al., 2014). Establishing evidence-based criteria for these assessments is warranted as insufficient rehabilitation and premature RTS have been suggested as risk factors for muscle re-injury and possibly symptomatic of inadequate discharge criteria (Hägglund et al., 2016; Wangensteen et al., 2016).

Existing expert-led RTS recommendations involving football-codes are mostly restricted to RTPlay and are limited by a lack of explicit criteria for a number of objective assessments proposed (Delvaux et al., 2014; Sclafani & Davis, 2016; van der Horst et al., 2017; Zambaldi et al., 2017). A lack of specificity and agreement surrounding the tests, metrics, and cut-off thresholds to gauge player readiness to RTS has also been previously documented in practice guidelines published for ACL rehabilitation (van Melick et al., 2016) and more recently for RTS decision-making following acute lateral ankle sprains (Smith et al., 2021; Wikstrom et al., 2020).

Significantly, in the absence of objective thresholds against which RTS decisions can be made, practitioners involved in rehabilitation are required to rely on their own subjective judgement to gauge player readiness to progress and/or return to competition and are subsequently also prone to influence from other stakeholders and surrounding external pressures (Hickey et al., 2017; Wikstrom et al., 2020).

Secondly, although the survey intended to establish the RTS practices of professional football teams when dealing with a hamstring muscle injury, respondents were asked to specify how their practices may change following an injury to one of the other muscle groups of the lower limb (i.e. adductor, quadricep, and calf). Analysis of the criteria reported and how it developed through a RTS continuum for these injury types was however restricted. Despite collectively being shown to represent a common problem of elite sport teams (Chapter Two), comparatively less is known about the rehabilitation and RTS process for these other lower-limb muscle injury types (Ishøi et al., 2020). Indeed, in a recently published clinical commentary to inform RTPlay progression in professional rugby following injury to the lower extremity, only general rehabilitation guidelines were outlined by the authors, with no targeted recommendations provided to advise the progression and RTS of any specific lower limb muscle injury (Sclafani & Davis, 2016). Bisciotti et al., (2019) have since consensually agreed upon general and specific criteria that may be useful to practitioners working in professional football when managing adductor, quadricep and calf injuries. However, this expert-led consensus statement outlined best practice to inform decisions to RTTrain and RTPlay only and did not present criteria to support the progression of players through the other key transitions of the RTS continuum framework (i.e. RTRun and RTPerf).

As far as can be determined, no research has yet been conducted to provide an extensive overview of the existing scientific literature into the RTS criteria adopted for the most common muscle injuries (i.e. hamstring, adductor, quadricep and calf) in the elite football code sports (i.e. football (soccer), rugby, Australian football, and American Football). Moreover, no attempt has been made to disseminate the specific assessments and discharge criteria reported to inform decision-making at each phase of a RTS continuum in this specific population. As previously acknowledged in the general discussion surrounding RTS decision-making within practice (Section 2.8), if decision-making paradigms such as the StAART framework are to be operationalised and more readily integrated within practice, providing clearer insights to the possible criteria that can form part of the wider risk assessment process to guide RTS decisions across a continuum is evidently required.

In line with the overall aim of this thesis, while study one attempted to determine if current scientific recommendations for RTS are being translated into practice, it remains to be established whether:

1) The RTS criteria reported in the injury research published for football code athletes following muscle injury is consistent with and can support the multifactorial rehabilitation approach currently observed in applied practice.

2) The RTS assessments and corresponding criteria reported in the scientific research can help to address some of the knowledge gaps identified in the practice-based evidence acquired from professional football teams.

Importantly, if evidence informed, criterion-based RTS decision-making paradigms are be developed to sit within a continuum framework that can guide injury-specific rehabilitation, determining how RTS testing is being approached in the published literature and how closely it aligns to current practice is clearly important. By examining the relation between practice and research from this opposing perspective to study one (i.e. from practice to science), the RTS research practice gap can be fully appreciated, and future priorities for scientific investigation identified. The outcome of this may facilitate the narrowing of evidence-based gap between research and practice and ultimately, enhancing the quality and confidence of RTS decisions being taken.

The conduct of scoping reviews has emerged as a relatively new form of knowledge synthesis in sports medicine research and are becoming increasingly prominent in rehabilitation and RTS specifically (Breed et al., 2021; Burgi et al., 2019; Colquhoun et al., 2020; Phan et al., 2017; Rambaud et al., 2018). As described by Peters et al., (2020), scoping reviews can be considered or viewed as 'exploratory projects' which aim to systematically map evidence to help assess and understand the extent of knowledge available on a given topic or field of interest. Opposed to other evidence synthesis methodologies such as systematic reviews, where research objectives are typically highly specific and intended to inform clinical decision-making (e.g. determining the effectiveness of a particular intervention), scoping reviews are particular useful when the goal is to assemble a large body of literature to clarify key concepts and theories underpinning the area, document the type of evidence available to inform current practice as well as outlining existing knowledge gaps and future research priorities (Peters et al., 2015).

4.1.1 Study Aim

Accordingly, the purpose of this study is to perform a scoping review to identify the criteria used within scientific research to progress the rehabilitation of the most common lower-limb muscle injuries in high-level, male and female football code populations.

4.2 Methods

A scoping review was conducted following the five-stage methodological framework outlined by Arksey & O'Malley, (2005) and integrates the methodological refinements subsequently proposed by Levac, Colquhoun & O'Brien, (2010) and the Joanna Brigs Institute (Peters et al., 2017). Previously published relevant scoping reviews were also used to help inform the conduct and reporting of this study (Burgi et al., 2019; Colquhoun et al., 2020; Rambaud et al., 2018). An *a priori* protocol was registered with the Open Science Framework (Registration DOI: 10.17605/OSF.IO/RTKZD) and served to predefine the objectives and methods underpinning this review (Appendix A.2). The study was developed and written in accordance with the Preferred Reporting Items for Systematic reviews and Meta-Analyses extension of Scoping Reviews (PRISMA-ScR) (Tricco et al., 2018).

In agreement with recommendations for the conduct of scoping reviews, two independent reviewers were selected to undertake study selection, data charting and the collation and reporting of results for this investigation to minimise the risk of reporting bias (Peters et al., 2017). As lead researcher of the project, I (GD) fulfilled one of these roles while RM, a PhD researcher whose area of expertise related to professional football, fulfilled the other. A third reviewer (AMcC), adept in review-based research, was elected to resolve any potential disagreements or discrepancies arising between the two independent reviewers.

4.2.1 Stage 1: Identification of the research question

The purpose of this review was guided by a roundtable discussion of experienced medical and science researchers and practitioners working in professional football, and primarily centred on findings emerging from the RTS survey previously undertaken (Study One). Taking account of the population, concept and context of interest as described by Peters et al. (2017), the following research questions were devised:

1. What are the common criteria used in the rehabilitation of football-code team-sport athletes following lower limb muscle injuries?

2. How are these criteria being specifically assessed within the published literature to guide progression through key stages of a RTS continuum framework?

3. What are the key research priorities in the field?

4.2.2 Stage 2: Identification of relevant studies

4.2.2.1 Eligibility criteria for inclusion

To identify and select articles of relevance in the scoping review, *a priori* inclusion and exclusion criteria were determined and informed by existing reviews (Burgi et al., 2019; Hickey et al., 2017; Rambaud et al., 2018; van der Horst et al., 2016) and discussion within the research group – members of which had extensive experience in conducting review-based research in this area.

Study Design: To provide a synthesis of the existing literature, a variety of levels of original evidence were included (i.e. not only level I); randomised-control trails (RCT), and non-randomised studies (NRCT). All of these levels of evidence are used by practitioners to guide their practice and provide recommendations to the rehabilitation of their athletes. Therefore, it was considered important to be less restrictive regarding the study types included.

Prospective or retrospective intervention or observational studies published in English language were included that prescribed a rehabilitation programme and described the criteria adopted. Systematic reviews, conference abstracts, narrative reviews, opinion pieces, textbook/book chapters, magazine or newspaper articles and non-peer reviewed articles were excluded. Only full text articles were included.

Participants: Articles pertaining to football code team-based sports (i.e. football (soccer), rugby (union or league codes), Australian football and American football were included. Both male and female populations were considered as long they were contracted to professional clubs/sporting bodies. In football codes such as American football where professional academy models are not adopted, studies involving National Collegiate Athletic Association Division 1 athletes were included. Moreover, in instances where mixed standard samples were investigated (i.e. professional and recreational classified athletes) but the same rehabilitation protocol was prescribed, studies were accepted. The review considered studies that included participants over 16 years of age undergoing rehabilitation practices for muscle injuries to any of the four major muscle groups of the lower limbs i.e. hamstring, quadriceps, adductor muscles and calf.

Study selection was not restricted by muscle injury classification as long as the injury reflected a traumatic distraction or overuse injury to one of the four muscle groups resulting in time-loss and the player unable to fully participate in training or match-play. Contusions, haematoma, tendon ruptures and chronic tendinopathies were excluded. Both surgical and non-surgical rehabilitation strategies were considered in this review as long as articles involving surgery or discussing surgical techniques also included a post-surgery rehabilitation protocol and RTS criteria.

Outcomes: For this investigation, the decision was made to accept both broad (e.g. functional) and specific (e.g. 3 sets of 5 repetitions – 30m sprint test performed at 90-100% max speed based on patient rated/determined running speeds) RTS criteria owing to a lack of consistency criteria reported (van der Horst et al., 2016) and shortage of available information outlining how criteria align to distinct phases of a RTS continuum. Accordingly, any description relating to the assessment type and discharge criteria used to inform progression through any rehabilitation phase defined by a RTS continuum framework modified for use in football were considered.

4.2.2.2 Search strategy and information sources

The search strategy was developed following a 3-step approach which has been previously implemented when undertaking scoping reviews (Murray et al., 2017; Rambaud et al., 2018):

Step 1: Initial limited search - In July 2019, an initial search of MEDLINE, SCOPUS and Web of Science electronic databases was performed using the search query (football OR soccer OR rugby OR “team sport*”) AND (rehabilitation OR “return to play”) AND (muscle injury OR tendon injury). These terms were considered by the research group to broadly cover the elements of the current scoping review and no search limits were placed on database searches (e.g. time or language).

Step 2: Identification of key words and index terms – Title, abstract and index terms used to describe the 271 articles retrieved in step 1 were analysed independently by reviewers GD and RM to identify key words to facilitate the development of the full search strategy. The full search strategy was created in accordance with published guidelines (Edoardo & Dagmara, 2014) and was subsequently peer reviewed by an expert librarian using the Peer Review of Electronic Search Strategies (PRESS) checklist, and modified as required (McGowan et al., 2016) (Appendix A.3).

Step 3: Execution of final search strategy and further searching of references and citations – On the 28th of October 2019, the following six electronic databases were searched from inception with no date restrictions imposed: MEDLINE (Pubmed), CINAHL, SCOPUS, SPORTSDiscus, PsycInfo, and Web of Science. The reference lists of included studies were screened in addition to those of relevant systematic reviews and narrative reviews to identify any potentially eligible articles that may have been missed in the electronic database searches. To ensure the review was representative of the most up to date literature published within this research area, subsequent searches were performed periodically until the 1st of December 2020. The full search strategy for all databases is presented in supplementary Appendix A.4.

4.2.3 Stage 3: Study selection

Upon completion of the search, all articles were imported to the reference management platform EndNote X8.3 (EndNote, https://endnote.com/) and cross-referenced to remove duplicate records before eligibility criteria were applied. Using two independent reviewers (GD and RM), a two-stage screening process was implemented to assess the relevance of articles identified in the search. For first level of screening, only titles and abstracts of retrieved articles were reviewed to establish possible eligibility. During this process, if at least one reviewer concluded that the study met selection criteria or if it was unclear whether the study should be included or excluded, the article was retained and included for further appraisal in the second stage of the screening process. All articles deemed relevant after title and abstract screening were subject to full-text review (i.e. level 2 screening) to determine their suitability for inclusion within the scoping review. In instances where full text articles were not available, authors of the source article were contacted directly via email. If no follow-up correspondence was received, articles without full text access were excluded. Following full text screening, any disagreements or discrepancies were resolved through discussion between the two reviewers or further adjudication by a third reviewer (AMcC).

4.2.4 Stage 4: Charting the data

4.2.4.1 Data extraction

Data from eligible studies were charted using a standardised data extraction form developed for the study using Microsoft Excel 2016 (Microsoft Corporation, Redmond, WA). The form was used to record and assimilate extracted information on study characteristics as well as the criteria and assessment tools/tests used to inform rehabilitation progression and return to play clearance. The charting form was pre-tested by both reviewers (GD and RM) on a sample of 30 articles to confirm consistency and ensure that all relevant data were captured. Owing the iterative process of scoping reviews, the data-charting form was continuously updated and refined during the data extraction process, thus the final version of included data items varies slightly from that presented protocol. The characteristics of each full-text article were charted independently by both reviewers. As described, any disagreement or discrepancies between reviews were resolved through discussion or intervention via a third reviewer for final inclusion.

4.2.4.2 Methodological quality appraisal of individual sources of evidence

On account of the descriptive and exploratory nature of the present scoping review, an appraisal of methodological quality and risk of bias among included articles was not performed as it was deemed not appropriate and would have no bearing on the intended outcomes of this review. This is consistent with the guidance on scoping review conduct (Arksey & O'Malley, 2005; Peters et al., 2015; Pham et al., 2014).

4.2.4.3 Data items

The following data items were extracted

- Author(s)
- Year of publication
- Country of study origin
- Study design
- Level of evidence
- Aims/purpose
- Study population (e.g. sport played, level of participation, sample size, age)
- Injury information (e.g. muscle group, diagnosis, duration of absence, re-injury)
- Rehabilitation programme
    - Treatment approach (e.g. surgical, non-surgical, any additional therapies used)
    - Domains of rehabilitation considered (e.g. physical / non-physical)
    - Stage(s) of recovery documented (e.g. RTRun, RTTrain, RTPlay, RTPerf)
    - Overall guidelines adopted for RTS decision-making
    - RTS decision-making practices (e.g. isolated or shared decisions)
- Assessment criteria (e.g. specific benchmarks, thresholds and assessment methods)
    - Criteria objective (e.g. inform progression, inform RTPlay, post-RTS follow up)
    - Assessment based criteria reported
    - Specific benchmarks, thresholds and cut-offs applied (where applicable)
    - Assessment tool/test(s) used to evaluate criteria (where applicable)

4.2.5 Stage 5: Collating, summarising, and reporting the results

Data were summarised and tabulated according to the 10 data extraction categories. After data extraction, consensus was used to identify four distinct global criterion domains and seven corresponding criterion sub-domains to which data would be subsequently affiliated. To collate the data extracted, judgements on the classification of criteria according to appropriate global domain were aided by existing definitions and approaches presented within the literature.

Specifically, clinical criteria were those considered to measure impairment and described as a dysfunction or significant structural abnormality in a specific body part or system but not reflective of an assessment of overall functional ability (Reiman & Manske, 2011). Adapted from the clinical definition used by Reiman and Manske (2011), strength criteria were considered to measure deficits and/or asymmetries in any muscle strength characteristic but were similarly considered isolated assessments and not reflective of overall functional ability. Functional criteria were defined as assessments used to provide qualitative or quantitative information related to specialised movements in sport and exercise and often closely mimicked a specific sport activity which provided an appraisal of global function capability (i.e. athlete as a whole) (Reiman & Lorenz, 2011). Psychological criteria were considered those used to assess any cognitive, behavioural or affective response associated with an individual's experience of injury, rehabilitation, and RTS (Truong et al., 2020). RTS criteria were summarised as frequencies (n) or where appropriate as percentages (%) and presented in summary Figures 4.3. through to 4.9. Where criteria could not be grouped to any of the four principal criteria domains, the classification of 'other' was used.

As part of the data management and presentation strategy, criteria were also categorised according to muscle group injured and phase of rehabilitation criteria corresponded to. Rehabilitation phases representative of a RTS continuum modified for use in professional football, as used in Study One and advocated in the literature, were also adopted in this review (Buckthorpe et al., 2018; Taberner et al., 2020) (the reader is referred to Study One for a description of how each of these phases were defined). Accordingly, criteria were grouped following data abstraction according to judgements made on whether they were reported to inform a players return to running (RTRun), training (RTTrain), match-play (RTPlay) or performance (RTPerf) following muscle injury. In instances where the specific rehabilitation phase was not reported or could not be determined among accepted articles, criteria were classified as general progression guidelines. Similarly, in cases where lower limb muscle injuries were reported but not specified according to muscle group, authors of the source article were contacted. On confirmation of any or all muscle groups targeted in this study, these injuries were categorised as non-specified lower-limb muscle injuries (non-specified LLMI).

To summarise time trends in RTS criteria being reported in football-code populations following lower limb muscle injury, studies were binned by year of publication (1966 to 2020) and presented as a frequency of total studies published per year. The level of evidence for each study that met inclusion criteria was assessed using the Oxford Centre for Evidence-Based Medicine 2011 Levels of Evidence (OCEBM) (Howick et al., 2011).

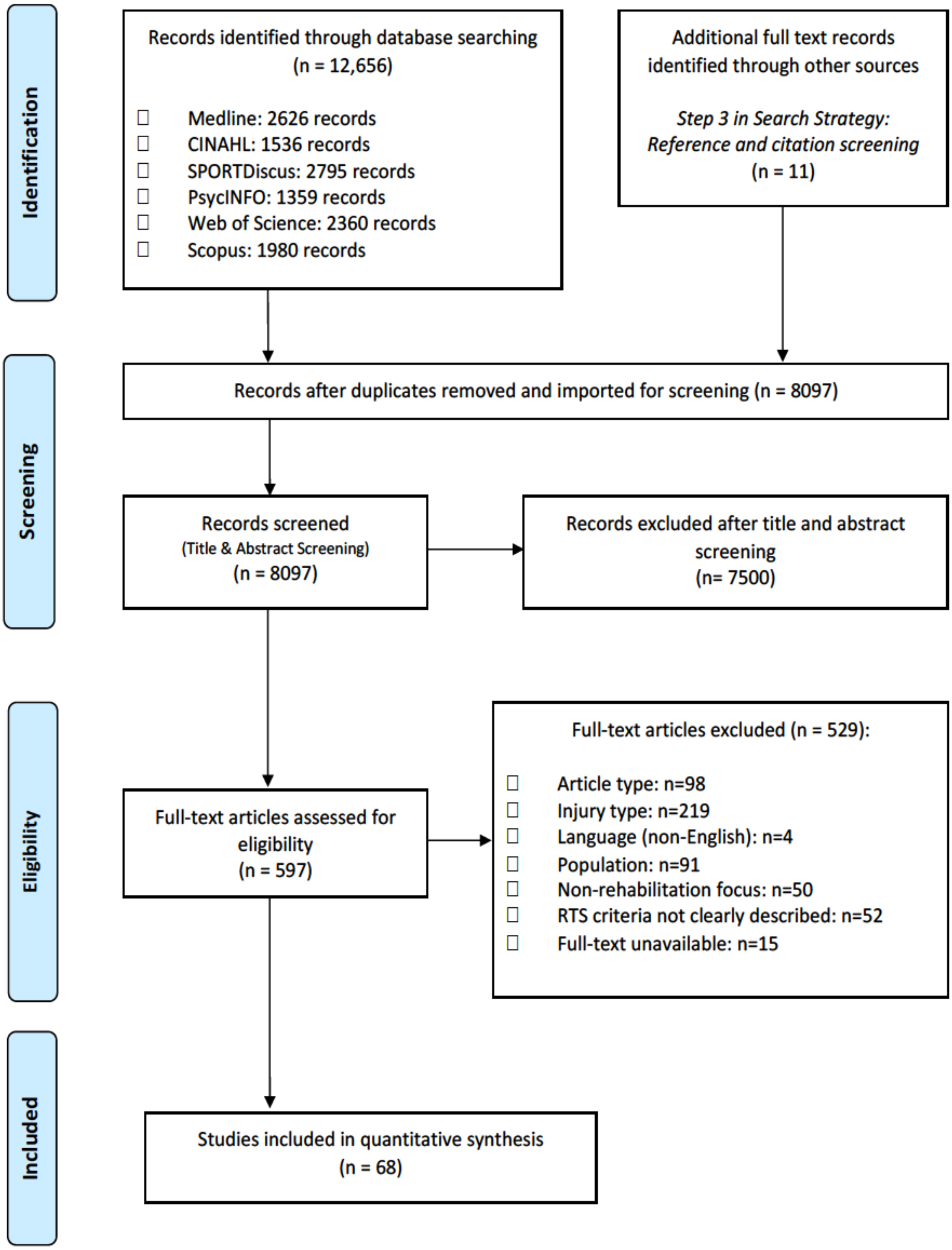

Figure 4.1. Preferred Reported Items for Systematic Reviews and Meta-Analyses Extension for Scoping Reviews (PRISMA-ScR) flow chart.

4.3 Results

4.3.1 Search results

An online search of six electronic databases identified 12,656 records, with 11 further eligible studies identified through reference screening. Following the removal of duplicates, 8097 titles and abstracts were screened. In total, 597 articles were retained for full-text screening, although 15 records were subsequently excluded as full-text articles could not be accessed. Sixty-eight studies were identified which met eligibility criteria and were included in the analysis (Figure 4.1). Extracted data of studies included for review are presented in Appendix A.5.

4.3.2 Characteristics of included studies

4.3.2.1 Year of publication

The earliest publication which satisfied inclusion criteria dated back to 1966 with no subsequent articles being published until 1984. The yearly number of publications remained relatively low until as recently as 2018 where 32 studies (47% of all included articles) were published in the subsequent three years (2018 to 2020 inclusive); compared to 36 studies in the previous 52 years (Figure 4.2).

4.3.2.2 Level of evidence

According to OCEBM hierarchy of evidence (Howick et al., 2011), four (6%) of the 68 studies included in this scoping review were considered level 2 evidence (i.e. randomised control trials). Thirty studies (44%) were considered level 3 evidence (i.e. prospective cohort studies) while 34 (50%) were considered level 4 evidence (i.e. case series, case-control studies). No studies of level 1 or 5 evidence were considered in this review.

4.3.2.3 Sex

Male high-level athletes from various football-code populations were represented in all 68 (100%) studies included for qualitative synthesis. High-level female athletes only participated in 12 (18%) studies and were not independently investigated in any of the articles included.

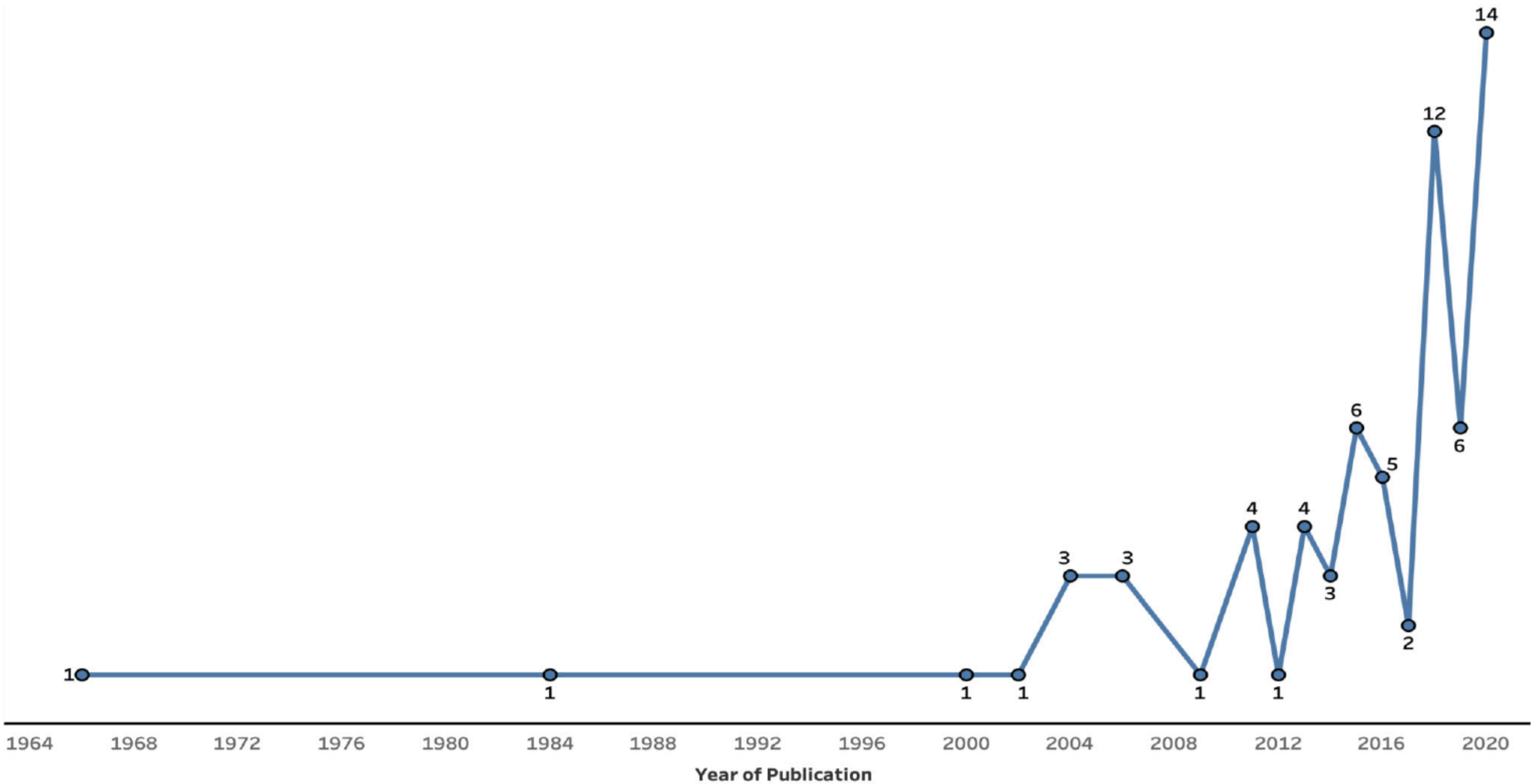

Figure 4.2. The trend in number of publications (per publication year) proposing rehabilitation criteria for lower limb muscle injuries in high-level football code sports

4.3.2.4 Sport and competition standard

Association football (soccer) was the most common sport studied with 50 (74%) articles. Australian Football League (AFL) was examined in 11 studies (16%) while rugby (inc. Union and League codes) and American Football populations were included in nine (13%) and eight (12%) studies respectively. Predominantly, the playing standard was categorised as professional (65 studies (96%)), while three (4%) focus specifically on high-level collegiate athletes. In 15 (22%) studies, athletes of mixed player standard including professional as well as competitive and recreational athletes were investigated. In each respective studies, participants were prescribed the same rehabilitation protocol and adhered to the same discharge criteria.

4.3.2.5 Muscles studied

Hamstring muscle injuries represented the most commonly studied muscle group in football-code athletes (Figure 4.3). Specifically, of the 53 (78%) studies involving hamstring injuries, criteria informing RTPlay were the most frequently reported (50 of 53 studies: 94%) followed by RTRun (30; 57%). For both RTTrain and RTPerf phases, eight studies (15%) proposed criteria to guide progression within these phases. Injuries involving the quadriceps (11; 16%), adductors (10; 15%) and calf (9; 13%) musculature were reported less frequently. For these three muscle groups, criteria to guide RTPlay represented the prominent focus (100%) of studies analysed. For quadricep injuries, criteria were established for each of the four progression phases outlined, while in the case of adductor and calf injuries, no criteria were reported to characterise a players’ return-to-performance.

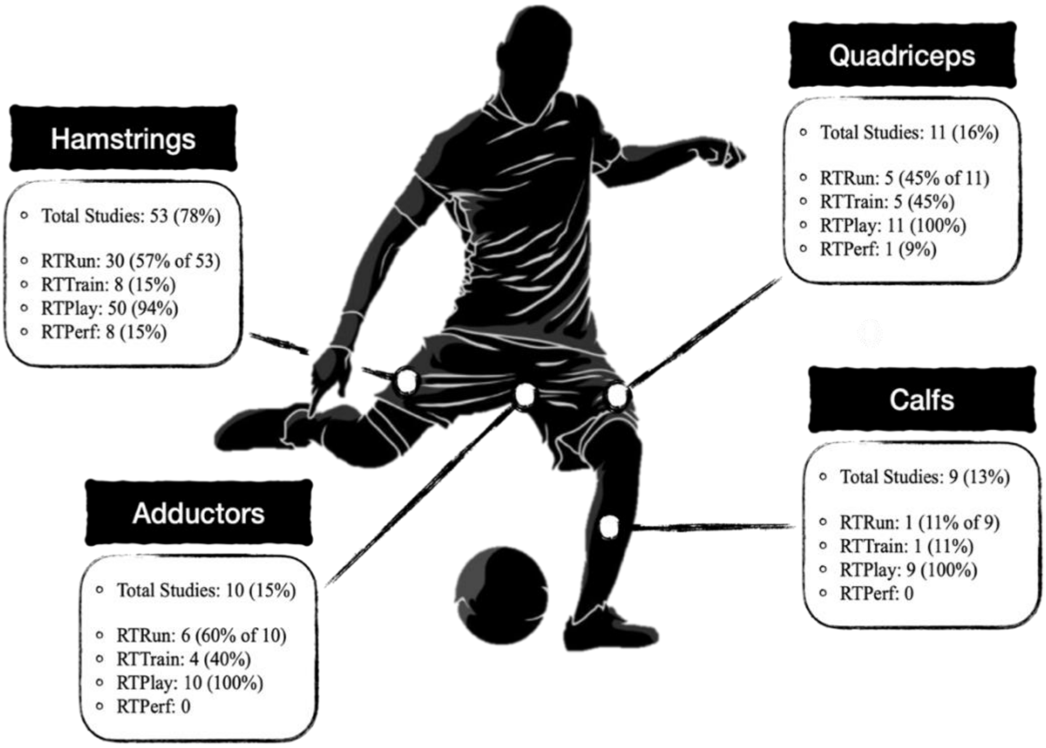

Figure 4.3. A breakdown of studies included for review. Studies are arranged by lower limb muscle group injured and phase of the return to sport continuum framework reported.

4.3.3 Criteria used according to rehabilitation phase

Of the 68 included studies, criteria used to progress rehabilitation following muscle injury were reported for all four phases of the rehabilitation pathway, albeit to varying degrees. Specifically, RTPlay was the most consistently reported with 64 (94%) studies describing progression criteria for this phase, while more than half of all included studies (37) also provided criteria to support the transition to RTRun following injury. Return-to-full-training was examined in 15 (22%) studies while RTPerf represented the least supported rehabilitation phase with only 11 (16%) studies included for qualitative synthesis proposing criteria to identify a player's return-to-performance. The relative reporting of RTRun (62%), RTTrain (73%) and

RTPerf (81%) as a proportion of their overall representation among included studies has increased since 2016, while the relative reporting of RTPlay criteria in during this time period was lower (57%).

4.3.3.1 Global criteria used at each rehabilitation phase and by muscle group

Collectively (i.e. all muscle groups), the criteria most commonly described to guide progression following lower-limb muscle injury were classified as functional (64 studies; 94%) and clinical (57 studies; 84%). Forty studies (59%) included muscle strength as a criterion while psychological evaluation was reported in seven (10%) of the 68 studies analysed. Figure 4.4 overviews the global criteria domains by rehabilitation phase and according to muscle type.

4.3.3.2 Specific criterion sub-domains and measurement types evaluated according to phase of rehabilitation and muscle group

The specific criteria used at each phase of rehabilitation and according to each muscle group is illustrated in Figure 4.5. Over the four rehabilitation phases, seven specific categories of criteria (i.e. criteria sub-domains emanating from the existing global criteria domains) were identified with a further 26 different measurement type classifications being used to assess these specific criteria.

4.3.3.3 Discharge criteria specified in accordance with the most common measurement types reported following hamstring muscle injury

A comprehensive analysis of the most common measurement types reported for hamstring muscle injury (i.e. most commonly studied injury type) is presented across Figures 4.6 to 4.9. Arranged by rehabilitation phase, the specific RTS discharge criteria used to assess pain, range of motion, strength and functional performance are summarised respectively.

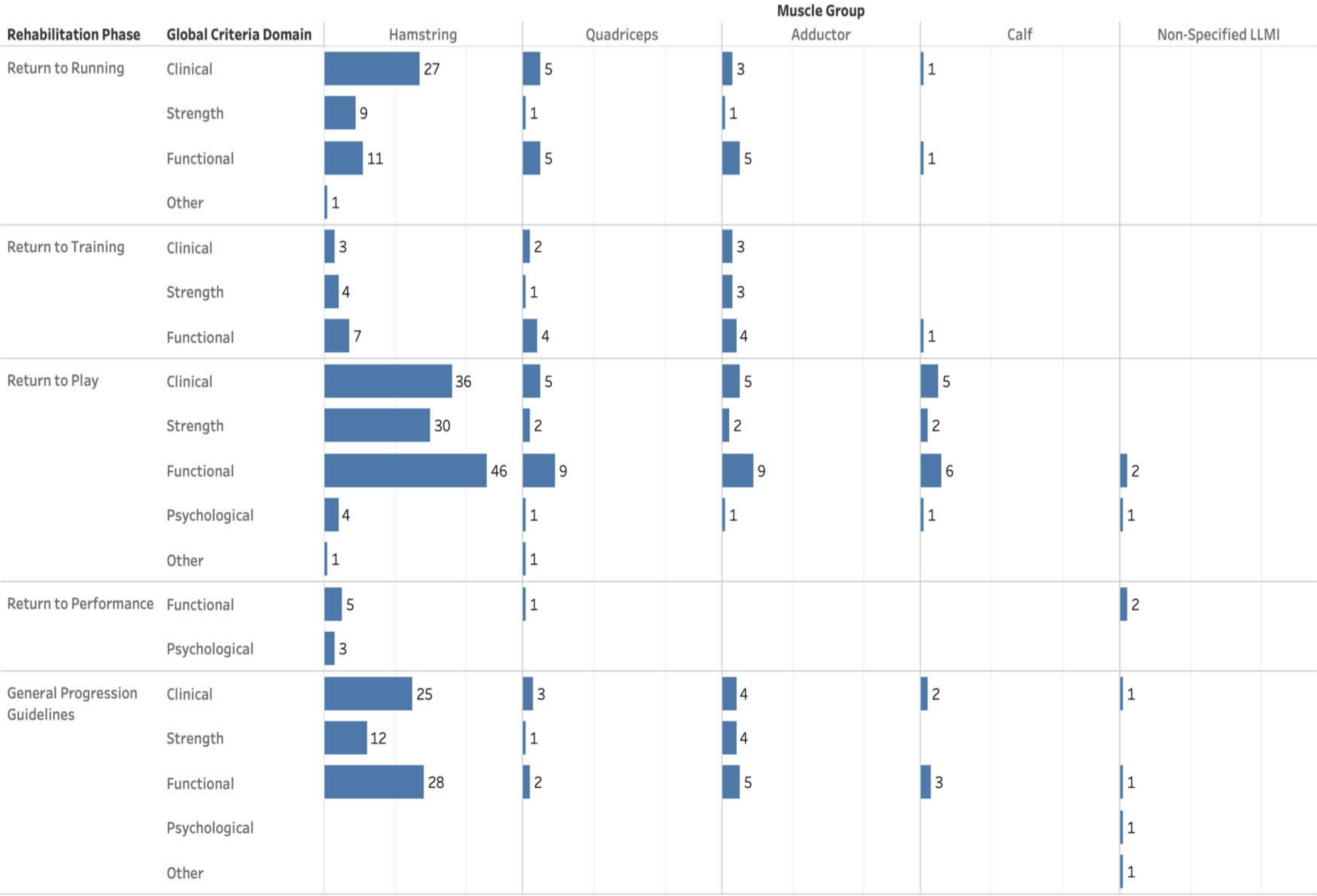
Muscle Group
Rehabilitation Phase
Global Criteria Domain
Hamstring
Quadriceps
Adductor
Calf
Non-Specified LLMI
Return to Running
Clinical
27
5
3
1
Strength
9
1
1
Functional
11
5
5
1
Other
1
Return to Training
Clinical
3
2
3
Strength
4
1
3
Functional
7
4
4
1
Return to Play
Clinical
36
5
5
5
Strength
30
2
2
2
Functional
46
9
9
6
2
Psychological
4
1
1
1
1
Other
1
1
Return to Performance
Functional
5
1
2
Psychological
3
General Progression Guidelines
Clinical
25
3
4
2
1
Strength
12
1
4
Functional
28
2
5
3
1
Psychological
1
Other
1

Figure 4.4. Multilevel assessment of studies per injured muscle group, rehabilitation phase and global criteria domain.

Rehabilitation Phase	Global Criteria Domain	Criteria Sub-Domain	Measurement Type	Muscle Group				
				Hamstring	Quadriceps	Adductor	Calf	Non-Specified LLMI
Return to Running	Clinical	Clinical Evaluation	Pain	21	2	2		
			Range of motion	22	4	1		
			Satisfactory clinical exam	2	1	1	1	
		Imaging	Ultrasound	1	1			
	Functional	Performance Based Testing	Agility		1			
			Completion of a Specific Programme	5	2	1	1	
			Jump / Hop Test		3			
			Low / Moderate Speed Running (Activity)	7	4	4		
	Strength	Strength Testing	Isometric Strength Assessment	8	1	1		
			Isokinetic Strength Assessment	1				
	Other	Other	Time	1				
Return to Training	Clinical	Clinical Evaluation	Pain	1	1	3		
			Range of motion	2	1	3		
			Satisfactory clinical exam	1		3		
		Imaging	Ultrasound		2			
	Functional	Performance Based Testing	Agility		3	3		
			Completion of a Specific Programme	7	4	4	1	
			High Speed Running / Sprinting	3	3	3		
		Training Load Monitoring	External Load Monitoring		1			
	Strength	Strength Testing	Isometric Strength Assessment	2		3		
			Isokinetic Strength Assessment	1				
			Eccentric Hamstring Strength Assessment	1				
			Predetermined Benchmark			3		
			Method Of Testing Not Clearly Stated	2	1			
Return to Play	Clinical	Clinical Evaluation	Effusion/Swelling	1	1	1	1	
			Pain	23	1	2	3	
			Range of motion	12	1	2	1	
			Satisfactory clinical exam	15				
		Imaging	MRI	9	2	2	2	
			Ultrasound	4	2	1		
	Functional	Performance Based Testing	Agility	4				1
			Completion of a Specific Programme	29	2	3	2	
			High Speed Running / Sprinting	13	1	1		
			Jump / Hop Test	1		1		1
			Predetermined Benchmark	1	1	1	1	
			Motor Control / Proprioception	1	1	1	1	
			Non-Specific Performance-Based Criteria	22	8	7	5	
		Training Load Monitoring	External Load Monitoring	1				1
			Internal Load Monitoring					1
	Strength	Strength Testing	Isometric Strength Assessment	10				
			Isokinetic Strength Assessment	20	1	1	1	
			Eccentric Hamstring Strength Assessment	2				
			Method Of Testing Not Clearly Stated	3	1	1	1	
	Psychology	Patient Report	Patient-Reported Outcome Measure	2				1
			Subjective Appraisal/Dialogue	2	1	1	1	
	Other	Other	Bioelectrical Impedance Vector Analysis	1				
			Time		1			
Return to Performance	Functional	Performance Based Testing	High Speed Running / Sprinting	1				
			Non-Specific Performance-Based Criteria	1				1
		Training Load Monitoring	External Load Monitoring	3	1			2
			Internal Load Monitoring					1
	Psychology	Patient Report	Patient-Reported Outcome Measure	2				
			Subjective Appraisal/Dialogue	1				
General Progression Guidelines	Clinical	Clinical Evaluation	Effusion/Swelling					1
			Pain	21	2	3	2	1
			Range of motion	19	1	4		
			Satisfactory clinical exam	3				
		Imaging	MRI	2	1	1		
			Ultrasound	3	1	1		
	Functional	Performance Based Testing	Agility	1		3		1
			Completion of a Specific Programme	25	2	5	1	
			High Speed Running / Sprinting	19		3	2	
			Jump / Hop Test					1
			Low / Moderate Speed Running (Activity)	5	1	4		
			Motor Control / Proprioception	1				1
	Strength	Strength Testing	Isometric Strength Assessment	11	1	1		
			Isokinetic Strength Assessment	3	1	1		
			Eccentric Hamstring Strength Assessment	1				
			Predetermined Benchmark			3		
			Method Of Testing Not Clearly Stated	1				
	Psychology	Patient Report	Patient-Reported Outcome Measure					1
	Other	Other	Body Composition Assessment					1

Figure 4.5. Multilevel assessment of studies per injured muscle group, rehabilitation phase, global criteria domain, the prescribed criteria sub-domain and specific measurement type evaluated.

Rehabilitation Phase	Measurement Type	Criteria Specified	Count
Return to Running	Pain	Absence of pain on palpation	1
		Demonstrate normal walking stride/gait without pain	9
		Pain-free bike at 150W or power output (equivalent to 2x BW) for 5mins	14
		Pain-free high knee march	3
		Pain-free pool based activities	1
		Pain-free single leg squat	13
		Perform multi-directional movements pain-free (e.g. thrusts and acceleration patterns)	1
		Perform Pain-free isometric hamstring exercises	1
Return to Training	Pain	Perform functional testing within pain-free limits	1
Return to Play	Pain	Absence of pain on palpation	2
		Asymptomatic completion of rehabilitation activities (to progress through protocol players had to be pain-free)	6
		Pain-free completion of sport-specific rehabilitation drills (e.g. shooting, 1v1's, scoring scenarios, passing + runs)	16
		Pain-free demonstration of match-pace activities performed at match-speed	1
		Pain-free during multidirectional movements and at all running speeds	1
		Pain-free sprinting	1
General Progression Guidelines	Pain	Absence of pain on palpation	1
		Demonstrate normal walking stride/gait without pain	1
		No pain when sprinting	1
		Pain-free completion of sport specific rehabilitation	1
		Pain-free during hamstring strengthening exercises	1
		Pain-free forward / backward running	1
		Pain-free high knee march	1
		Pain-free high speed changes of direction	13
		Pain-free jogging, variable pace running and interval running of progressive speeds	1
		Pain-free sport specific functional field testing (e.g. COD drills (with/without ball), jumping drills, pass/run, pass/cross progressions)	12
		Players must complete rehabilitation exercises without pain to progress	5

4.6. Multilevel assessment of studies per rehabilitation phase, specific measurement type evaluated (Pain) and the discharge criteria specified for hamstring muscle injury.

Rehabilitation Phase	Measurement Type	Criteria Specified	
Return to Running	Range of Motion	Full ROM in passive knee extension test (hip & knee 90º)	1
		Full ROM in passive straight leg raise	1
		Full hip and knee ROM	3
		Full active knee extension ROM (supine)	13
	Range of Motion + Pain Appraisal	Pain-free passive ROM	1
		Pain-free in passive hamstring stretching	2
		Regain pain-free full ROM and weight bearing capacity	2
Return to Training	Range of Motion + Pain Appraisal	Pain-free full ROM	2
Return to Play	Range of Motion	Full active knee extension ROM (hip flexion 90º)	1
		Full ROM during straight leg raise	1
		Paasive straight leg raise ROM comparable to contralateral limb	1
		Demonstrate full ROM	2
		Asymptomatic dynamic flexibility H-test without hesitation / insecurity	3
	Range of Motion + Pain Appraisal	Full ROM in passive straight leg raise	2
		Pain-free full ROM	4
General Progression Guidelines	Range of Motion	Achieve normal hamstring ROM	2
		Hamstring ROM ≥75% uninvolved side	13
		Straight leg raise ≥75% uninvolved side	13
	Range of Motion + Pain Appraisal	Achieve ≥ 60 inch (from the floor) pain-free benchmark in progressive static elevated stretching	1
		Pain-free full ROM in all rehabilitation exercises	3

4.7. Multilevel assessment of studies per rehabilitation phase, specific measurement type evaluated (Range of motion) and the discharge criteria specified for hamstring muscle injury.

Rehabilitation Phase	Measurement Type	Criteria Specified	Count
Return to Running	Isokinetic Strength Assessment	Peak torque > 70% pre-injury performance (3 reps at 60º/s)	1
	Isometric Strength Assessment	Limb symmetry index <10% in peak force	1
	Isometric Strength Assessment + Pain Appraisal	Pain-free submax strength test (50-70% resistance) in prone 90º knee flexion	6
		Pain-free full strength (5/5) on manual muscle test	1
Return to Training	Eccentric Hamstring Strength Assessment	Limb symmetry index < 10% eccentric knee flexor strength test (Nordic curl)	1
	Eccentric Hamstring Strength Assessment + Pain Appraisal	Asymptomatic full bodyweight eccentric knee flexor strength test (Nordic curl)	1
	Isokinetic Strength Assessment	Limb symmetry index <5% in H:Q ratio (eccentric hamstring strength 30º/s; concentric quadricep strength 240º/s)	1
		Bilateral symmetry in knee flexion angle of peak concentric torque (60º/s)	1
	Isometric Strength Assessment	Achieve accepted standard in isometric strength examination	1
	Isometric Strength Assessment + Pain Appraisal	Perform 4 consecutive pain-free prone knee flexion max efforts (15º / 90º knee flexion)	1
		Pain-free full strength (5/5) max effort prone knee flexion manual muscle test (90º knee flexion)	1
	Method Of Testing Not Clearly Stated	No detectable difference clinically in strength between limbs	1
		Achieve accepted standard in eccentric strength exam	1
Return to Play	Eccentric Hamstring Strength Assessment + Pain Appraisal	Pain-free maximal eccentric knee flexor strength test (Nordic curl) and within accepted limits for aysmmetry	2
	Isokinetic Strength Assessment	Perform 5 maximal reps (eccentric knee extension 60º/s; concentric knee flexion 180º/s)	13
		Perform 5 maximal reps (60º/s concentric knee flexion and extension)	13
		Perform 10 maximal reps (300º/s concentric knee flexion and extension)	13
		Limb symmetry index <5% in H:Q ratio (eccentric hamstring strength 30º/s; concentric quadricep strength 240º/s)	3
		Limb symmetry index <10% between limbs	3
		Bilateral symmetry in knee flexion angle of peak concentric torque (60º/s)	3
		Concentric Eccentric strength parameters equal to uninjured limb	1
		Concentric Eccentric strength parameters appropriate to body weight	1
		Concentric Eccentric strength parameters > 100% pre-injury levels	1
		Adequate H:Q ratio in concentric and eccentric strength parameters	1
	Isokinetic Strength Assessment + Pain Appraisal	Pain-free max eccentric strength in lengthened state (20º knee flexion) (eccentric knee extension 20º/s)	1
	Isometric Strength Assessment	Full strength (5/5) and bilateral symmetry on manual muscle testing for 4 consecutive reps (prone with hip in 0º and 15º, 90º knee flexion)	4
		Limb symmetry index <10% max resisted knee flexion force at various knee flexion positions (0º,15º,45º and 90º)	2
		Bilateral symmetry on manually resisted isometric knee flexion test	2
		Perform maximal effort contraction at various knee flexion positions (0º,45º and 90º)	1
		Limb symmetry index <5% in peak isometric strength between limbs	1
		Full strength (5/5) during manual strength test to resist knee flexion (prone)	1
	Isometric Strength Assessment + Pain Appraisal	Perform 4 consective pain-free maxmial effort reps during prone knee flexion testing (15º and 90º knee flexion)	3
	Method Of Testing Not Clearly Stated	Restore pre-injury strength levels	2
		Restore muscle strength balance (H:Q ratio)	1
		Address aysmmetry and restore muscle strength balance limb to limb	1
	Method Of Testing Not Clearly Stated + Pain Appraisal	Perform plank test without pain	1
		Pain-free restoration of eccentric hamstring strength	1
General Progression Guidelines	Eccentric Hamstring Strength Assessment	Peak force >350N in eccentric knee flexor extension test (nordic curl)	1
		Limb symmetry index <10% in peak force during eccentric knee flexor extension test (nordic curl)	1
	Isokinetic Strength Assessment	Limb symmetry index <5% in H:Q ratio (eccentric hamstrings 30º/s; concentric quadriceps 240º/s)	1
		Bilateral symmetry in angle of peak concentric knee flexion torque (60º/s)	1
		Achieve bilateral symmetry and pre-injury strength during isokinetic testing (Protocol 1 - High Speed; Protocol 2 - Power/Speed)	1
		Achieve bilateral symmetry and pre-injury strength during isokinetic testing (300º/s knee flexion; extension for 90 secs each side)	1
	Isometric Strength Assessment	Limb symmetry index <10% in peak isometric force during posterior chain test	2
		Full strength (5/5) during manual strength testing (90º knee flexion)	2
		Limb symmetry index <10% in peak isometric force generated at 100msec	1
	Isometric Strength Assessment + Pain Appraisal	Pain-free full strength (5/5) 1 rep maximal effort strength test in prone knee flexion (90º knee flexion)	5
		Limb symmetry index <25% in eccentric strength during mid-range strength test (Pain < 2 on VAS 0-10)	2
		Demonstrate 4/5 strength during manual muscle testing (90º flexion) without pain	2
		Perform pain-free submaximal isometric contraction	1
		Perform pain-free maximal effort contraction at various knee flexion positions (0º,45º and 90º)	1
		Perform 4 consecutive maximal pain-free effort reps in prone knee flexion (90º and 15º flexion)	1
	Method Of Testing Not Clearly Stated	Address bilateral discrepancies	1

4.8. Multilevel assessment of studies per rehabilitation phase, specific measurement type evaluated (Strength) and the discharge criteria specified for hamstring muscle injury.

Rehabilitation Phase	Measurement Type	Criteria Specified	
Return to Running	Completion of a Specific Programme	Eccentric focused strength programme before returning to running/sprinting/kicking	1
	Completion of a Specific Programme + Pain Appraisal	Pain-free completion of gym-based rehabilitation programme	4
	Low / Moderate Speed Running (Activity)	Perform continuous jogging (4x500m)	1
		Perform interval running (70% max speed) (4x500m)	1
	Low / Moderate Speed Running (Activity) + Pain Appraisal	Perform forward + backward running at 50% max speed without pain	1
		Perform pain-free cross-trainer (2x 20-30mins) on 2 consecutive days without limitation/set-back	1
		Perform very low speed running without pain	5
Return to Training	Completion of a Specific Programme	Eccentric focused progressive strengthening programme	1
		Eccentric focused progressive stretching programme	1
		Progressive running + sport specific functional testing (concurrent completion of drills of increasing complexity/intensity)	3
		Progressive running programme	2
		Sport specific functional testing - football specific assessment battery (with/without ball)	1
		Sport specific functional testing - staged kicking programme	1
	Completion of a Specific Programme + Training Load Evaluation (GPS)	Progressive running programme guided by markers of external load	1
	Completion of a Specific Programme + Training Load Evaluation (RPE)	Progressive running programme guided by markers of internal load	1
	High Speed Running / Sprinting	Perform 40m acceleration runs (various starting positions e.g. standing / crouched start)	1
		Perform 40m sprints at 80-90% max speed using various starting positions (e.g. rolling / stationary start)	1
		Perform 40m sprints at 90% max speed incorporating breaking distance progressions (20m to 10m)	1
	High Speed Running / Sprinting + Pain Appraisal	Perform 30:30s high speed intervals at various speeds (16.2/18/19.4km/h) within accpeted pain threshold < 4 (VAS 0-10)	1
		Sustain 1x1km high speed run at 16.5km/h within accepted pain threshold < 4 (VAS 0-10)	1
		Sustain 2x2km high speed run at 14.4m/h within accepted pain threshold < 4 (VAS 0-10)	1
Return to Play	Agility	Agility T-Test to be completed in pre-injury time	1
		Demonstrate ability to side-step and change direction at max speed	1
		Demonstrate adequate agility	1
		Illinois agility test to be completed in pre-injury time	1
	Agility + Pain Appraisal	Perform controlled full speed activities whilst changing direction, kicking and chasing ball without pain	1
	Completion of a Specific Programme	Ball based specific skills programme (technical proficiency subsejectively assessed against uninjured capability)	1
		Progressive agility and trunk stabilisation programme	1
		Progressive running and eccentric strengthening programme	1
		Progressive running programme	1
		Rehabilitation programme - Hamstring lengthening protocol	1
		Sport specific functional field testing protocol without limitation/restriction	17
		Sport specific functional testing - position specific conditioning	1
		Successful completion of a RTP clearance test battery	5
	Completion of a Specific Programme + Pain Appraisal	Pain-free completion of progressive pitch based running programme	1
	High Speed Running / Sprinting	Achieve >100% pre-injury max speed	1
		Achieve near full running speed	1
		Demonstrate ability to change sprint speed from 70-100% mid-run	1
		Perfom maximal sprint from a standing start	1
		Perform 10m / 40m / 100m linear sprints at max speed and within pre-injury times	1
	High Speed Running / Sprinting + Pain Appraisal	Achieve max speed on linear sprint test displaying no apprehension	2
		Achieve max speed sprinting without pain	5
		Achieve pre-injury max speed without pain (2x50m sprints)	1
		Perform 4-6 rolling start pain-free sprints at 90-95% max speed	1
	High Speed Running / Sprinting + Training Load Evaluation (GPS)	Achieve >90% max speed & external load markers in HSR drill (20m sprint + staged reduction accel/decel distance (20m/15m/10m/5m)	1
	Non-Specific Performance Based Criteria	Complete at least 1 week full team training prior to clearance to return to partial match-play	4
		Progressive resumption and completion of full-team training	4
	Non-Specific Performance Based Criteria + Pain Appraisal	Unhindered completion of sport specific functional tests at full-speed without pain or hesitation	1
		Unhindered completion of sport specific functional tests at full-speed without pain, hesitation or guarding	3
	Non-Specific Performance Based Criteria + Training Load Evaluation (GPS / RPE)	Resume and complete full-team training meeting markers of internal/external load	3
	Non-Specific Performance Based Criteria + Training Load Evaluation (GPS)	Complete 1 week full team training meeting markers of external load	2
	Predetermined Benchmark	Accumulated recovery score of 100% required to RTP (Coach/Physio subjective performance evaluation (rating scale 0-6))	1
Return to Performance	High Speed Running / Sprinting + Training Load Evaluation (GPS)	Achieve >90% max speed & external load markers in HSR maintence drill (20m sprint + staged reduction accel/decel distance (20m/15m/10m/5m)	1
	Non-Specific Performance Based Criteria	Coach subjective match performance rating (VAS 1-10) (mean score recorded in first 2 games post RTP)	1
General Progression Guidelines	Agility	Perform agility and speed drills at 100% max speed	1
	Completion of a Specific Programme	3-stage standardised physiotherapy programme	12
		Jump landing and plyometric programme	2
		Progressive agility and trunk stabilisation programme	5
		Progressive running programme	16
		Sport specific functional field testing protocol without restriction	2
		Strength programme	1
		Strengthening and stretching programme	1
	High Speed Running / Sprinting	Achieve 100% running speed (30m sprint)	13
		Ground reaction force running analysis during incline/decline running	1
		Perform sport-specific running drills at 90% max speed	1
		Run ≥70% running speed (30m)	14
	High Speed Running / Sprinting + Pain Appraisal	Achieve 100% max linear speed without pain	1
		Pain-free accleration and deceleration during high speed running	2
		Player required to run at 14mph without pain/hesitation (progressed through various interval running protocols)	1
		Sprint at 100% max speed (progress from rolling to standing start + pace change activities) maintaining pain threshold <1 (VAS 0-10)	1
	Low / Moderate Speed Running (Activity) + Pain Appraisal	No pain on COD at medium intensity (15km/h) performed with/without ball	1
		No pain when running at medium intensity (12km/h)	1
		Pain-free forward / backward running at 50% max speed	4
		Perform modifed practice (excluding high-speed maneuvers) without limitation or restriction	1

4.9. Multilevel assessment of studies per rehabilitation phase, specific measurement type evaluated (Functional evaluation) and the discharge criteria specified for hamstring muscle injury.

4.4 Discussion

4.4.1 Summary of findings

The aim of this study was to scope the RTS criteria reported in research used to inform the progression of the football code athletes following injury to the major muscle groups of the lower limb. As part of this approach, particular interest lay in establishing how closely RTS criteria reported in research aligned with those used in applied practice as well as understanding how criteria reported in football code research were being specifically assessed to inform RTS decisions. It was considered such outcomes would help examine the research practice gap regarding RTS decision-making and identify future research priorities that may better support practitioners and improve rehabilitation outcomes following muscle injury in football code populations.

The main categories of criteria studied in high-level athletes competing in football code sports as per the criterion definitions used for data extraction were clinical, strength, functional and psychological. Following lower-limb muscle injury, these criteria were identified to guide progression throughout a return to sport continuum (i.e. RTRun, RTTrain, RTPlay and RTPerf), with RTPlay being the phase most consistently studied. Despite a clear distinction in these main criterion domains, there was a wide array of specific criteria used within each category and even greater heterogeneity displayed in the specific tools and tests used to measure these criteria. Hamstring muscle injuries were found to be the most commonly studied muscle group with male athletes participating in high-level football codes also being by far the most investigated population to date and represented in 100% of included studies. Female athletes competing in football code sports only featured in 12 studies (18%) with no single study dedicated to this population alone.

4.4.2 Return to sport continuum phases

Returning to sport following injury is widely accepted in the sport and research community to occur along a continuum that emphasises a stepwise, criteria-based progression of activity through defined phases of rehabilitation (Ardern et al., 2016). This scoping review revealed that some form of RTS continuum framework appears to be utilised in research, with evidence presented to inform progression across each of the four rehabilitation phases following lower limb muscle injury, albeit to varying degrees.

As indicated by the findings presented, the predominant focus of studies to date has been directed toward RTPlay (64 of 68 studies; 94%) and typically, supported by more generalised non-phase specific progression criteria (39; 57%). The absence of phase-specific progression guidelines in research literature should perhaps not come as surprise given that the continuum concept was only formally introduced and agreed upon in the most recent international consensus on RTS in 2016 (Ardern et al., 2016).

Since 2016, greater attention does appear to have been placed on describing progression through other key milestones of the RTS continuum, with the relative reporting of each phase (i.e. as a proportion (%) of their overall representation) being markedly higher among included studies (RTRun – 62%, RTTrain – 73%, RTPerf – 81%). This observed shift in the reporting of RTS criteria and use of phase specific terminology is in line with the wider research literature and growing interest in establishing how and when athletes should progress across specific phases of rehabilitation (Buckthorpe & Della Villa, 2020; de Fontenay et al., 2021; Mendiguchia et al., 2017; Rambaud et al., 2018).

The requirement to deliver high-quality rehabilitation throughout the whole RTS pathway has recently been underlined as a critical aspect to improving rehabilitation outcomes following ACL reconstruction (Buckthorpe, 2019; Buckthorpe & Della Villa, 2020). In this two-part review, it was outlined that enhancing training and testing practices across earlier stages of rehabilitation may enable athletes to transition through late-stage rehabilitation and RTS testing optimally. As demonstrated by this scoping review, available guidance to practitioners to inform how and when players should specifically progress to RTRun and RTTrain following muscle injury is largely absent and typically underpinned by low-level evidence. This may be a potential contributing factor as to why deficits are commonly exhibited in a variety of qualities assessed at, and also, following RTPlay in football cohorts (Askling et al., 2013; De Vos et al., 2014; Tol et al., 2014; Whiteley et al., 2021).

Owing to the performance and economic consequences associated with injury, a prominent focus of research conducted in high-level football code athletes has been to examine the value of baseline clinical and imaging findings to predict time to RTS (Gibbs et al., 2004; Reurink et al., 2015; Serner, Weir, Tol, Thorborg, Yamashiro, et al., 2020; Wangensteen et al., 2015; Warren et al., 2010). Conversely, there remains limited research to indicate what measures may actually bear any useful relation to the progression of rehabilitation after lower limb muscle injuries (Jacobsen et al., 2016; Serner et al., 2021; Whiteley et al., 2018). As Serner and colleagues attest, such information can be particularly valuable to the development of standardised criteria-based rehabilitation programs for specific phase completion as well as informing content decisions, such as exercise selection or loading progressions (Serner et al., 2021). This represents an important avenue for future research as currently, there is no convincing evidence to indicate that any initial clinical or imaging findings provide a valuable prognosis for time to RTS (Schut et al., 2016).

4.4.3 Availability of research to inform rehabilitation progression for specific muscle groups

The most recent published literature appears to be evolving in line with consensus recommendations regarding the contextualisation of RTS as a continuum and presents guidance on how football-code athletes are progressed through distinct phases of rehabilitation. However, similar findings were not found when studies were analysed by the muscle group injured.

As illustrated in Figure 4.3. the vast majority of included studies concerned injuries involving the hamstring muscle group (53 of 68 studies, 78%), while only 16%, 15% and 13% of studies analysed, provided guidance when rehabilitating quadricep, adductor, and calf muscle injuries respectively. On one hand, a reporting bias toward hamstring injuries is to be expected given this injury type represents one of the most common injury experienced across the football codes (Chavarro-Nieto et al., 2021; Ekstrand, Hägglund, et al., 2011; Orchard, 2001; Orchard et al., 2013), carries a high injury burden (Bitchell, Mathema, et al., 2020; Ekstrand, Waldén, et al., 2016;

Feeley et al., 2008) and is particularly suspectable to recurrence (Hägglund et al., 2016; Orchard et al., 2013, 2020; Williams et al., 2017). However, as established, injuries to the quadriceps, adductors and calves also represent a significant problem for teams and therefore should not be overlooked. In fact, examination of the epidemiological literature indicates at the individual team level, the prevention of injuries involving these other muscle groups can sometimes be more challenging (Reis et al., 2015).

Currently, guidance available for each of these lesser investigated muscle groups has been primarily focused toward RTPlay. As represented in Figure 4.3, for each of these specific muscle injuries there remains limited insight with respect to what specific criteria are currently adopted and maybe useful to practitioners when informing progression of players across all other phases of rehabilitation within the RTS continuum. While there were examples among included studies that have attempted to address such knowledge gaps (Portillo et al., 2020; Serner, Weir, Tol, Thorborg, Lanzinger, et al., 2020; Valera-Garrido et al., 2020), if RTS practices are to become more evidence-based within professional football, future research is urgently required for these other muscle groups and should incorporate guidance across all stages of the RTS continuum.

4.4.4 Sex differences

Despite an exponential rise in the professionalism and profile of female sport, compared to their male counterparts, female athletic populations remain significantly underrepresented across many fields including sport science and medical research (Costello et al., 2014), especially those participating at the highest-level of competitive sport (Emmonds et al., 2019) and within professional football specifically (Okholm Kryger et al., 2021; Pfister, 2015). This gap in the representation of female athletic populations across research is also evident in this review. Akin to the reporting biases observed for specific muscle injuries, female football code athletes only featured in 12 studies (18%) and were actually never investigated exclusively (i.e. they were always part of mixed sex cohorts). Contrastingly, male football code athletes were represented in all 68 studies included for review.

As discussed, a fundamental aspect in the adoption and application of practices that are evidence-based is ensuring they are supported by the best relevant research (Coutts, 2017). However, as indicated here and supported elsewhere (Breed et al., 2021; Okholm Kryger et al., 2021), owing to the limited representation of female athlete populations in research, practices adopted in high-level female sport are likely being underpinned by research conducted in male athlete cohorts where gaps in current understanding of how best to support female athletes exist. Consequently, for practitioners working with elite female athletes, the development of an evidence-informed approach to practice can be particularly challenging (Emmonds et al., 2019).

From a rehabilitation perspective, the translation of evidence derived from male athletic populations into female athlete contexts is of specific concern as possible sex-based differences in injury risk profiles indicate female athletes may benefit from their own targeted preventative and rehabilitation programs (O'Sullivan & Tanaka, 2021; Van Der Worp et al., 2015). Despite this, a distinction between sexes has rarely been made in available RTS guidelines (Ardern et al., 2016; Bisciotti et al., 2019; van der Horst et al., 2017; Zambaldi et al., 2017).

To help optimise decision-making, addressing this lack of differentiation between sexes should be an important consideration of future research, as in the case of some specific injury types (e.g. sport-related concussion), females have been found to present with a greater number of symptoms and require longer periods of recovery prior to RTS (Koerte et al., 2020; Stone et al., 2017). Moreover, establishing the contextual challenges facing female sports as well as identifying those that differentiate them from male sporting environments is essential, as the availability of key provisions (e.g. access to facilities, access to a multidisciplinary staff, allocated finances) may influence the effectiveness of research being developed and translated into practice (Emmonds et al., 2019).

In the absence of studies providing sex-specific guidelines for RTS after muscle injury, and in evidence of the clear disparity in the reporting of male and female football code athletes, the ensuing discussion and evidence presented will be primarily relatable to high-level male football code populations.

4.4.5 Criteria based decision-making

Four distinct RTS criteria domains were identified and categorised as clinical, strength, functional and psychological. To optimise recovery and better determine the individual needs of the athlete to facilitate a safe RTS, adopting a more holistic, athlete-centred view of rehabilitation has been advocated (Ardern et al., 2016). A recommendation echoed among various published football-specific RTS guidelines

(Bisciotti et al., 2019; van der Horst et al., 2017; Zambaldi et al., 2017). Focused on the management of lower limb muscle injuries specifically, each publication agreed that to comprehensively evaluate player readiness to RTS, a battery of clinical, strength, functional, and psychological assessments should ideally be used within applied practice. Aligning with this approach, a combination of clinical, strength, functional and psychological criteria were described among studies reviewed (Figure 4.4), wherein an array of measurement types corresponding to various sub-domain classifications of these four global criteria were found to inform progression through a RTS continuum in football code athletes (Figure 4.5).

At a global level, criteria relating to the evaluation of clinical, strength, and functional qualities were found to be the most commonly described among studies included in this review. More specifically, recovery of these qualities was found to be particularly prominent in guiding a player's RTPlay and to a lesser extent RTRun following lower limb muscle injury. Additionally, their assessment also appears to represent a key component among more general guidelines described for rehabilitation progression. In accordance with these findings, clinical and functional criteria appear to be widely adopted among teams surveyed in Study One to support decision-making across all phases of the RTS continuum (Figure 3.2), while the expert-led RTS Delphi surveys of Zambaldi, Beasley and Rushton (2017) and van der Horst et al., (2017) agreed clinical, strength and functional criteria were important to evaluating readiness to RTPlay in professional football players, following hamstring injury. More recently, when rehabilitating muscle injuries, it has been recommended that clinical-functional criteria should be prioritised when informing RTTrain decisions, while greater emphasis should be placed on functional-performance orientated criteria to guide RTPlay (Bisciotti et al., 2019). Broadly depicted in Figure 4.5 and more explicitly reported across Figures 4.6 to 4.9, this approach also appears to be reflected in the research literature. As players transition from RTRun through to RTPlay, RTS judgements appear to become increasingly based on criteria assessing sport-specific functionality and performance capacities, as opposed to criteria that primarily evaluate recovery in distinct clinical and functional attributes.

Notably however, based on the findings of this review, an evident disconnect between research and practice does exist with respect to the emphasis placed on psychological testing and training load monitoring (i.e. a sub-domain criterion of the functional global domain) to support RTS decision-making in football-code athletes. As evidenced by the results presented in Study One, practitioners place high importance on these tools to inform progression through a RTS continuum, but as highlighted in Figures 4.4 and 4.5, specific guidance relating to these tools appears to be largely absent within research literature. Only seven studies (10%) were identified as using external and/or internal markers of training load to support RTS decision-making (Jiménez-Rubio, Navandar, et al., 2020; Jiménez-Rubio, Valera-Garrido, et al., 2020; Portillo et al., 2020; Ritchie et al., 2017; Taberner & Cohen, 2018; Valera-Garrido et al., 2020; Whiteley et al., 2021) while similarly, only seven studies (10%) reported to using psychological criteria (Ayuob et al., 2020; Cohen et al., 2011; De Vos et al., 2014; Gomez-Piqueras et al., 2018; Kayani et al., 2020; Silder et al., 2013; Wright-Carpenter et al., 2004).

4.4.6 Most common criteria used to inform progression

Clinical criteria featured most prominently at RTRun (31 of 57 studies; 54%) and RTPlay (39 of 57 studies; 68%) phases. Although not commonly considered when returning to training, it is possible this finding may be confounded by a lack of distinction observed among 39 studies - whereby clinical criteria could not be categorised according to a specific phase of rehabilitation. This inability to distinguish between clearance to return to full unrestricted team training and returning-to-play is possibly due to the RTS definitions used in reporting guidelines being equally unclear. For example, guidelines proposed by Fuller and colleagues for football (soccer) and rugby codes respectively (Fuller et al., 2006, 2007), recommended to define RTS as a *"return to full participation in team training and availability for match selection"*. Greater clarity to distinguish between RTTrain and RTPlay is warranted to better inform practitioners about criteria to support decisions regarding a player's progression at specific timepoints during rehabilitation.

Among clinical criteria reported, pain and range of motion (ROM) were the most prominent criteria represented in the literature. As per Figures 4.5 and 4.6, pain as a criterion is commonly reported to inform RTRun and is also widely used as a guideline for general rehabilitation progression. The application of pain as a criterion in these earlier phases appears to be less complex and focused on pain-free completion of activities predominantly of a closed nature (e.g. walking gait, cycling). As a player is progressed through the continuum, there is an evident shift toward demonstrating pain-free completion of movement patterns more associated with match-play (e.g. sport-specific passing and running drills). The practice of remaining pain-free throughout rehabilitation has been questioned, and more recently a pain-threshold approach to rehabilitation (i.e. perform and progress rehabilitation exercises under mild pain or discomfort; VAS $\leq$ 2 of 10) has been permitted (Herrington, 2000; Kilcoyne et al., 2011; Serner, Weir, Tol, Thorborg, Lanzinger, et al., 2020). Despite preliminary evidence favouring this approach (Hickey et al., 2020), further research is required to determine the effectiveness of pain-threshold guided rehabilitation in relation to several key RTS outcomes underpinning professional sport (e.g. time to RTPerf and re-injury incidence).

Recognising that the presence of pain may be indicative of incomplete tissue healing, the decision was taken, as per the definitions used within this study (see section 4.2.5), to classify pain symptomatology as a clinical criterion. It is however acknowledged, that categorising pain in this way to encapsulate its role within RTS decision making belies the true way in which practicing clinicians evaluate and interpret pain responses (e.g., Hickey et al., 2021; Podlog et al., 2014). Indeed, as represented across Figures 4.6 to 4.9, the appraisal of pain in a rehabilitation context does not exist outside the confines of functional activity. In this respect, pain, in and of itself, carries limited meaning and relevance to aid decision-making and as such, should always be considered in an integrated (i.e. in response to provocative testing of the injury site) and holistic way (i.e. biopsychosocial elements) to inform rehabilitation progression.

The assessment of range of motion equally features prominently when determining a player’s return to running, and as a guideline for general progression. However, its explicit use diminishes across subsequent phases and is not reported as a RTPerf criterion. Despite preliminary evidence indicating that ROM may be important to evaluate after RTPlay, as persisting deficits may be associated with an increased risk of re-injury (De Vos et al., 2014), this practice does not appear to be consistently reflected across studies.

Isometric strength testing was primarily investigated during early rehabilitation and specifically when returning to running. However there appears to be very little evidence of its use at RTPlay. Comparatively, isokinetic strength testing and the assessment of concentric and eccentric strength becomes more predominant when RTPlay. Irrespective of the contraction type, the tests tend to focus on the measurement of absolute strength (maximum and sub-maximum), limb symmetry or asymmetry and muscle ratios, comparison to baseline measures and repetition. Most tests reported within the literature tend to be measures of isolated joint action with very few functional strength assessment tests reported. Outwith hamstring muscle injuries, there appears to be very little information to guide the rehabilitation of strength for specific muscle types within the literature, especially calf and quadricep injuries (Figures 4.4 and 4.5). However, Serner, Weir, Tol, Thorborg, Lanzinger, *et al.*, (2020) have recently published a detailed rehabilitation protocol wherein specific predetermined benchmark criteria have been proposed which may be important in measuring the general progression of strength during rehabilitation from adductor injury. As highlighted by Tol et al., (2014) full recovery of muscle strength may not be essential to RTS. In this study, 67% of male professional footballers were cleared to return to competitive match-plat despite having at least one hamstring isokinetic testing deficit of the ipsilateral leg of >10%. Within football-code athletes, it remains unclear how persisting deficits in strength following injury, actually affect re-injury risk and the quality of subsequent playing performances.

Functional criteria were presented at each phase of the RTS continuum, although they featured most prominently when informing a player's transition to RTPlay (57 of 64 studies: 89%). This finding was anticipated, as underpinning a player's clearance to return to match-play, ensuring sport-specific function is restored and physiological capacities are sufficiently developed to tolerate competition demands, represent important pillars in supporting the transition back to match-play (Buckthorpe et al., 2019). Although limited criteria were found within the literature to appraise a player's RTPerf, evidence presented within included studies indicates the application of functional orientated criteria may be important in evaluating performance outcomes following lower limb muscle injuries within football code sports. Less emphasis is placed on functional criteria to direct decision-making when returning-to-running (17 of 64 studies: 27%), with the resolution of clinical symptoms and strength deficits holding greater weight when initially returning players back to running and pitch-based sessions. However, the assessment of function appears to be a key component in informing rehabilitation progression in general.

Two sub domains, namely performance testing and training load monitoring, were found to characterise the specific criteria measured within the global functional domain. Performance tests were frequently reported among included studies wherein an array of agility, running, jump and hop, motor control and proprioception tests were assessed to guide RTS following muscle injury (Figures 4.5 and 4.9). Specifically, the successful completion of a specified programme or achieving more broad functional milestones (i.e. non-specific performance-based criteria) play a prominent role in assessing player readiness to RTS, especially when returning to competitive match-play. At a muscle group level, graded exposure to high-speed running and the attainment of maximal speed sprints represents an important criterion following hamstring muscle injury.

Contrasting the perceptions and practices of premier-league football teams (Study One), where training load monitoring represented an essential criterion in guiding progression through a RTS continuum, this criterion category was infrequently described among included studies (7 of 68 studies: 10%). Load progression is a key aspect of every rehabilitation protocol and RTS decision, yet to date, determining whether a player has trained sufficiently to return to full unrestricted training and match-play is an often neglected component of this process (Blanch & Gabbett, 2016). A finding notably reinforced by the studies captured within this review.

Aligning with calls for greater objectivity in RTS decision-making (Ardern et al., 2016; Hickey et al., 2017), the application of tools to monitor internal (e.g. heart-rate monitoring, sRPE) and external load (e.g. GPS) may offer value in quantifying the RTS process (e.g. the prescription and progression of load as well as the physiological stress imposed) and help avoid exposure to sudden and unaccustomed peaks in workload (Murphy & Rennie, 2018; Ritchie et al., 2017; Taberner & Cohen, 2018). However, as mirrored within several expert consensus (van der Horst et al., 2017; Zambaldi et al., 2017), there appears to be currently very little in the way of explicit criteria reported within this review to actually guide practitioners in how to best use these tools to help inform decision-making.

A detailed 5 phase framework for on-pitch rehabilitation to address this knowledge gap has recently been proposed (Taberner et al., 2019). The 'control-chaos continuum' describes a dynamic process moving from high control (i.e. pre-planned actions) to high chaos (i.e. unpredicted and responsive movements) and involves the progressive increase of running load demands and incorporation of greater perceptual and neurocognitive challenges within sport-specific drills to return a player back to sport. While promising, the validity of this conceptual framework has not yet been comprehensively assessed and thus, its bearing on key rehabilitation outcomes (e.g. performance and re-injury) remains unknown. Concurrently, the work of Stares and colleagues in Australian Rules Football has indicated the progressive development of higher training loads during rehabilitation (i.e. weekly and cumulative loads) via internal and external load measures, is associated with a decreased risk of re-injury risk on RTS (Stares et al., 2018).

4.4.7 Lack of standardisation and poor reporting of RTS criteria

In line with existing literature and my own survey findings, there appears to be very little standardisation regarding what criteria should be used. As a result, it makes it very difficult to determine the specific tests / thresholds / cut-offs which should be applied to and where within the continuum process to guide progression. Similarly, in a recent scoping review of exercise interventions used for hamstring strain injury rehabilitation, it was outlined that the use of exercise prescription and reporting guidelines, such as sets, repetitions, load and frequency must improve to ensure a minimum standard of reporting and to support the implementation of exercises interventions in practice as well as future research studies (Breed et al., 2021). The findings of the scoping review reiterate the calls of others (van der Horst et al., 2016;

Wikstrom et al., 2020) that urgent research is required to develop consensus around what criteria are possibly important to consider at each phase of the continuum. As part of this approach particular attention should be directed toward establishing agreement on the specific parameters and objective thresholds for these RTS assessments to be able to standardise decisions. After which, prospective studies are needed to evaluate their relevance to the decision-making process.

4.4.8 Limitations

This scoping review followed the PRISMA-ScR checklist (Tricco *et al.*, 2018) as well as the recommended best practice guidelines for the conduct of scoping reviews (Arksey & O'Malley, 2005; Levac et al., 2010; Peters et al., 2017). However, the chosen methodology still contained a number of limitations which should be acknowledged when interpretating the findings presented. Firstly, although a comprehensive research strategy was implemented, only articles that were peer-reviewed, available in full-text and published in English were included in this review. Such publication bias may therefore have resulted in the exclusion of studies that would have otherwise fit the inclusion criteria.

Secondly, evaluating the literature from the perspective of determining phase specific criteria to inform progression through a RTS continuum proved to be very challenging. For example, despite following definitions to classify criteria and applying approaches used in previous research to report data (e.g. Rambaud et al., 2018; Burgi et al., 2019), the process of grouping criteria into global domains, sub-domains, and measurement types remained somewhat open to interpretation and may have been influenced by some level of bias. To mitigate this risk, two researchers independently screened and charted the data and in instances where disagreement did exist, these were resolved through open discussion and involvement of a third reviewer. Scoping reviews are particularly effective for addressing widely frame research questions as they can offer a broad overview of the research area. This scoping review included 68 studies and resulted in the extraction of 866 individual RTS criteria across four different lower limb muscle groups in football-code populations. Owing to the lack of standardisation in reporting, it was difficult to collate and interpret these criteria (e.g. by specific tools, metrics, thresholds, cut-offs used). It was considered important to illustrate this difficulty by outlining the criteria reported for some common measurement types used in the rehabilitation of hamstring injuries (Figures 4.6. to 4.9). However, it was decided that while less specific, grouping and analysing criteria at more global level (Figures 4.3 to 4.5), enabled clearer interpretation of results and identification of the research gaps. Furthermore, nearly half of the studies included in this scoping review (43%) were published prior to the 2016 consensus statement, which introduced the continuum concept (Ardern *et al.*, 2016). Consequently, demarcation of RTS phases was therefore often not considered and even in studies published post 2016, commonly found to be poorly defined. This lack of clarity that may have influenced the results and also resulted in the introduction of bias. To minimise the risk of bias, such criteria were categorised as general rehabilitation progression guidelines. Although, it is acknowledged, this will have invariably resulted in an underrepresentation of criteria intended for use at specific phases within a RTS continuum framework.

Thirdly, studies that reported to using the same rehabilitation protocol and RTS criteria were included in this review. However, it was discovered during full text screening that a number of studies (16 of 68; 24%) used pooled data from subjects participating in larger pre-existing clinical trials, many of which are still ongoing (e.g. Van Der Made, Almusa, Reurink, et al., 2018; Van Der Made, Almusa, Whiteley, et al., 2018; Vermeulen et al., 2021). It cannot therefore be overlooked that duplicate data from the same subjects was included in this review and has resulted in higher frequencies of some specific criteria used to inform RTS following muscle injury being reported.

Fourth, although consistent with guidance of scoping review conduct (Arksey & O'Malley, 2005; Pham et al., 2014; Peters et al., 2015), formal assessment of the methodological quality and scientific rigor of individual studies was not performed. Finally, an important limitation to recognise is that this review reflects the literature up to and including the 1st of December 2020. Consequently, it is not inclusive of the most current published literature in this area and therefore by default, presents an outdated picture of the research evidence available to support practitioners when rehabilitating lower-limb muscle injuries in football-code athletes. That said, in consideration of the key research-practice gaps identified and dearth in available evidence, these gaps it is believed, are still likely to be present and the focus of further investigation.

4.6 Conclusion

This scoping review included 68 articles that reported RTS criteria in football-code athletes after muscle injury from 1966 to 2020. Following the most recent international consensus statement on RTS (published 2016), research outputs in this area have markedly increased. While criteria are presented within the research literature to guide progression through all phases of a RTS continuum, RTPlay was the phase most consistently reported (64 of 68 studies; 94%). Hamstring muscle injuries were also found to be the most commonly studied muscle group in this population (53 of 68 studies, 78%).

To inform RTS decisions, four distinct criteria domains were identified and reflected clinical, strength, functional and psychological assessment. A number of criterion sub-domains and measurement types were found to relate to each of these global domains of criteria. Across the RTS continuum, clinical and strength criteria were most commonly reported in the earlier phases, while greater emphasis toward functional criteria to inform RTS decisions become more evident as players transitioned toward RTPlay.

Several knowledge gaps were identified which must be considered by future research. These include an absence of any form of consistently reported or recommended criteria to support RTS decision-making following quadriceps, adductor, and calf muscle injuries. A lack of criteria to inform progression at specific phases of the continuum and also an inherent bias toward male football-code athletes. In the case of commonly studied muscle injury types (i.e. hamstring injuries), a lack of standardisation in the criteria used to inform RTS decision-making characterises the research literature. Accordingly, a high degree of ambiguity exists and the ability to guide practice, as to what criteria should be adopted, is limited.

Chapter Five

Study Three – Preliminary evaluation of the internal structure of the Injury-Psychological Readiness to Return to Sport (I-PRRS) scale in male professional football players: A worldwide study of 29 professional teams

5.1 Introduction

To this point, the primary focus of this thesis has been to examine the gap between research and practice with respect to the criteria used to inform decision-making in the progression of professional footballers through the RTS process following muscle injury. Adopting an integrated approach, the relation between research and practice has been analysed in two ways: firstly, by investigating the adoption of research based RTS recommendations by professional football teams (Study One – Chapter Three) and secondly, by evaluating the criteria described in the research literature that is available to football practitioners to guide RTS testing (Study Two – Chapter Four). Through this process, a number of important knowledge gaps have emerged that warrant further investigation to help bridge the gap between research and practice and ultimately, better support teams in their decision-making.

One specific gap identified, was the lack of research in professional football (and football-code sports generally) investigating the psychological aspect involved in RTS following muscle injury. Only 10% of studies (7 of 68 studies) included in the scoping review made specific reference to psychological criteria when guiding a player's RTS. A finding that perhaps attests to the emphasis that has historically been placed on physical testing to inform RTS following injury (Ardern & Kvist, 2016; Forsdyke et al., 2016).

In line with current thinking, the process of returning to sport, following injury, should be one that fosters autonomy, ensuring the perceptions and perspectives of the player are considered. Consequently, this approach should account for any psychological concerns that may be experienced during the recovery process (Hess et al., 2018; Podlog & Eklund, 2007a, 2009). Indeed, rehabilitation environments which reinforce feelings of autonomy may carry important motivational, performance and anxiety related implications for an athlete's rehabilitation and RTS (Podlog et al., 2011). As a result, ways of practising that are athlete-centred have become increasingly endorsed (Ardern et al., 2016; Dijkstra et al., 2017; King et al., 2019) with the involvement of the player considered a prerequisite of the shared decision-making process to RTS.

Despite this, Study One indicated that, when informing progression through RTS continuum stages, although a shared decision-making approach was commonly adopted, less than 60% of teams formally included players in the decision-making process. A recent cross-sectional study of male professional footballers has in fact shown that players who have suffered at least 3 severe (>28 lay-off days) muscle injuries during their career has 2.6 times higher odds of reporting distress (i.e. a symptom of common mental disorders) than players without previous severe muscle injuries (Gouttebarge et al., 2016). This suggests that greater consideration toward the psychological needs of a player returning from injury are perhaps warranted and this may be an avenue through which teams can empower and engage players, allowing them to assume a more active role in the decisions being made.

To facilitate a safe and successful RTS, it is now widely accepted that players must be both physically and psychologically prepared, with the assessment of psychological readiness regarded as an integral component of the decision-making process (Ardern et al., 2016; Bisciotti et al., 2019; van der Horst et al., 2017; Zambaldi et al., 2017). A perception that has been reflected in the current RTS practices of elite football teams (Study One) and one that has also been previously demonstrated by sports medicine physicians working in professional football, who ranked the 'subjective feeling reported by the player' among the most important criterion to inform RTPlay after hamstring muscle injury (Delvaux et al., 2014).

Despite the perceived importance placed on psychological readiness as a criterion to inform progression through key timepoints in a RTS continuum (reader is referred to Figure 3.2 and Table 3.2 - Chapter Three), respondents completing the survey did not state if they used any specific instruments to assess psychological readiness, nor what construct(s) of psychological readiness they targeted. A finding that may reflect the absence of available football-specific research in this area to direct psychological screening. This disconnect between research and practice is of particular concern as being psychologically underprepared to RTS has been associated with unsatisfactory rehabilitation outcomes, including diminished post-injury performance, as well as greater re-injury risk (Ardern, Österberg, et al., 2014; Hart et al., 2020; McPherson et al., 2019; Podlog et al., 2015; Webster et al., 2019). Accordingly, raising awareness to the availability of specific psychological instruments with appropriate psychometric properties to formally assess and track psychological readiness in professional football cohorts following injury is urgently required.

Although it is outwith the scope of this thesis to critique psychological theory, the theoretical construct of psychological readiness is thought to be multi-dimensional in nature (Podlog et al., 2015). While authors have offered slightly different conceptualizations of what it means to be psychologically ready to RTS, the fact that 'confidence' has emerged in each of these studies examining psychological readiness suggests it is likely to be a central component of what it means to be mentally prepared to resume high-performance activities (Carson & Polman, 2012; Conti, di Fronso, Pivetti, et al., 2019; Gómez-Piqueras et al., 2020; Podlog et al., 2015; Thomeé et al., 2006; Webster et al., 2008). In fact, confidence to RTS was a specific element highlighted in expert consensus as being potentially important to monitor throughout a rehabilitation programme in professional male footballers (Bisciotti et al., 2019; Zambaldi et al., 2017).

Confidence has been related to an athlete's self-belief in their ability to remain injury-free, to perform at a high-level, or to achieve appropriate levels of physical fitness and skill execution (Conti, di Fronso, Pivetti, et al., 2019; Podlog et al., 2015). Using ACL injury as an example, high levels of confidence to RTS have also been suggested as being important in minimising re-injury risk and enabling athletes to achieve pre-injury levels of performance, given a significant proportion (45-66%) of athletes fail to return to competitive level sport despite displaying good physical function (Ardern et al., 2011; Ardern, Taylor, et al., 2014). Nevertheless, this assumption is not currently supported by high-level scientific evidence.

Athlete reported outcome measures (AROM) are widely adopted as both an informative and practical method for athlete monitoring (Jeffries et al., 2020; Saw et al., 2016) Athlete reported outcome measures are also commonly used to evaluate psychological constructs and can be adopted to monitor progress over time, evaluate treatment effectiveness and facilitate treatment modifications in athletes (Snyder et al., 2012). In professional football, the use of an appropriate AROM during the RTS process may provide a valuable measure of confidence in players returning from injury. While a number of measures have been developed to assess confidence to RTS after injury (e.g. the Knee-Self-Efficacy Scale and the Anterior Cruciate Ligament Return to Sport After Injury scale (ACL-RSI) (Thomeé et al., 2006; Webster et al., 2008), their application within football is inherently limited by their injury-specific focus. For instance, while serious, an anterior cruciate ligament injury is not among the most prevalent injuries in professional male football (i.e. a team can expect ~ 1 ACL injury every second season) (Waldén et al., 2016). Alternatively, the Trait Sport Confidence Inventory (TSCI) and the State Sport Confidence Inventory (SSCI) (Vealey, 1986) can also be used to measure confidence within sport settings. However, as these instruments represent more general trait assessments, and also require athletes to rate their confidence against the most confident athlete they know this can cause scores to vary widely, it is argued AROMs capable of measuring confidence across unique sport-specific situations such as injury and RTS are needed (Glazer, 2009).

One AROM proposed to measure confidence in athletic populations returning to sport after injury is the Injury Psychological Readiness to Return to Sport scale (I-PRRS) (Glazer, 2009). The I-PRRS has undergone preliminary validation in a cohort of collegiate athletes and has been subsequently cross-culturally adapted into Dutch (Slagers et al., 2019), Italian (Conti, di Fronso, Robazza, et al., 2019) and Persian (Naghdi et al., 2016) for use in other athletic populations. Consisting of 6 items, this instrument is aimed at ascertaining an athlete's confidence in general and specific to their injury. Importantly, the I-PRRS can be used at any time-point within rehabilitation (e.g. following injury, return-to-training, return-to-play and following a period of competition) and can be applied to any injury-type. This is likely to be a factor attributing to this measure being frequently recommended in RTS guidelines (Ardern et al., 2016; Elliott et al., 2020) including those specific to professional football following muscle injury (Bisciotti et al., 2019; Zambaldi et al., 2017). In fact, a brief case report in an elite male footballer (Mccall et al., 2017) illustrated how the I-PRRS can feasibly be applied in practice - a key aspect underpinning the successful adoption of AROMs within professional teams (Robertson et al., 2017). Feasibility alone, however, is not sufficient justification to adopt an AROM, especially those that are intended to inform decision-making. Before an instrument can be considered acceptable for use in research and professional practice, a number of psychometric properties related to validity, reliability and responsiveness must also be established within the target population (Impellizzeri & Marcora, 2009; Mokkink et al., 2010). To ensure that scientific rigor is upheld, greater scrutiny of the I-PRRS is therefore required before its use within rehabilitation practices of professional football can be recommended.

Critical appraisal of the original work by Glazer (2009) has identified a number of underlying weaknesses in the development and validation of the I-PRRS. Firstly, the I-PRRS does not appear to be theoretically or conceptually grounded, with item development the product of consensus, based on the appropriateness and representation of the construct in the suggestions proposed by members of an expert panel.

Secondly, despite claiming to have established content validity of the I-PRRS, no attempt was made by the author to consider the perspectives of athletes when developing scale items. According to Terwee and colleagues, content validity is the degree to which the content of an instrument is an adequate reflection of the construct to be measured and accordingly is considered to be the most important measurement property. Specifically, it refers to the relevance, comprehensiveness, and comprehensibility of the AROM for the construct of interest within a given population and context of use (Terwee et al., 2018). As the expert panel assembled did not include athletes (i.e. the end-users), content validity of the I-PRRS cannot be assumed (Terwee et al., 2007).

Third, while appreciating clear and scientifically supported recommendations on sample size requirements to assess measurement properties of AROMs are lacking (Anthoine et al., 2014; Boateng et al., 2018). In following the COnsensus-based Standards for the selection of health Measurement Instruments (COSMIN), the sample of athletes used by Glazer (n=22) is inadequate for validating a psychometric instrument and providing evidence of validity and reliability of the I-PRRS scale (Terwee et al., 2007). Specifically, as part of the validation process, correlation in scores between Total Mood Disturbance (TMD) (measured using the Profile of Mood States short form (POMS)) and the I-PRRS were provided as evidence of concurrent validity. As a type of criterion validity, concurrent validity refers to the extent to which the results of a measure of interest correlate with the results of an established (ideally gold standard) measure of the same or a related underlying construct within a similar timeframe. However, no rationale or support was provided for using the POMS as a criterion measure and importantly Glazer did not outline why TMD should be related to psychological readiness and specifically an athlete's confidence following injury. The lack of a conceptual framework specifying why specific associations were assumed between confidence and total mood disturbance of the POMS is a limitation of this study since it is prone to hypothesizing after results are known (i.e. HARK-ing) (Jeffries et al., 2020). As explained by Jeffries et al., while this approach is acceptable in an explorative phase, where associations can be used for hypothesis generation or model development, the results should not be used as evidence of validity (Jeffries et al., 2020).

Lastly, in proposing that the I-PRRS can be used to assess psychological readiness to RTS after injury through measuring athlete confidence, the use of a single confidence score indicates this instrument is intended to be employed as a unidimensional scale to evaluate a unitary construct. However, Glazer did not examine the structural validity of the I-PRRS as part of this study. Consequently, uncertainty currently surrounds the dimensionality of the I-PRRS with recent studies having challenged its unidimensional nature (Conti, di Fronso, Robazza, et al., 2019; Naghdi et al., 2016).

Findings from a recently published systematic review on AROMs for monitoring training responses highlighted that most of the commonly used AROMs in sport science have not been validated, despite often being presented as validated (Jeffries et al., 2020). In this respect, despite the aforementioned limitations presented in the development and validation of the I-PRRS, it is perhaps not surprising that this instrument is commonly outlined as a tool to assess psychological readiness and monitor confidence throughout rehabilitation and has subsequently already been used in professional football (McCall et al., 2017). Collecting and using data of poor validity and reliability to inform decisions, could lead to the mismanagement of players and potentially a premature RTS. It is therefore clear that further validity and reliability testing of the I-PRRS is necessary before it can be recommended for use in professional football populations.

The internal structure of an AROM is key to determining if it can confidently be implemented in practice and represents an important starting point from which to develop evidence of validity and reliability to support the use of the I-PRRS in the rehabilitation setting of professional football (Prinsen et al., 2018). Specifically, internal structure refers to how the different items in an AROM are related (Prinsen et al., 2018) and how the construct (i.e. the variable of interest which cannot be directly observed/measured) manifests itself in the items (i.e. questions of an AROM perceived to embody the underlying construct) (Fayers et al., 1997). An AROMs internal structure is verified through evaluating its structural validity, internal consistency and measurement invariance (Prinsen et al., 2018). Structural validity measures the degree to which item scores adequately reflect the dimensionality of the construct to be measured (Mokkink et al., 2010). More specifically, in the case of this study, as the I-PRRS is suggested to consist of one single factor (confidence), it is expected that its 6-items load on this single factor. Internal consistency (reliability) is the degree of the interrelatedness (i.e. general agreement) among items whereby high agreement is preferable (Mokkink et al., 2010). Measurement invariance assesses either the invariance of corresponding parameters across independent population groups (cross-sectional invariance) or across time within a population group (longitudinal invariance) (Gregorich, 2006; Meredith & Horn, 2001). Specifically, longitudinal measurement invariance assesses whether the same constructs are measured equally at different time-points (e.g. throughout out a period of rehabilitation) ensuring that the development in scores can be attributed to an actual development in the construct under investigation (Dimitrov, 2010; Luo et al., 2020; Millsap & Cham, 2012; Putnick & Bornstein, 2016). Despite the I-PRRS having been used in the practical setting of professional male footballers (Mccall et al., 2017), the internal structure of this instrument has not yet been evaluated and shown to be appropriate in the target population.

5.1.1 Study Aim

Accordingly, the overall purpose of this study was to evaluate the internal structure of the I-PRRS by assessing (i) the structural validity, (ii) the internal consistency and (ii) the longitudinal measurement invariance of the I-PRRS in professional male football players.

5.2 Methods

5.2.1 Participants

In an effort to follow expert guidance presented within the literature (Impellizzeri, 2017) one-hundred and three professional football teams from 22 international leagues and 4 continents were invited to participate in this multi-centre study. Reflecting a convenience sample, teams were primarily selected based on participation in the earlier global survey and their indicated openness to engaging in future research opportunities. The invitation was emailed to the Head of Medicine/Sport Science of each team outlining the purpose of the study. Institutional ethics review board approval was granted by Edinburgh Napier University (SAS/00014). Confidentiality and anonymity were detailed to clubs before agreeing to participate. First team professional male players meeting the study inclusion criteria were invited to take part in the study and written and informed consent was collected.

The study period lasted 18 months with injury data collected across 2017/2018 and 2018/2019 seasons. Prior to data collection, participating teams completed a one-month familiarisation period (January 2018) to become accustomed with the protocol. Officially, data collection began on the 1st February 2018 and concluded on the 1st June 2019, covering pre and in-season periods. To maximise reliability of data, teams were provided with an instruction manual containing definitions and detailed protocol to record data (Appendix A.6). Teams were required to appoint a contact person from medical/sport-science staff who was responsible for collecting and submitting relevant data to the research group. There was monthly communication between the contact person and the principal researcher (GD) throughout the study.

5.2.2 Player inclusion criteria

A player was eligible if he incurred a contact or non-contact injury with a prognosis time-loss ≥ 3 weeks. In cases where injured players returned earlier than originally anticipated (i.e. < 3 weeks) data was not collected. This time-loss duration was agreed following roundtable discussion and agreement of the research group (involving medical, science and psychology experts) under an assumption based on the group's knowledge and experience that players would not be expected to display significant changes in confidence with an injury duration < 3 weeks were adopted. We anticipated this inclusion criterion would also mean less burden to participating teams and minimise dropouts

Diagnoses and prognoses were made by the medical doctor of each team. In instances where a player(s) joined a participating team during the study period, they were included from the date of arrival. Conversely, for any player(s) leaving a participating team during in-season or off-season (e.g. transferred to another club, contract expiry), all injury data were included until their departure date. If a player(s) went on loan and then returned to their parent team before the end of the study period, they were admitted back in. Any player(s) who sustained an end-of-season injury which was eligible for inclusion was followed over the off-season period.

5.2.3 Injury definition

An injury was defined, using a time-loss definition, as ‘any physical complaint sustained by the player that resulted from a football match or football training and led to the player being unable to take part in future football training or match play’ (Fuller et al., 2006). In line with UEFA guidelines, the player was considered injured until he was cleared by team medical staff to participate in full unrestricted training and were available for match selection (Hägglund, Waldén, et al., 2005). Injury absence was measured as number of days from injury occurrence to full training participation. Re-injury was defined as an ‘injury of the same type and location as the index injury that occurred after the player’s return to full participation from index injury’(Fuller et al., 2006). Contusions, lacerations, and concussions were not recorded as re-injury.

A standardised injury report form was completed after injury occurrence to minimise reporting inaccuracies associated with recording information retrospectively. Data were sent to the principal researcher to establish prospective timelines regarding players return-to-training and competition respectively. The procedure allowed email reminders to be sent to club contact personnel to ensure timelines were met.

5.2.4 Injury-Psychological Readiness to Return to Sport scale (I-PRRS)

The Injury-Psychological Readiness to Return to Sport scale (I-PRRS) (Glazer, 2009) was used to assess injured player confidence to return-to-training and match-play. To calculate a total score for confidence, the scores from the 6 items of the I-PRRS were summed and then divided by 10 (Glazer, 2009). The maximum score was 60. In line with thresholds adopted by the original author, a score of 60 implied that the player had utmost confidence to return-to-training or match-play at that time; 40, the player exhibited moderate confidence to return; and ≤ 20, the player demonstrated low overall confidence (Glazer, 2009). The I-PRRS was administered to players on two separate occasions, the day before a player was medically cleared to return to full unrestricted training and again, a day prior to clearance to return to match-play (i.e. selection in the squad for a match). It was requested that questionnaires be completed by the player, alone in a quiet room, free from the influence of teammates or any other personnel. The purpose of the I-PRRS questionnaire and how it was to be used within the return process was explained to participating players by the elected club contact.

5.2.4.1 Cross-cultural adaptation of I-PRRS scale

The I-PRRS questionnaire was translated and cross-culturally adapted to French, Spanish, Italian, Portuguese, and Brazilian-Portuguese (Appendix A.7). In accordance with WHO guidelines (World Health Organisation, 2017), this procedure involved five key steps and was conducted to achieve different language versions of the original English instrument that were conceptually equivalent in the target countries/cultures (i.e. equally natural and acceptable and that practically performed in the same way). Players were allowed to complete the I-PRRS in the language they felt most comfortable.

Stages one to four (as outlined below) followed the cross-cultural adaptation procedure as used in Study One (Chapter Three) with the addition of stage five which is as follows:

Stage 1 – Forward Translation

Stage 2 – Translation Synthesis

Stage 3 – Back Translation

Stage 4 – Expert Committee Review

Stage 5 – Pretesting of Prefinal Version: The final stage of the translation and cross-cultural adaption process was to pilot each translated questionnaire on a preliminary sample of the intended target population. The I-PRRS was tested on 10 professional football players affiliated to a professional team in each target language to assess clarity and certify that the prefinal version used appropriate vocabulary and expressions representative of each target language and culture. In addition to completing the questionnaire, all players were interviewed to establish how they interpreted the meaning of each questionnaire item and their subsequent response. Feedback received was considered by the expert panel and amendments were made (where necessary) before producing a finalised version of each translated questionnaire. This process was necessary to ensure that the final version of each questionnaire retains its equivalence to the original version in the applied setting.

5.2.5 Statistical analysis

IBM Statistical Package for the Social Sciences Version 25 (SPSS V-25) software for Windows were used to calculate descriptive statistics for player injury characteristics and where appropriate, were presented as means and standard deviations. The main analyses were performed using Bayesian structural equation modelling (BSEM) in Mplus (version 8.3; Muthén & Muthén 1998-2019). BSEM is a specific application of Bayesian statistical analysis to conduct factor analysis and structural equation modelling (Muthén & Asparouhov, 2012). In comparison to the more traditional frequentist framework, the Bayesian statistical framework is based on different assumptions and has been proposed to carry a number of advantages when analysing the psychometric properties of an AROM (for more information see Stenling et al., 2015).

When compared against frequentist statistics, a particular advantage of the Bayesian framework is the higher likelihood of producing reliable estimates even with small sample sizes due to less restrictive distributional assumptions (Song & Lee, 2012; Yuan & MacKinnon, 2009). More specifically, the Bayesian statistical approach allows for the simultaneous estimation of all cross-loadings and residual correlations within an identifiable model. Accordingly, the prospect of model misspecification and rejection as a consequence of having to impose very strict criteria (i.e. model constraints - exact zero cross-loadings and zero residual correlations), as is the case with frequentist SEM, is mitigated. Furthermore, BSEM allows the researcher to directly draw upon prior information about the parameter(s) of interest to guide their analysis. As such, knowledge for a given AROM can continuously evolve and be updated in line with the emergence of new studies and new insights. Lastly, in contrast to the frequentist confidence interval, the Bayesian counterpart (i.e. the credibility interval) allows an interval to be calculated that indicates the probability (e.g. 95%) that the parameter of interest lies between the two values given the observed data. It is important to note, as highlighted by Stenling et al., (2015), that the frequentist confidence interval does not, rather, it indicates a property of the procedure (i.e. across a large number of repeated samples from the population, the true parameter will lie within the confidence intervals in 95% of the cases under the null hypothesis). In this respect the credibility interval represents a more intuitive and meaningful interpretation that is easier to communicate.

In Bayesian estimation, the Markov Chain Monte Carlo (MCMC) simulation procedures with a Gibbs sampler was used to generate credible parameter values for all path analyses. All models were run using 100000 iterations (50000 burn-in by default). In line with previous recommendations, a potential scale reduction factor of around 1.0 was considered evidence of convergence (Kaplan & Depaoli, 2012). To evaluate model fit, the posterior predictive p value (PPp) was used in combination with its 95% credibility interval (CI). The PPp denotes the proportion of post burn-in iterations with a set of parameters that reflects the data poorly. A PPp value close to 0.50 and a symmetrical 95% credibility interval centring on zero is considered to be an indication of good model fit (Muthén & Asparouhov, 2012; Song & Lee, 2012).

A 95% credibility interval (CI) was estimated for each parameter specified in the analyses. The CI indicates the probability that, given the observed data, the value of the specified parameter lies between the upper and lower bound (Zyphur & Oswald, 2015). If the 95% CI around the parameter estimate did not include zero, I considered it to be a credible parameter estimate (i.e. I could reject the null hypothesis of no effect) (Zyphur & Oswald, 2015).

The model testing procedure was conducted in the following steps:

5.2.5.1 Structural validity

To test the dimensionality of the I-PRRS, confirmatory factor analyses (CFA) was conducted. More specifically, an *a priori* factor structure for the I-PRRS (1-factor solution) was specified and tested. Factor loadings were calculated to give a representation of the relationship of each item to the underlying factor (i.e. construct) of the scale. The factor loading is the correlation between the observed score and the latent score. For all estimated models, the factors loadings were given an informative prior of 0.70 with a variance of 0.02. For all cross-loadings, zero mean accompanied with small variance priors (0.02) was specified. Zero mean and small informative variance priors were specified (0.01; inverse-Wishart [IW] distribution) for the residual correlations.

5.2.5.2 Internal consistency (reliability)

Internal consistency was used as an index of scale reliability and assessed with McDonalds Omega (ω) (Mcdonald, 1999). A threshold of between 0.70 and 0.95 is desirable when assessing the internal consistency of items in health status questionnaires, however a reliability coefficient of ≥ 0.70 is accepted as being satisfactory for each unidimensional scale or subscale (Terwee et al., 2007).

5.2.5.3 Longitudinal measurement invariance

Ensuring appropriate and proper comparison of psychological outcomes over time within the same population is dependent on first confirming equivalence (or invariance) of meaning in the construct(s) under investigation (i.e. is the construct of interest being interpreted in a conceptually similar way across repeated measurements) (Dimitrov, 2010; Gregorich, 2006; Luo et al., 2020; Millsap &

Cham, 2012; Putnick & Bornstein, 2016). Without establishing measurement invariance, observed differences over time may not be valid, reflecting differences related to the scale itself (e.g. item interpretation) rather than any meaningful change in the construct(s) intended to be measured (Shi et al., 2019) and thus, providing no basis for interpreting observed differences.

To evaluate measurement invariance of the I-PRRS between administration time-points, CFA was conducted. Tested sequentially, from configural to scalar invariance, establishing measurement invariance (across all three steps) allows one to assume that differences observed over time (i.e. between repeated measurements) are due to changes in the latent variable (i.e. construct of interest) rather than differences in scale properties (e.g. discrepancy in item functioning – how items are being interpreted and scored for example). Specifically, ascertaining scalar invariance enables valid inferences of latent factor mean differences between groups or across repeated measurements to be made (Dimitrov, 2010).

To establish which model of invariance (i.e. configural, metric or scalar) showed best fit to the data, the deviance information criterion (DIC) and Bayesian information criterion (BIC) were inspected. Lower values on these two metrics are indicative of better model fit (van de Schoot et al., 2012). For the model parameters the same priors as used in step 1 were specified.

5.3 Results

5.3.1 Study participants

Thirty-six professional football teams (35% of teams invited) from 19 leagues across 17 countries accepted the invitation to participate. During the study, seven clubs were withdrawn from participation due to non-correspondence with the research team during the data collection period, despite repeated contact attempts. In total, 29 (28%) teams from 17 leagues, representing 15 different countries participated as reflected in Figure 5.1 and specifically detailed in Table 5.1

5.3.2 Recorded injuries

During the data collection period, 113 injuries (involving 108 players) satisfied inclusion criteria. At timepoint 1 (return-to-training) the I-PRRS was collected for all injury cases (n=113) while 96 players completed the I-PRRS questionnaire at return-to-play. In total, 96 completed I-PRRS data sets were collected. Despite being partially completed (i.e. collected at return-to-training only), the remaining 17 data sets of injured players were not excluded from analysis and were used where appropriate to address specific study aims. Partially completed data sets were attributed to the following reasons: transfer or contract expiry of injured players (n=5), club contacts leaving position (n=5), injured players lost to follow-up (i.e. unable to collect data at specified time-point(s) (n=6) and players experiencing a new injury (or re-injury) before all data could be collected for the index injury (n=1). During data collection, 10 (9%) re-injuries were reported. Injury characteristics are presented in Table 5.2. The English I-PRRS was most commonly used (n=141;68%)

followed by Spanish (n=42;20%), Portuguese (n=14;7%), French (n=9;4%) and then Italian (n=3;1%). No data were received for the Brazilian-Portuguese I-PRRS

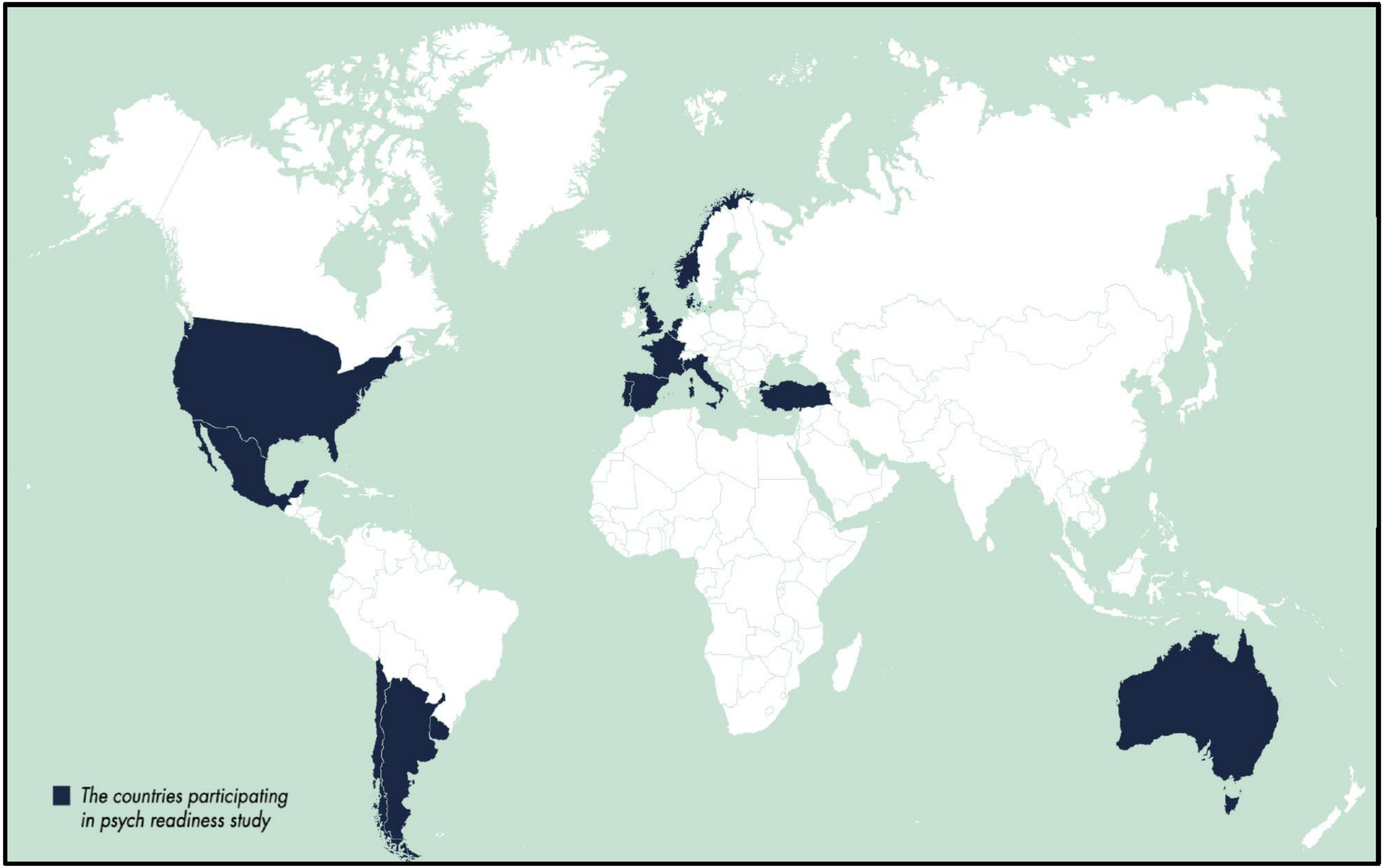

Figure 5.1. World map representing the countries of teams who participated in psychological readiness to return to sport study.

Table 5.1 Details of participating teams by confederation and country.

Football Confederation	**Union of European Football Associations (UEFA)**	**Asian Football Confederation (AFC)**	**South American Football Confederation (CONMEBOL)**	**Confederation of North, Central American and Caribbean Association Football (CONCACAF)**
Confederation Representation	**(23)**	**(1)**	**(4)**	**(1)**
Associated Country of Participating Teams	Belgium (1)	Australia (1)	Argentina (1)	America (1)
	Denmark (1)		Chile (1)	
	England (5)		Uruguay (2)	
	France (1)			
	Holland (2)			
	Italy (5)			
	Norway (1)			
	Portugal (1)			
	Scotland (4)			
	Spain (2)			

Table 5.2 Injury characteristics and mean (SD; range) time to return to full unrestricted training and competition.

Injury Type / Injury Location	Injury Count	Injury Occurrence		Injury Nature		Re-Injury	Return to Training (days)	Return to Competition (days)	Difference (days)
	(n)	Training	Match-Play	Contact	Non-Contact	(n)	Mean ± SD (Range)	Mean ± SD (Range)	Mean ± SD (Range)
Muscle and Tendon	**55**	**16**	**39**	**4**	**51**	**5**	**50.76 ± 40.43 (21 − 237)**	**60.73 ± 45.33 (22 − 259)**	**10.33 ± 10.01 (1 − 43)**
Thigh: Anterior	12	5	7	1	11	2	58.25 ± 46.26 (27 − 199)	70.25±48.68 (29 − 212)	12.00±7.59 (1 − 25)
Thigh: Posterior	22	4	18	0	22	2	38.14 ± 19.62 (21 − 103)	43.05 ± 18.44 (22 − 95)	7.90 ± 9.05 (1 − 43)
Lower Leg / Achilles tendon	7	1	6	0	7	0	82.86 ± 77.47 (26 − 237)	90.43 ± 83.85 (27 − 259)	7.57 ± 6.85 (1 − 43)
Hip/Groin	11	6	5	2	9	1	49.36 ± 27.00 (23 − 102)	61.00 ± 36.39 (30 − 141)	12.70 ± 14.41 (2 − 40)
Knee	2	0	2	1	1	0	26.50 ± 0.71 (26 − 27)	42.00 ± 0.00	15.00 ± 0.00
Ankle	1	0	1	0	1	0	78.00	108.00	30.00
Joint and Ligament	**36**	**9**	**27**	**23**	**13**	**2**	**82.97 ± 71.62 (21 − 343)**	**95.39 ± 78.68 (27 − 355)**	**12.85 ± 10.86 (2 − 43)**
Ankle	13	6	7	10	3	1	53.92 ± 30.76 (25 − 138)	56.00 ± 22.57 (27 − 103)	8.36 ± 6.31 (2 − 20)
Knee	22	3	19	12	10	1	97.68 ± 84.38 (21 − 343)	113.86 ± 91.29 (28 − 355)	15.62 ± 12.07 (2 − 43)
Shoulder / Clavicula	1	0	1	1	0	0	137.00	141.00	4.00
Fracture and Bone Stress	**17**	**5**	**11**	**8**	**9**	**2**	**65.65 ± 43.03 (26 − 185)**	**79.19 ± 45.07 (35 − 196)**	**12.75 ± 9.66 (1 − 35)**

Injury Type / Injury Location	Injury Count	Injury Occurrence		Injury Nature		Re-Injury	Return to Training (days)	Return to Competition (days)	Difference (days)
	(n)	Training	Match-Play	Contact	Non-Contact	(n)	Mean ± SD (Range)	Mean ± SD (Range)	Mean ± SD (Range)
Ankle	3	0	3	3	0	0	49.33 ± 21.73 $(26 - 69)$	58.00 ± 32.53 $(35 - 81)$	10.50 ± 2.12 $(9 - 12)$
Foot/Toe	5	4	1	1	4	0	63.80 ± 39.06 $(27 - 129)$	84.80 ± 45.97 $(46 - 164)$	21.00 ± 11.64 $(10 - 35)$
Hip/Groin	2	0	2	0	2	1	93.00 ± 4.24 $(90 - 96)$	105.00 ± 0.00	12.00 ± 4.24 $(9 - 15)$
Knee	3	0	3	1	2	0	94.00 ± 79.79 $(36 - 185)$	101.67 ± 83.55 $(37 - 196)$	7.67 ± 5.77 $(1 - 11)$
Elbow	1	1	0	1	0	0	29.00	50.00	21.00
Forearm	1	0	1	1	0	0	37.00	42.00	5.00
Hand	1	0	1	1	0	0	50.00	52.00	2.00
Lower Back / Pelvis / Sacrum *****	1	0	0	0	1	1	65.00	68.00	3.00
Nervous system	**2**	**1**	**1**	**2**	**0**	**1**	$\mathbf{43.00 \pm 11.31}$ $(35 - 51)$	$\mathbf{51.50 \pm 13.44}$ $(42 - 61)$	$\mathbf{8.50 \pm 2.12}$ $(7 - 10)$
Head/Face	2	1	1	2	0	1	43.00 ± 11.31 $(35 - 51)$	51.50 ± 13.44 $(42 - 61)$	8.50 ± 2.12 $(7 - 10)$
Other	**1**	**1**	**0**	**1**	**0**	**0**	$\mathbf{34.00}$	$\mathbf{38.00}$	$\mathbf{4.00}$
Lower Leg / Achilles Tendon	1	1	0	1	0	0	34.00	38.00	4.00
Not Reported * #	**2**								
Total §	**113**	**32**	**78**	**38**	**73**	**10**	$\mathbf{62.20 \pm 53.87}$ $(21 - 343)$	$\mathbf{74.30 \pm 59.27}$ $(22 - 355)$	$\mathbf{11.42 \pm 10.10}$ $(1 - 43)$

***** Site of injury occurrence not determined; **#** Mechanism of injury not determined; **§** 3 injuries with missing injury information; SD, standard deviation

5.3.3 Structural validity

Data from 113 players were collated and used to examine the structural validity and internal consistency of the I-PRRS questionnaire. The one-factor model showed good fit to data (PP*p* = 0.41, 95% Confidence Interval = [-20.22, 22.99]). All six factor loadings were credible and ranged from 0.59 to 0.60. The item correlations ranged between 0.27 and 0.72.

5.3.4 Internal consistency

The McDonald Omega coefficient of the six-item I-PRRS questionnaire was 0.88, indicating good internal consistency and higher than that of the proposed criterion of >0.70 (Terwee et al., 2007).

5.3.5 Longitudinal measurement invariance

All completed I-PRRS scales at return-to-training (n=113) and at return-to-competition (n=96) were included for analysis. All three models (i.e. configural, metric, scalar) showed good fit to the data. Comparing the DIC and BIC values for the different models the result showed that the scalar model had the best fit to the data (for model fit indices see Table 5.3). The scalar model showed good fit to the data (PP*p* = 0.54, 95% CI = [-0.42, 0.37]). All factor loadings were credible and ranged between 0.44 and 0.76. The cross loadings between items ranged between -0.004 to 0.46. The correlation between the two latent variables was credible and strong (r = 0.80, 95% Credible Interval = [0.54, 0.90]).

Table 5.3. Summary of model fit indices for measurement invariance testing of the Injury-Psychological Readiness to Return to Sport (I-PRRS)

Model	PP*p*	DIC	BIC
Configural	0.48	9321	9675
Metric	0.48	9321	9648
Scalar	0.54	9307	9638

PP*p*, Posterior Predictive *p* value; DIC, Deviance Information Criterion; BIC, Bayesian Information Criterion.

5.4 Discussion

5.4.1 Summary of findings

An AROM that is commonly recommended for use in professional football populations to support RTS decision-making, is the Injury-Psychological Readiness to Return to Sport scale (Bisciotti et al., 2019; Zambaldi et al., 2017). Through the conduct of prospective two-season study of 29 male professional football teams, the aim of this study was to evaluate the internal structure of this instrument. To achieve this, the structural validity, internal consistency, and longitudinal measurement invariance of the I-PRRS was assessed in injured male professional players. Study findings indicate the I-PRRS measured a unidimensional trait and demonstrated good structural validity, internal consistency, and longitudinal measurement invariance in professional male football players returning to sport after injury.

5.4.2 Structural validity

Indices of model fit demonstrated that structural validity of the I-PRRS is upheld in this sample of injured professional male footballers with a time-loss ≥ 3 weeks. In agreement with the unidimensional factor structure proposed by Glazer (2009), CFA indicated a 1-factor solution wherein the construct 'confidence' appears to reflect the unique construct that is proposed as being measured. The structural validity findings reported in this study are consistent with the recently translated and culturally adapted Dutch version of the I-PRRS (Slagers et al., 2019). However, evidence for the factor structure of the I-PRRS is not unequivocal. Factor analysis of both Persian (Naghdi et al., 2016) and Italian (Conti, di Fronso, Robazza, et al., 2019) adaptations of the I-PRRS have challenged this unidimensional nature, instead presenting a two-factor solution whereby confidence to perform and confidence in recovery from the injury itself were suggested to reflect the dimensions of confidence being assessed. However, latent constructs composed of fewer than three items, as observed in both Persian and Italian I-PRRS versions, are typically considered weak and unstable and indicative that a larger sample is warranted to achieve a stable solution (Costello & Osborne, 2005). It has been recommended, particularly when working with small data sets, that a stable factor should be comprised of at least five strongly loading items (i.e. .50 or better) (Costello & Osborne, 2005). This would indicate, as the original study by Glazer (2009) intended, that the main focus and application of the I-PRRS within male professional football players should be as a unidimensional scale.

While this finding offers greater clarity and guidance as to how the I-PRRS should be used within the rehabilitation setting of male professional football, owing to the purported multi-dimensional nature of confidence in returning to sport following injury, it is perhaps appropriate to question how well a single composite score based on six-items actually captures this construct. As indicated by Podlog et al., (2015), having confidence in relation to different areas may be essential in ensuring that athletes are psychologically prepared to return to competitive sport. (The reader is referred to Podlog et al., (2015) for a wider discussion on psychological readiness and the components and precursors underpinning confidence in returning to sport from injury).

5.4.3 Internal consistency

The I-PRRS demonstrated good internal consistency (ω = .88) signifying a high degree of interrelatedness (correlation) among scale items which means that items intended to measure the same underlying construct, yield similar scores (Terwee et al., 2007). Internal consistency is particularly important for AROMs that are intended to measure a single construct by adopting multiple items (Terwee et al., 2007). Although not directly comparable, our results appear consistent with existing reliability estimates presented for the I-PRRS, albeit in other athletic populations (Glazer, 2009), across translated versions (e.g. Dutch I-PRRS) (Slagers et al., 2019; Vereijken et al., 2019) or used to assess specific injury types (e.g. ACL injury) (Slagers et al., 2019).

5.4.4 Longitudinal measurement invariance

Longitudinal measurement invariance assesses whether the same constructs are measured equally at different timepoints (Dimitrov, 2010; Luo et al., 2020; Millsap & Cham, 2012; Putnick & Bornstein, 2016). Failure to demonstrate measurement invariance indicates test scores may not be able to be reliably compared (nor attributed to changes in the construct(s) measured) because differences may be confounded by irregularities in the psychometric properties of the instrument between administrations. In this study, invariance testing revealed that scalar invariance of the I-PRRS was supported and demonstrated best fit to the data (see Table 5.3 for model fit indices). The observed variance in I-PRRS scores (within this sample) from the first time-point of return-to-training to the second time-point of return to unrestricted match-play were attributable to change at a construct level. It is important that the reader does not confuse this finding with the ability of a AROM to detect changes over time in the construct (i.e. responsiveness, which is a measurement property in its own right and should be evaluated accordingly).

5.4.5 Practical implications

There are various strengths to this study which carry important implications for both research and professional practice moving forward. Firstly, this study represents the inclusion of multiple teams (29 teams) from a notoriously difficult to access population. Many recommendations for top-level professional male footballers are based on extrapolated evidence from lower levels or other sporting populations (McCall et al., 2020). As such, this study represents an important advance in the psychometric assessment of injury-related constructs in this specific population and provides a basis from which to develop this area of research.

Secondly, this study was conducted prospectively over a longitudinal period of 18 months with a low drop out of teams (n=7). This demonstrates that with careful planning, clear instructions (i.e. detailed study manual) and close communication (i.e. between research group and participants) even top-level professional teams are open to international collaboration and willing to engage with research projects to address challenges faced in daily practice and advance scientific knowledge to improve levels of player care.

Thirdly, consistent with recommendations for best-practice proposed within the 2016 RTS consensus statement (Ardern et al., 2016), this study evaluated the internal structure of the I-PRRS at two key timepoints during the RTS process. This better reflects the typical rehabilitation programme and progression milestones of professional male footballers as opposed to one generic timepoint and should be subsequently followed in future investigations of this population.

Fourth, the identification and validation of tests to guide RTS decision-making through the course of rehabilitation has been recognised as a research priority, of which, consideration to the temporal relationship between key psychological factors and RTS has been advocated (Ardern et al., 2016). Established to be invariant over time, preliminary evidence is provided that the I-PRRS could be useful in tracking changes in psychological status of players through the RTS process. However, further research is required to evaluate the responsiveness of the I-PRRS and determine its ability to detect changes over time in this population (Impellizzeri & Marcora, 2009)

5.4.6 Considerations for future research

As the specific objective of this study was to evaluate the internal structure of the I-PRRS, it is important to draw attention to the fact that the validity of this instrument is far from being established. Accordingly, endorsing its application within male professional football, and indeed sport in general, is considered premature and should be done so cautiously. Drawing on available literature, it is evident that a level of uncertainty continues to surround content, construct, and criterion validity of the I-PRRS scale. To help support future research in this area, a number of important considerations must therefore be discussed.

Derived predominantly from self-efficacy theory (i.e., the belief in one’s perceived capability to perform a specific task), the six-items comprising the I-PRRS focus exclusively on an athlete’s confidence when returning to sport. However interestingly, during the development of the original I-PRRS scale, ‘confidence’ and ‘psychological readiness’ were used interchangeably, with the author concluding that the I-PRRS can be a beneficial tool to assess an athletes psychological readiness to RTS participation following injury (Glazer, 2009). This would infer psychological readiness and confidence are considered synonymous, with the items of the I-PRRS proposed to constitute the entirety of what it means to be psychologically ready to RTS following injury.

In recognition of the central tenets proposed to underpin efficacy perceptions (i.e. performance accomplishments, vicarious experiences, verbal persuasion and physiological states), reservations exist as to the comprehensiveness of such a narrow range of items to fully encompass one’s confidence to RTS. As suggested by Podlog et al, (2015), confidence across a number of different areas (e.g. program of rehabilitation used, expertise of treating clinicians, available social support) may be also important to ensuring athletes are psychologically prepared to RTS. Similarly, in drawing upon the experiences of athletes returning to sport from injury (e.g., Carson & Polman, 2012; Conti, di Fronso, Pivetti, et al., 2019; Podlog & Eklund, 2006, 2009), the assumption that the I-PRRS is of a sufficient nature to provide a global representation of an athlete’s psychological readiness to RTS likely belies the true complexity of this process and would appear equally optimistic. As supported by Wiese-Bjornstal et al., (1998), a more integrated perspective is warranted to help capture an athlete’s rehabilitation journey following injury and explain observed RTS outcomes. According to their model, an athlete’s cognitive appraisal of injury and progress will influence their emotional response which in turn affect their behavioural response through rehabilitation. The proposed triadic relation between thoughts, feelings and behaviours can function bi-directionally such that behaviours can influence emotions and therefore subsequent athlete appraisals throughout the rehabilitation process. In this respect, the interplay between efficacy beliefs, goals and expectations as well as environmental and individual factors are likely to all carry important implications for athletes' psychological well-being, motivation and return to sport outcomes following injury (Podlog & Eklund, 2007b).

Since the inception of the I-PRRS in 2009, conceptual clarity around what it possibly means to be psychologically ready to RTS has evolved. Accordingly, while confidence to RTS does appear to be central to this psychological state, the possession of other attributes may also be required for players to be considered psychologically ready. As proposed by Podlog et al., (2015), to comprehensively screen a player's psychological readiness to RTS, consideration of their motivation to regain previous performance standards, as well as ensuring they possess realistic expectations of their sporting capabilities, may also be important. An absence of items pertaining to these other potentially relevant components of psychological readiness indicates the I-PRRS may not fully capture all aspects of this construct and thus, lacks sufficient content validity. Because of this, the use of the I-PRRS in isolation is perhaps insufficient to provide a complete and accurate representation of this construct. Acknowledging the preliminary nature of Podlog and colleague's findings, further research is needed to determine whether psychological readiness is a multidimensional construct and what the key constructs are that comprise it.

Despite developments in our understanding of the dimensions believed to comprise this theoretical construct, at present, there is no widely accepted definition of psychological readiness (Conti, di Fronso, Robazza, et al., 2019). A finding that attests to the different operationalisations used for this construct among existing psychological readiness inventories (Glazer, 2009; Gómez et al., 2014; Webster et al., 2008). This lack of conceptual clarity may have also contributed to the apparent confusion within the literature when using the I-PRRS. As observed across studies attempting to validate cross-cultural adaptations of the I-PRRS, an array of conceptually different reference measurements (e.g. profile of mood states (POMS), Knee Injury and Osteoarthritis Outcome Score (KOOS) and International Knee Documentation Committee score (IKDC)) have been used to provide evidence of validity via examination of concurrent and convergent validity (Naghdi et al., 2016; Conti, di Fronso, Robazza, et al., 2019; Slagers et al., 2019). It could be argued that the continued use of proxy indicators related to mood, pain and/or functional activity, engenders this conceptual ambiguity. As a consequence, our understanding of psychological readiness and its possible component parts continues to be compromised. It is therefore recommended that clear rationale be provided as to why particular instruments are being selected and how they are related to either confidence and/or psychological readiness constructs in order to support their use in the validation process.

The I-PRRS has been frequently recommended in RTS guidelines, including those specific to professional football following muscle injury. While this is perhaps attributable to the fact there exists an absence of suitable psychological instruments to help assess psychological readiness and specifically confidence across a diverse range of contexts (e.g. injury type, rehabilitation phase), it is important to recognise this instrument was developed 12 years ago. Based on this discussion, it is clear since then that knowledge has progressed regarding psychological readiness, its purported dimensions and the precursors that may be important to facilitating its development. Accordingly, if these initial assumptions are to be subsequently confirmed, it may be more appropriate to direct future research efforts toward developing new measures of psychological readiness that better reflect its multi-dimensional nature and provide a more detailed and complete assessment of this desirable psychological state.

5.4.6 Limitations

It should be outlined that there are limitations to this existing study that could also be addressed in future research. First, face validity of the I-PRRS was assumed (i.e. on the face of it, the AROM appears to assess the desired quality; confidence). Appropriately evaluated content validity is a key property to establish in an AROM, yet is one of the most challenging to assess (Terwee et al., 2018). The criterion for face validity typically represents a subjective judgement based on a review of the instrument by one or more experts, in which an empirical approach is rarely adopted (Jenkinson et al., 1996; Streiner et al., 2015). Even when assuming face validity, its assessment should be performed in the target population (in this case, professional male footballers) as fundamentally it is they who need to indicate whether the AROM appears to adequately reflect the construct to be measured (Jenkinson et al., 1996). Accordingly, the degree to which the I-PRRS is accepted as a measure of confidence requires further empirical scrutiny in this population, and indeed in general, given the limitations outlined when developing the original instrument.

Second, the sample size may be considered as relatively small, however based on recommendations for both CFA (Wolf et al., 2013) and the COSMIN (Terwee et al., 2007), our sample size is considered adequate for the statistical testing conducted.

Thirdly, only injuries with a time-loss of ≥ 3 weeks were included. While this decision was based on a subjective agreement of science, medical and psychology experts, the impact of injuries < 3 weeks on confidence is not known and may vary according to the individual player (e.g. previous injury history) and specific contexts (e.g. accelerated RTS for upcoming key fixtures). Nevertheless, injuries with ≥ 3 weeks' time-loss do represent a significant proportion of injuries that are seen in professional male footballers (Ekstrand, Hagglund, et al., 2011).

Fourth, player responses to the I-PRRS with multiple languages in were included in the analyses. While this can be viewed as a limitation, it reflects the multi-lingual/cultural nature of professional male football both between and within leagues and teams worldwide. For example, the squad of one team participating comprised 20 nationalities from 4 continents, speaking 17 different languages/dialects. Given this study took 18 months and involved collaboration with 29 teams, it is logistically challenging to assess each language independently. To minimise any impact of this limitation, an established cross-cultural adaptation procedure was adopted to achieve different versions of an original English instrument that is conceptually equivalent in other languages and cultures.

Fifth, on account of their subjective nature, social desirability represents a potential source of bias commonly associated with AROMs i.e. participants electing to respond to questionnaire items in accordance with what is assumed to be socially desirable (Chang et al., 2019). Given their strong intent to RTS, it is possible players may not have been entirely honest when answering items on the I-PRRS owing to a perception that undesirable responses (e.g. low confidence) may have subsequently impeded their return. To minimise the masking effects of socially desirable responses, contact persons were asked to report any doubts regarding the accuracy of I-PRRS data collected and these were then excluded from analysis.

5.5 Conclusion

The I-PRRS showed good internal structure in professional male footballers. Specifically, the I-PRRS measured a unidimensional trait, indicative of good structural validity and internal consistency and additionally exhibited good longitudinal measurement invariance, signifying potential utility for implementation prior to returning to full training and competition following injuries of ≥ 3 weeks' time-loss. Despite the current findings representing a basis from which to progress research into the I-PRRS within elite male professional football players and investigate other important measurement properties (e.g. predictive validity), it is imperative to acknowledge that fundamentally, issues surrounding the content validity of this AROM remain. Presently, these impair its application within applied practice. At this point, to better support practitioners in their RTS decision-making, the proposed multidimensional nature of psychological readiness should be the subject of further empirical scrutiny.

Chapter Six

General Discussion, Conclusions and Future Recommendations

6.1 Overview

The aim of this thesis was to examine the evidence gap between research and current practice regarding the criteria and strategies used to inform and guide decision-making in the progression of male professional football players through the RTS process following lower limb muscle injury. In view of the iterative nature of this process, three broad objectives were formulated over the course of this research programme to enable this aim to be achieved:

1. To explore the current return to sport practices of elite male professional football teams following muscle injury

2. To scope the existing literature with respect to the criteria used to inform rehabilitation progression and support return to sport decision-making following muscle injury in professional football players

3. To examine psychometric properties of an existing psychological readiness questionnaire related to return to sport following injury in a cohort of male professional football players

In each of the three studies that subsequently followed (Chapters 3-5), a number of novel research questions were devised that were intended to address the specific objectives outlined within this thesis.

The aim of this chapter is therefore to provide a summary of the main research findings of this thesis and discuss the extent to which the research questions proposed have been answered during this programme of work. In doing so, the extent to which these findings have provided an original and significant contribution to existing knowledge in this area of research will be discussed and important avenues for future research recommended. Additionally, owing to the nature of this body of work, a wider discussion around the realities of attempting to bridge the research to practice translation gap within the landscape of professional football will also be provided. Lastly, the general limitations of this work will be reflected upon and in doing so, provide a lens through which the research findings should be contextualised, the scientific validity of the research undertaken interpreted, and the credibility of the conclusions presented examined.

6.2 Addressing the research objectives

6.2.1 Study one

In 2016, the Bern consensus statement on RTS was published (Ardern et al., 2016). Recognising that return to sport decision-making after injury is complex and multifactorial, the purpose of this consensus was to present and synthesise existing evidence to provide recommendations to better support this process within practice. Acknowledging the recurrence of muscle injury continues to represent a significant problem within professional football, determining how these key recommendations were being translated into the rehabilitation practices of teams, if at all, was of clear interest. Accordingly, it was considered that an appropriate starting point for this programme of research would be to explore the current RTS decision-making practices of elite male professional football teams following lower-limb muscle injury. More specifically, paying particular attention to RTS from hamstring injury, Study One sought to address Objective One by examining the following research questions:

i. Do professional football teams competing in various premier leagues worldwide follow a RTS continuum?

ii. What criteria are used and considered important by premier-league teams to inform progression through a RTS continuum?

iii. How does RTS decision-making occur in applied practice?

Key Research Findings:

Among the key findings emerging from this study, it was found that the majority male professional teams surveyed (95%) adopted a continuum approach to guide the RTS process following hamstring injury. In consideration of this, novel insights were subsequently provided in respect of how this framework is being applied within rehabilitation setting of professional football to support decision-making. More specifically, at least on a global level, knowledge was acquired as to what types of criteria are being incorporated into this framework and additionally those which are perceived as being particularly important to informing progression through each stage of the continuum. A shared approach to decision-making at all phases of the continuum was reported by 80% of professional football teams surveyed. However, the involvement of specific stakeholder groups within RTS decisions varied widely, both from an intra and inter-stakeholder group perspective. The proportion of key stakeholders involved at each phase was only consistent for medical staff. Notably, the specific involvement of other groups within this process, namely sport science staff, coach and managerial staff and the player was less clear. Interestingly, despite premature RTS being recognised as a possible risk factor for re-injury, teams reported to achieving the criteria they set most of the time following hamstring muscle injury.

6.2.2 Study two

While Study One provided some novel insights into how criteria were being developed across a RTS continuum and what criteria were considered most important by professional football teams to determine rehabilitation progression after muscle injury, it was clear several knowledge gaps remained. In particular, beyond identifying the global RTS domains and specific assessment types used to inform decision-making, a deeper understanding of how these measures were actually being evaluated following hamstring injury failed to be determined. This was similarly the case when respondents were asked to reflect on how their practices changed when dealing with an adductor, quadricep or calf injury respectively.

Consequently, the overall aim of Study Two was to scope the existing research literature with respect to the criteria used to inform rehabilitation progression and support RTS decision-making following lower limb muscle injury in professional football players. More specifically, this scoping review sought to address Objective Two by elucidating:

i. What are the common criteria used in the rehabilitation of football-code team-sport athletes following lower limb muscle injuries?

ii. How are these criteria being specifically assessed within the published literature to guide progression through key stages of a RTS continuum framework?

iii. What are the key research priorities in the field?

Key Research Findings:

While studies eligible for inclusion within this review dated back 55 years, interest surrounding RTS following muscle injury in football-code populations and specifically professional football has increased significantly in recent years. In fact, close to 60% of included studies were published in the year of or following the 2016 RTS consensus. To guide the RTS decision making process, four distinct criteria domains were identified and were representative of clinical, strength, functional and psychological assessment. When collated data were analysed according to rehabilitation phase, the reporting of global criterion domains varied widely, with the focus of included studies predominantly concerning RTPlay. A reporting bias that was similarly observed among muscle groups, with 80% of studies concerning injury to the hamstring. To support progression through a RTS continuum, emphasis within research appears to be largely placed on using clinical, strength and functional measurement criteria. More precisely, clinical criteria were most commonly reported at RTRun while greater weighting within the decision-making process was afforded to functional criteria as players transitioned toward RTPlay. When analysis of abstracted data was extended beyond this broad level of reporting however, a high degree of inconsistency was observed within the research literature surrounding how best to guide RTS following muscle injury. There exists limited consensus concerning the specific parameters that should be evaluated (e.g. prescribed thresholds, cut-offs) for identified measurement types and equally, where within the RTS continuum, these criteria should be integrated to support progression.

6.2.3 Study three

In support of a holistic athlete-centred approach to RTS, findings from Study One highlighted that practitioners use psychological criteria throughout the rehabilitation process and appear to place particular importance on a player's psychological wellbeing to inform decisions to RTPlay and to determine RTPerf. When scoping the rehabilitation literature of football-code populations (Study Two), despite the psychological appraisal of football-code athletes being equally recognised as a global criterion domain used to support progression through a RTS continuum, included studies failed to provide clear insight as to how this should be measured in a robust and purposeful manner. Confidence in returning to sport after injury has been highlighted in expert consensus as being potentially important to monitor throughout the rehabilitation programme in professional male footballers. Despite promoting the Injury-Psychological Readiness to Return to Sport (I-PRRS) scale as an appropriate tool to measure this construct, evidence of its validity and reliability to support it use within this population, has not yet been established. Therefore, Study Three aimed to address Objective Three by evaluating the internal structure of the I-PRRS in a cohort of male professional football players. This was achieved by assessing:

i. The structural validity of the I-PRRS

ii. The internal consistency of the I-PRRS

iii. The longitudinal measurement invariance of the I-PRRS across two specific rehabilitation timepoints

Key Research Findings:

The Injury-Psychological Readiness to Return to Sport scale measured a unidimensional trait, indicative of good structural validity and internal consistency. Additionally, the I-PRRS exhibited good longitudinal measurement invariance across key timepoints embedded within the RTS process and signifies potential utility for implementation within professional practice. Importantly however, without further investigation, issues pertaining to the content validity of this AROM impair its application within professional football at this stage. As such, its recommendation within expert-led consensus and football specific Delphi surveys can be considered somewhat premature. To progress research within this developing field, establishing a clearer conceptual understanding of psychological readiness and its relevant components is necessary to not only determining the value of the I-PRRS to the decision-making process but also in charting the course of future work in this area.

6.3 What does this mean for practice and research within professional football

The notable finding of this research project is that evidence-based recommendations for RTS are being broadly translated into the decision-making practices of male professional football teams following lower limb muscle injury. This alignment of current thinking and guidance for RTS with the practices being employed by teams is clearly encouraging given a disconnect between research and practice has historically been cited within male professional football (Bahr et al., 2015; McCall, Carling, et al., 2015). Appraisal of the findings presented within this thesis indicate, the process of returning to sport following injury is being viewed by teams as a continuum through which emphasis is placed on a graded, criterion-based progression of activity across four distinct milestones of recovery. Moreover, at each specific phase of this process (i.e. RTRun, RTTrain, RTPlay and RTPerf), a shared decision-making approach is being largely adopted to deliberate the relevant medical and non-medical factors that shape the decision to either progress or delay a player's RTS.

Appreciating these findings are confined to broad and more general research outcomes, it is maintained they serve to advance knowledge in this area. Importantly, such insights help to contextualise recommendations for RTS presented within the 2016 Bern consensus and subsequently may offer guidance to professional teams and practitioners wishing to adopt and follow an evidence-based approach to support their decision-making. It is important to note that over the duration of this programme of research, RTS following lower limb muscle injury has itself been the subject of increasing investigation within professional football specifically (Bisciotti et al., 2019; van der Horst et al., 2017; Zambaldi et al., 2017). The focus of these studies however has been predominantly toward examining players' return to competitive match-play, with little in the way of guidance offered to this point to support progression through the other phases embedded within the continuum framework. Considering this, the novel and significant contribution of this research to the existing knowledge base can be recognised and discussed.

Providing preliminary evidence of the practices employed by professional teams throughout a RTS continuum, it is proposed that this work serves as an important foundation from which to direct future research in this area. It is envisioned that the knowledge acquired can contribute to the development of evidence-informed practices that can sit within this framework and subsequently provide practitioners with greater confidence in the RTS decisions being made. Drawing on the insights offered by this thesis, the capacity to translate and implement forthcoming research is enhanced owing to a greater appreciation of not only the intricacies underpinning this framework but also the specific needs of those actively applying this approach within an elite male professional football environment.

It is imperative to outline however, that while the RTS practices of professional teams appear consistent with key recommendations proposed within the 2016 consensus statement, comprehension of these processes remain restricted to a relatively superficial level. A prime example of this, and one that has represented a prominent focus of this thesis, is the use of criteria to support progression through the specific phases of the RTS continuum. Outwith identifying different domains of criterion and affiliated measurement types used to inform decision-making, a deeper understanding of how these measures were being evaluated in practice could not be deduced from the RTS survey. In turning to the research literature to attempt to offer some form of clarity and direction as to how RTS testing for these measurement criteria is being approached, variation in the reporting of criteria was also apparent, with little in the way of clear and consistent guidelines for practitioners to draw upon. In some instances, it appears that professional teams are adopting and placing importance on measurement criteria that are not yet supported by research-based evidence (e.g. training load monitoring).

Further exploration of the research-practice evidence gap revealed several notable omissions within the existing literature. Such findings speak to a continuing disconnect between football orientated RTS research and recommendations for best practice put forward in the 2016 consensus. In some respects, this is to be expected and can be accredited to the fact that the conduct of this research project was undertaken in the four years following the publication of the RTS consensus statement in question. Admittedly, a relatively small window of time has been afforded for the translation and routine uptake of the recommendations outlined. This disconnect with current thinking is characterised by the fact that the existing research base continues to be primarily centred on RTPlay and underpinned by general guidelines for rehabilitation progression. Inconsistent with the RTS continuum framework, the management of muscle injuries, and in particular those involving the adductors, quadriceps, and calf, continues to be largely unsupported across other rehabilitation phases, with a distinct lack of evidence in the form of criteria to help guide practitioners.

As evidenced by this body of work, expert-led consensus statements can strongly influence the direction of research, applied practice and sporting policy. While such guidelines are intended to represent best evidence synthesis, it is important to recognise consensus statements also carry limitations that should be accounted for (Blazey et al., 2021; Shrier, 2021). For instance, there have been occasions where consensus statements have included recommendations that were later deemed inappropriate (Impellizzeri et al., 2019). Moreover, representing the foundation by which scientific evidence and experiences are integrated, interpreted and subsequently improved, consensus statements by design often fail to capture the rich discussion occurring between panel members and rarely do they report dissenting, yet equally valid, opinions that oppose that of the majority. Due to this, these reports do carry some form of bias. As Shrier eloquently states:

"…. it is better for clinicians and research to be appropriately confused rather than inappropriately certain when there are disagreements within the research community" (Shrier, 2021, p. 545)

In recognition of this, it is important for both researcher and practitioners to acknowledge that, as this field of research continues to mature, there will be a need to update the recommendations proposed within the 2016 RTS consensus statement. Owing to the inherent complexity underpinning the RTS decision-making process, it is essential that future statements embrace dissenting opinion and draw on the expertise and opinions of the diverse disciplines that contribute to decision-making within applied practice.

6.4 Recommendations for future research

Over the course of this programme of research three objectives have been systematically explored. However, several broad avenues for further study are advocated to build upon and advance the knowledge gained from the investigations conducted within this thesis.

6.4.1 Recommendation one - standardise criteria used to inform progression decisions throughout the return to sport continuum

The findings of this thesis extend the appeals made by other researchers who have emphasised the need for consensus on RTS criteria, by highlighting the inherent variability in criteria reported to guide RTS decisions across both practice and research contexts (Delvaux et al., 2014; Tassignon et al., 2019; van der Horst et al., 2016; Wikstrom et al., 2020). Whilst progress within this area has already been made (e.g. van der Horst et al., 2017; Zambaldi, Beasley and Rushton, 2017; Bisciotti et al., 2019), additional research is required to clearly articulate how RTS discharge criteria evolve across each phase of the RTS continuum framework.

Particular emphasis should be directed toward establishing agreement on the specific parameters and objective thresholds for RTS assessments to be able to standardise decisions. Importantly, this should extend to the development of injury-specific RTS decision-making paradigms for each of the lower limb muscle groups as well as other injury types. These test batteries then need to be actually applied, using prospective longitudinal research designs, to determine their relevance to RTS decision-making within a professional football context. To complement these proposals, the creation of explicit reporting standards is also strongly encouraged in order to enhance the quality and reproducibility of future research examining RTS outcomes following muscle injury in male professional football players.

6.4.2 Recommendation two - reinterpret what it actually means to be psychologically 'ready' to return to sport

Despite the merits of a quantitative approach from an RTS decision-making perspective, it appears, in developing psychological readiness measures, researchers have attempted to operationalise psychological readiness before having a clear conceptual understanding of this construct. Accordingly, existing AROMs may lack content validity. In this respect, despite its use being widely advocated (e.g. Ardern et al., 2016; Zambaldi et al., 2017; Bisciotti et al., 2019), it is currently unclear whether the I-PRRS is actually a valid way to think about and/or measure psychological readiness (i.e. do six-items pertaining to a player's confidence to RTS constitute the entirety of what it means to be psychological ready?).

Before further work is undertaken on the I-PRRS or indeed, other available psychological readiness measures, it is perhaps more appropriate to take stock of recent empirical developments in this field of research. In view of its proposed multi-dimensional nature (Podlog et al., 2015), further qualitative investigation involving professional athletes is urgently required to either support or refute these preliminary findings. Ideally, to gain a more nuance understanding of what psychological readiness is, what precedes it and what its implications are, insights from the perspectives and experiences of professional footballers (including those failing to RTS) are warranted. It is argued this will help direct the course of future work in this area and determine whether the I-PRRS is of value within male professional football populations to assess psychological readiness. It may be the case that future research should be more invested toward developing new football specific measure(s) of psychological readiness that better encapsulate this construct.

Interestingly, this concept of being psychologicallu 'ready' appears to be centred around the period between injury incidence and an athlete's clearance to return to competition only. As outlined by Podlog and Eklund, (2007), difficulties such as poor performances or failing to meet personal or external expectations may be particularly challenging issues for players following their return to competitive match-play after injury. This perhaps speaks to the importance of practitioners also having the capacity to monitor a player's psychological response during their transition to RTPerf, and thus, across an entire RTS continuum.

Facilitating the appraisal of a player's own perceptions of their RTS success, the Return to Sport After Serious Injury Questionnaire (RSSIQ) may be a useful tool to incorporate within RTS test batteries as it can indicate whether athletes associate their RTS with either positive or negative psychological outcomes (Podlog & Eklund, 2005). Understandably, further validation of this instrument is required to examine its value as a practical tool which can be used as part of the RTS process within professional football.

6.4.3 Recommendation three – explore the perspectives of players and management regarding return to sport decision-making

Based on the findings of this thesis, it can be inferred that while professional teams do place importance on collaboration to inform RTS decisions, this does not appear to align with a truly player-centred approach (Hess et al., 2018). Equally, at least from the perspective of medical and science staff, the contribution of managers is primarily confined to the RTPlay decision. An evident direction for future research is therefore to establish a more multi-disciplinary outlook with respect to what this process looks like and how it is being applied within a professional football context. For example, how are decisions weighted in terms of stakeholder influence across phases of the continuum? how is the risk management approach actually performed?

Increased consideration to the perspectives of non-medical staff, such as players and coaches, as part of this approach is imperative to advancing our knowledge of this process. Determining the needs of these stakeholder groups (i.e. how they want to be involved, the information they want to know and equally what they are capable of understanding and how they would like this information disseminated) can help to more clearly establish how diverse disciplines, who often retain competing interests, can work more effectively together (Fullagar et al., 2019). It is envisaged that the outcomes of this work could form an important component of training and education resources (e.g. coach education, university degrees) and help to promote an increased consciousness to the importance of a team-based approach to RTS.

6.4.4 Recommendation four – develop our understanding of return to sport decision-making practices beyond that of elite-level male professional football

An important observation relating to this thesis and its findings was its focus toward elite-level male professional teams. Consequently, how representative this is of the RTS practices adopted by less well supported teams remains unclear. As all teams, irrespective of playing standard, have a duty of care to their players following injury, a broader exploration of the research-practice gap is advocated. It is proposed that the conduct of this research at an association level (e.g. Scottish Football Association) would be a suitable approach. Operating independently, these football authorities are best positioned to initiate change at country specific level. In view of the anticipated disparity in available resources and staffing structures across teams and divisions, identifying the needs of teams across the entire professional football pyramid (i.e. male, female, and academy levels) can provide associations with much needed insight. This information can subsequently be acted upon to ensure teams receive the appropriate support to help implement best practices recommendations for RTS and provide the highest level of player care possible.

6.5 Perspectives on bridging the research-practice gap in professional football

The development of an evidence-based approach requires the conduct of well-designed prospective studies that are characterised by a low risk of bias and a large sample size (Bahr & Holme, 2003) - a process that also requires significant resources (e.g. time, money, equipment, expertise, and energy) and access to participants (e.g. teams, players, coaches and/or support staff) who are willing to engage and adhere with research. This is something that unfortunately, is not always possible and/or afforded in the practical setting of elite football and is a reality which has likely contributed to the observation that there are more football-related injury prevention reviews published than actual RCTs (Bricca et al., 2018).

Importantly, without high-quality original research, the field cannot progress and identified knowledge gaps between research and practice will remain unresolved. Adding to this challenge, siloed research efforts aiming to answer similar research questions have become a hallmark of football research. Such noble endeavours however, are often restricted to small single team studies and undermined by a high risk of bias. Accordingly, the clinical application of published findings and the inconsistencies that appear among studies make it difficult for practitioners to determine the appropriate evidence-based strategies and practices to mitigate the risk of injury and re-injury (Fanchini et al., 2020).

‘Thinking bigger and working together’ was coined originally by Professor Jan Ekstrand to highlight the gap between research and practice within professional football which must be bridged if injuries are to be prevented (Ekstrand, 2016). To achieve this, collaboration between researchers, governing bodies, national associations, and their affiliated teams is required to provide the appropriate scientific and clinical rigour necessary to deduce meaningful conclusions and increase our ability to answer key questions that are important to practice. Unfortunately, beyond the conduct of injury surveillance (e.g. UEFA-ECIS), there currently appears to be little in the way of centralised approaches (i.e. governance led projects) to translate these words into actionable policy.

If we are to continue to narrow the research-practice gap, greater onus must be placed on governing bodies (e.g. FIFA, UEFA) and national football associations to invest in processes that can provide opportunities for information exchange between research and practice. For example, to better connect research with practice, the advent of dedicated research and development departments within the structures of professional clubs such as Arsenal FC, FC Barcelona and SL Benfica are becoming more common. This complements the bottom-up approach to research advocated by this thesis, embedding a research strategy into practice as an effective way to support the fast-paced, intuitive nature of applied practice (Coutts, 2016; Jones et al., 2017; McCall, Davison, et al., 2016). Understandably, these departments maintain a very singular focus (i.e. to provide support at an individual club level) and therefore, research activities and findings are not always broadly applicable nor being actively disseminated.

Sanctioning similar initiatives, albeit on a larger scale (e.g. league wide, national association level), may provide teams and practitioners with an opportunity to share their practices and challenges encountered on a more global level. Furthermore, ensuring subsequent avenues are in place through which to engage with researchers, participate in well-designed multi-team studies and effectively disseminate findings of this work is an equally imperative as part of this approach. While the responsibility of facilitating this clearly lies at a national level of governance, onus is equally on professional practice as this cannot be achieved without an openness from teams to share, allow others to learn from their own experiences (i.e. successes and mistakes) and review current practice and intuition. In this respect, the benefits of participation must be clearly conveyed (e.g. access to high-quality evidence-based practices that can help minimise injury/re-injury risk and support them a performance, financial and player welfare perspective).

6.6 General limitations

A variety of limitations have already been highlighted throughout the thesis which relate to the design of the specific studies contained within. However, there are a few more global limitations related to this research programme which must also be acknowledged.

Firstly, an evident limitation of the findings presented within this thesis is that they are primarily confined to the practices of European male professional football teams and particularly, those competing in their respective country's premier division. In fact, across Studies One and Three, this specific population accounted for close to 70% (107 teams) of all teams contributing to this research project. Furthermore, teams affiliated to the leading five football leagues in Europe, namely the 'Big Five' (i.e. the Premier League in England, the Bundesliga in Germany, La Liga in Spain, Serie A in Italy, and Ligue 1 in France), equated to 52% (56 of 107 teams) of all European teams participating. Accordingly, it should be acknowledged that a significant proportion of the insights obtained reflect those of professional teams possessing well-established infrastructures. In a rehabilitation context, such infrastructures are consistent with superior resources, including access to specialised multidisciplinary support staff, high-quality facilities, and substantial budgets (Hägglund et al., 2016). It is therefore plausible that such teams are in fact those best positioned to facilitate the integration recommendations outlined into their existing RTS practices (Hägglund et al., 2016).

In view of this, many of the research practice gaps identified and subsequent recommendations proposed are potentially only applicable to this cohort of professional football teams. Consequently, while broad agreement was typically observed in the uptake of evidence-based recommendations for RTS by high-level male professional teams, it is unknown if this message is equally consistent across other cohorts within professional football (e.g. elite-level non-European professional teams, sub-elite male professional teams, female professional teams, and youth academy teams). As outlined, future studies may be interested in exploring the decision-making processes of these other populations and establishing what may be the key barriers impeding the translation of evidence-based recommendations for RTS.

Secondly, the survey employed in Study One was developed to target the person/s of the sport medicine and science team responsible for the design and implementation of the RTS programme. It is therefore important to appreciate the findings presented in Study One only correspond to the perceptions of stakeholders specific to this department. Acquiring insights from those responsible for the delivery of the programme of rehabilitation was considered an appropriate starting point from which to address the overall aim of this thesis. In accordance with the steps outlined in StARRT framework for RTS decision-making (Shrier, 2015), these stakeholders are best positioned to establish how risk is assessed within professional football from the perspective of evaluating tissue health status (i.e. medical factors) and assessing stresses applied to the tissue (i.e. activity risk). Be that as it may, step three of the StARRT frameworks requires consideration of the wider context surrounding the RTS decision and the specific circumstances of the player, as well as those of the team and other stakeholders. In this respect, the locus of responsibility cannot lie solely within the medicine and science department. Accordingly, it is conceivable that responses relating to certain RTS processes (e.g. contribution to decisions, challenges encountered) would have varied according to the position of the stakeholder surveyed. Being able to obtain insights from other key stakeholders (e.g. players, managers) would have provided a richer quality of data from which to examine how recommendations presented within research are being translated into professional practice and how these are perceived and accepted by members of the decision-making team.

Thirdly, while the conduct of a scoping review was considered an integral component to achieving the aim of this thesis and played an important role in consolidating the areas of disconnect between research and current practice regarding the use of RTS criteria. Attempting to establish consistency with respect to the common assessments and specific thresholds used was perhaps ambitious given that a lack of standardisation and poor reporting of RTS criteria knowingly characterises the research literature. To better support current practice and progress the field, one could argue that a more appropriate direction following completion of the RTS survey would have been to conduct follow-up focus groups or individual interviews with medical and science practitioners. This may have provided a more comprehensive understanding of how RTS criteria are actually being used to support decision-making across a continuum following lower limb muscle injury. An approach that would have contributed to existing efforts to standardise the RTS decision-making process. However, I recognise that this thesis cannot be all things to all people and unfortunately, the approach was beyond its current scope. As outlined, this is an important avenue for future research that should be explored.

The final general limitation identified within this programme of research relates to the functionality of software (Novi Survey) used to administer the online RTS survey in Study One (Chapter Three). In attempting to comply with ethical standards, whilst trying to develop a user-friendly survey, the restrictive capabilities of this software were exposed. For example, to help secure a high response rate, a ‘save and continue later’ function was embedded into the survey to allow respondents to complete the survey at a time convenient to them. However, in doing so, the ability to protect the anonymity of respondents, whilst simultaneously attempting to guarantee the authenticity of collected data to be analysed, was increasingly challenged.

On account of the limitation of this software, to be able to conduct the survey, respondents had to be tracked semi-anonymously. This approach allowed participants to resume and complete the survey at their own convenience and also allowed me (as the researcher) to track initiated surveys via a system generated identification number (i.e. no personal details were required to be provided or stored). The latter of which, helped to protect against the inclusion of multiple survey responses by the same person/team. However, as this identification number was saved as a cookie on the device used to access the survey (e.g. smart phone, tablet, or computer), if cookies were disabled or several devices were used to access the same survey link, progress could not be saved, and respondents could not resume a previously saved survey. To account for this, in all correspondence with participants (i.e. initial email invitation and follow up reminders), it was explicitly outlined that they would not be able to resume answering a previously saved survey if cookies were disable or several devices were used to access and answer the same survey. Despite this, it cannot be ruled out that had a platform more compatible to the requirements of this survey been available (e.g. Qualtrics), a higher response rate may have been obtained and improved the external validity of the survey findings – at least within a male professional football capacity. To illustrate the potential impact of this limitation, of the 304 teams consenting to participate (99% of invited premier-league teams), 173 teams either failed to start the survey or were excluded due to incompletion.

6.7 Thesis conclusion

The practices of professional male football teams align with the current but basic recommendations of scientific research with respect to following a RTS continuum for rehabilitation and adopting criteria linked to clinical, functional, and psychological assessments. It is likely practitioners were following some form of RTS continuum whether formal or not, prior to the consensus statement in 2016. However, following on from the consensus, it appears to have formalised the approach to research and how practitioners may think more deeply about using a graded approach to rehabilitation practices. Despite some superficial alignment in the domains of criteria being adopted and agreed upon, an absence of standardised criteria as well as poor reporting of how these criteria are actually being used underpins both applied practice and scientific research. As a result, in turning to the research literature for guidance, football-based practitioners continue to remain largely unsupported with respect to selecting the best possible criteria to assist in the management of lower limb muscle injuries and decision-making processes.

Offering a broader perspective on the conclusions that can be extracted from this programme of work, perhaps the most significant finding is the strong desire among professional football teams and medical and science practitioners to think and work in a collaborative way to address challenges faced within practice. Specifically, this research project engaged directly with 160 male professional teams competing in 36 different leagues across 34 countries and over six continents; all of whom demonstrated a clear commitment to sharing and learning from each other to support the advance of scientific knowledge and ultimately levels of player care when returning to play following muscle injury. Through new initiatives outlined such as research and development departments, the field of professional football must continue to harness the advantages of working collectively to improve the ability to address key questions and challenges arising from applied practice.

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Appendix A.1.

Return to sport survey:

Progression criteria during return to play following a hamstring injury in professional football

(Chapter Three)

Progression criteria during return to play following a hamstring injury in professional football

The purpose of this survey is to determine the perceptions and practices put in place by the medical and sport science departments of premier league football teams worldwide regarding the criteria used to progress players throughout the return to play process following a typical hamstring time loss muscle injury of 18 days (Esktrand et al., 2016).

Please answer the survey based on your perceptions and practices during the 2016-17 season. The survey should take approximately 15 minutes to complete.

A report of the overall findings will be sent to each participating team. In accordance with the 1998 Data Protection Act all completed individual responses will be treated confidentially and anonymised.

Any publications and presentations concerning this survey will consist of overall results only and no identifying information will be shown or disclosed. The overall findings of this survey could be presented in congress and/or published in scientific articles.

1. I agree to partici pate

◯ Yes ◯ No

Progression criteria during return to play following a hamstring injury in professional football

Respondent Demographics

2. To be completed by the lead practitioner responsible for the return to play programme

Position held

League of club

Club (Optional)

If applicable, state the confederation cup competition you competed in last season (e.g. UEFA Champions league, Copa Liberatadores)

Please state which round of this competition you reached (e.g. group stages, knockout stages)

Progression criteria during return to play following a hamstring injury in professional football

Definitions

Injury Diagnosis

Typical hamstring time loss muscle injury - 18 days (Ekstrand et al., 2016)

Definition of Rehabilitation Phases

1. From Injury to Return to High Speed Running - The period between the injury occurring and the player being cleared to run on-field and progress to high speed running

2. Return to Run to Return to Training - When you allow the player to return to on-field unrestricted training with the first team

3. Return to Training to Return to Play - When the player is cleared to return to competitive match-play with the first team (whether selected or not)

4. Return to Play to Return to Performance - When the player has been deemed to return to pre injury levels of performance (or higher)

Progression criteria during return to play following a hamstring injury in professional football

Section 1: Return to High Speed Running

The period between injury occurring and the player being cleared to run on-field and progress to high speed running

3. Do you consider any of the following criteria to determine a players' clearance to return to high speed running? *Select as appropriate*

- ☐ Clinical
- ☐ Functional (e.g. physical, movement)
- ☐ Psychological
- ☐ None, we do not use any specific criteria at this stage
- ☐ Other

4. In order of importance, being as specific as possible, specify up to 3 criteria you use to decide a player is cleared to return to high speed running (e.g. pain, flexibility, X% of pre injury hamstring eccentric or isometric strength etc)

1.
2.
3.

5. With respect to the criteria you mentioned above, please specify (in corresponding order to Q4) which tool or test do you use to measure this (e.g. VAS-100 scale, Asking H-test, force plate etc)

1.
2.
3.

6. In general, please specify how often do you clear a player to return to high speed running without meeting all of the specific criteria you set?

Frequency (%)

7. What are the main challenges (if any) you face that would lead you to clear a player to return to high speed running before they have met the criteria you have set?

Please specify below

Challenges

8. At this stage, who is typically involved in the decision-making process to release or clear a player to return to high speed running?

Select as appropriate

- [ ] Manager
- [ ] Coach (technical staff)
- [ ] Club Doctor
- [ ] Physiotherapist
- [ ] Player
- [ ] Sport Scientist
- [ ] Strength and Conditioning Coach
- [ ] Other

9. If dealing with a quadricep, calf or adductor muscle injury, is there anything you would change or add with respect to the criteria, tools or tests you implement during this phase of rehabilitation?

Please specify below

Adductor

Quadricep

Calf

Progression criteria during return to play following a hamstring injury in professional football

Section 2: Return to Train

When you allow the player to return to on-field unrestricted training with the first team

10. Do you consider any of the following criteria to determine a players' clearance to return to train? *Select as appropriate*

- ☐ Clinical
- ☐ Functional (e.g. physical, movement)
- ☐ Psychological
- ☐ None, we do not use any specific criteria at this stage
- ☐ Other

11. In order of importance, being as specific as possible, specify up to 3 criteria you use to decide when a player is cleared to train (e.g. X% of average or maximal high-speed running performed in a match, within X% of pre injury hamstring eccentric strength, limb symmetry index >X% etc)

1. __________
2. __________
3. __________

12. With respect to the criteria you mentioned above, please specify (in corresponding order to Q11) which tool or test do you use to measure this (e.g. global positioning system (GPS), nordbord, isokinetic dynamometry etc)

1. __________
2. __________
3. __________

13. In general, please specify how often do you clear a player to return to training without meeting all of the specific criteria

you set?

Frequency (%)

14. What are the main challenges (if any) you face that would lead you to clear a player to return to training before they have met the criteria you have set?

Please specify below

Challenges

15. At this stage, who is typically involved in the decision-making process to release or clear a player to return to train? *Select as appropriate*

- [ ] Manager
- [ ] Coach (technical staff)
- [ ] Club Doctor
- [ ] Physiotherapist
- [ ] Player
- [ ] Sport Scientist
- [ ] Strength and Conditioning Coach
- [ ] Other

16. If dealing with a quadricep, calf or adductor muscle injury, is there anything you would change or add with respect to the criteria, tools or tests you implement during this phase of rehabilitation?

Please specify below

Adductor

Quadricep

Calf

Progression criteria during return to play following a hamstring injury in professional football

Section 3: Return to Play

When the player is cleared to return to competitive match-play with the first team (whether selected or not)

17. Do you consider any of the following criteria to determine a players' clearance to return to play? *Select as appropriate*

- [ ] Clinical
- [ ] Functional (e.g. physical, movement)
- [ ] Psychological
- [ ] None, we do not use any specific criteria at this stage
- [ ] Other

18. In order of importance, being as specific as possible, specify up to 3 criteria you use to decide when a player is cleared to return to play (e.g. achieved X% of players worst case match scenario for sprint distance, exposure to maximal speed X times, horizontal force mechanics etc)

1.
2.
3.

19. With respect to the criteria you mentioned above, please specify (in corresponding order to Q18) which tool or test do you use to measure this (e.g. global positioning system (GPS), speed gates, radar gun etc)

1.
2.
3.

20. In general, please specify how often do you clear a player to return to play without meeting all of the specific criteria you set?

Frequency (%)

21. What are the main challenges (if any) you face that would lead you to clear a player to return to play before they have met the criteria you have set?

Please specify below

Challenges [ ]

22. At this stage, who is typically involved in the decision-making process to release or clear a player to return to play? *Select as appropriate*

- [ ] Manager
- [ ] Coach (technical staff)
- [ ] Club Doctor
- [ ] Physiotherapist
- [ ] Player
- [ ] Sport Scientist
- [ ] Strength and Conditioning Coach
- [ ] Other

23. If dealing with a quadricep, calf or adductor muscle injury, is there anything you would change or add with respect to the criteria, tools or tests you implement during this phase of rehabilitation?

Please specify below

Adductor [ ]

Quadricep [ ]

Calf [ ]

Progression criteria during return to play following a hamstring injury in professional football

Section 4: Return to Performance

When the player has been deemed to return to pre injury levels of performance (or higher)

24. Once cleared to return to play, do you continue to monitor the player to assess when/if pre-injury performance levels (or higher) have been achieved?

◯ Yes

◯ No

25. Do you consider any of the following criteria to determine a players' return to pre-injury levels of performance (or higher)?

Select as appropriate

☐ Clinical

☐ Functional (e.g. physical, movement)

☐ Psychological

☐ None, we do not use any specific criteria at this stage

☐ Other

26. In order of importance, being as specific as possible, specify up to 3 criteria you use to decide a player has returned to performance

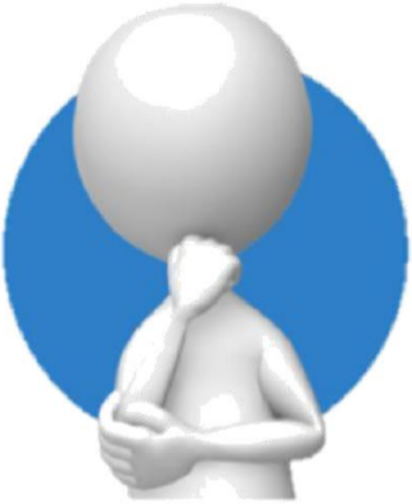
1. __________

2. __________

3. __________

Progression criteria during return to play following a hamstring injury in professional football

Section 5: Additional Comments



27. Is there any additional information regarding your current rehabilitation programme that potentially may not have been directly addressed within the survey that you would like to add?

Please specify below

28. Would you be open to a follow up telephone interview if requested?

- Yes
- No

29. Please provide your personal details as directed

Name

Email Address

Contact Telephone Number

Appendix A.2.

A priori study protocol registration

(Chapter Four)

Criteria informing rehabilitation progression and return to play clearance following lower limb muscle injury in 'football code' team sport athletes: A scoping review

Scoping Review Protocol Registration

Gordon Dunlop, Dr Roberto Modena, Dr Alan McCall

This scoping review protocol registration is based on a modified version of the PROSPERO systematic review registration format. This protocol is registered with the Open Science Framework

1. **Review title:** Criteria informing rehabilitation progression and return to play clearance following lower limb muscle injury in 'football code' team sport athletes: A scoping review

2. **Start date:** October 2019

3. **Anticipated completion date:** July 2020

4. **Stage of review at time of submission**

	Started	Completed
Preliminary Searches	✓	✓
Piloting of the study selection process	✓	✓
Formal screening of search results against eligibility criteria	✓	✓
Data extraction		
Risk of bias (quality) assessment	N/A	
Data analysis		

5. Named contact:

Gordon Dunlop

6. Named email address:

[redacted]

7. Named contact address:

Room 1B.27, Edinburgh Napier University, Sighthill Campus, 9 Sighthill Court, Edinburgh, EH11 4BN

8. Named contact phone number:

[redacted]

9. Organisational affiliation of the review:

Edinburgh Napier University

Arsenal Football Club

Oslo Sports Trauma Research Centre

University of Verona

10. Review team members and their organisational affiliations:

Gordon Dunlop. Edinburgh Napier University, Edinburgh Napier University

Dr Roberto Modena – University of Verona, Department of Neuroscience, Biomechanics and Movement.

Dr Alan McCall - Edinburgh Napier University, Edinburgh Napier University

Prof Thor Einar Andersen – Oslo Sports Trauma Research Centre, Norwegian School of Sport Sciences

Dr Susan Brown – Edinburgh Napier University, School of Applied Sciences

11. Funding sources/sponsors:

This research is being conducted as part of a PhD funded by Edinburgh Napier University and PUMA who are in partnership with Arsenal Football Club. The funders of the study played no role in the study design, data collection, data analysis, data interpretation or writing of the report.

12. Conflicts of interest:

The review team members declare that they have no conflicts of interest directly relevant to the content of this scoping review.

13. Collaborators:

Dr Clare L Ardern - Linkoping University, Department of Medical and Health Sciences

14. Review question:

The research question was developed based upon the PCC (Population, Concept and Context) elements as recommended by the Joanna Briggs Institute (Peters et al., 2017). Unlike systematic reviews, scoping reviews aim adopt a broader 'scope' of enquiry with correspondingly less restrictive inclusion criteria. For this reason, a less restrictive alternative to the PICO (Population, Intervention, Comparator and Outcome) elements is being used.

This scoping review seeks to assess and analyse the body of scientific literature surrounding the criteria used to guide rehabilitation progression and return to play clearance following lower limb muscle injury. The specific research question is:

1. What types of criteria are used to inform decision-making following injury to the major muscle groups of the lower limb in football-code team-sport athletes?

15. Searches:

The following six electronic databases will be searched to identify articles which meet the a priori eligibility criteria: MEDLINE (Pubmed), CINAHL, SCOPUS, SPORTSDiscus, PsycInfo and Web of Science.

No date restrictions were placed on publication period with all databases being searched from their inception until the date the search is performed. The full search was restricted to English publications only.

Adhering to the methodological framework outlined by Arskey and O'Malley (2005) an initial limited search was performed in July 2019 to help identify relevant studies. We conducted an initial search of the MEDLINE, SCOPUS and Web of Science electronic databases using the search query (football OR soccer OR rugby OR "team sport*") AND (rehabilitation OR "return to play") AND (muscle injury OR tendon injury). These terms were considered by the review team members to broadly cover the elements of the current scoping review and no search limits were placed on the database searches (e.g. time or language).

<u>Our initial search strategy returned 1089 articles:</u>
Medline (176 articles retrieved)
Web of Science (534 articles retrieved)
Scopus (379 articles retrieved)

Following the removal of duplicate articles and those not meeting inclusion criteria, the title abstract and index terms of 271 articles were screened to identify keywords to facilitate the development of the full search strategy.

The full search strategy was created in accordance with published guidelines (Aromataris et al., 2014) and subsequently peer reviewed by an expert librarian using the Peer Review of Electronic Search Strategies (PRESS) checklist (Appendix I), and modified as required (McGowan et al., 2016). The reference lists of included studies will be screened in addition to those of relevant systematic reviews to identify any potentially eligible articles that may have been missed in the electronic database searches. The full search strategy is presented in the supplementary appendix (Appendix II)

The full search strategy was first performed on the 28th of October 2019. It was subsequently re-run the 1st of May 2020 prior to completing formal screening to include any additional relevant articles published since October and ensure the review was representative of the current literature within this specific field. This subsequent search was restricted to articles published between October 2019 and May 2020 (where possible) and returned 811 articles which were then subject to screening.

Including both searches, the articles retrieved are presented below.

Full search strategy returned 12,413 articles:
Medline (2583 articles retrieved)
Cinahl (1807 articles retrieved)
Psycinfo (1444 articles retrieved)
SPORT Discus (2927 articles retrieved)
Web of Science (1940 articles retrieved)
Scopus (1712 articles retrieved)

Following the removal of duplicate articles (4329 articles), 7512 articles were carried forward into level 1 screening. As part of this process, article titles and abstracts were screened against the eligibility criteria for the current study. Following the removal of articles which did not meet eligibility criteria, 599 articles were taken forward to level 2 screening wherein the full text of each article will be screened.

16. URL to search strategy: N/A

17. Condition or domain being studied:
The domain being studied is injury rehabilitation. Specifically, the rehabilitation of muscle injuries involving the major muscle groups of the lower limb.

18. Participants/Population:
Professional team sport athletes who participate in high intensity intermittent football-code sports - Soccer, Australian Rules Football, Rugby Union, Rugby League, American Football.

19. Concept:

The types of criteria being used and reported in published literature to help support and inform decision making in relation to rehabilitation progression and return to play clearance.

20. Context:

This scoping review is specifically centred around injury to the four major muscle groups of the lower limb i.e. hamstrings, quadriceps, adductors and calf muscles.

21. Intervention(s), exposure(s): N/A

22. Comparator(s)/control: N/A

23. Types of studies to be included:

Prospective or retrospective intervention or observational studies published in English language will be included that document a rehabilitation program or describe the criteria adopted. Only full text articles will be included.

24. Main outcome(s):

The outcomes of this review will be to:

1. To describe the criteria used in published research to progress rehabilitation and clear football-code team sport athletes to return to unrestricted training and match-play following injury to the major muscle groups of the lower limb.

2. To describe how criteria is being used to inform decision-making.

3. To identify and analyse the knowledge gaps in the literature to inform future research.

25. Additional outcome(s): N/A

26. Data Extraction (selection and coding):

Within this study, a two-stage screening process will be implemented to assess the relevance of articles identified from the literature search. Authors GD and RM will independently screen titles and abstracts (first stage screening) of retrieved articles to establish eligibility of articles which may fit inclusion criteria for analysis (Table 1). All articles which satisfy first-level screening will be retained for second-level screening (review of the full-text article). Once again, authors GD and RM will independently screen full-text articles to determine inclusion in the scoping review. Upon completing each stage of the screening process, any discrepancies or disagreements between the authors will be resolved through discussion or further adjudication by a third reviewer (AMcC).

Table 1: Eligibility Criteria

Inclusion Criteria	Exclusion Criteria
• Original Research Articles - prospective, retrospective intervention, observational studies and rehabilitation guidelines/protocols • Articles relating to intermittent football code team-based sports: Football (soccer) Rugby (union or league codes) Australian football league (AFL) National football league (NFL) • Both male and female populations will be included • Articles that include participants of a professional academy standard or higher (snr professional). This should include Collegiate levels for American football players • Any participants from populations under investigation who are undergoing rehabilitation practices for muscle injuries to any of the four major muscle groups of the lower limbs (i.e. hamstring,	• Systematic reviews, conference abstracts, narrative reviews, opinion pieces, magazine or newspaper articles and non-peer reviewed articles. • Non-professional populations • Articles involving surgery or discussing surgery techniques which then do not include post-intervention rehabilitation intervention protocols or criteria • Articles whose focus is toward injury diagnosis (i.e. injury grading, clinical evaluation tests) without providing a prognosis outcome for RTP will not be included • Articles which do not include any of the described team-sport populations under investigation • Articles which do not include injuries to any of the four muscle groups under investigation

quadriceps, adductor muscles and calf). • Muscle injuries will be considered to be a traumatic distraction or overuse injury to skeletal muscle tissue (including both first time or recurrent lesions) sustained by an athlete that results from training or competition participation and leads to the athlete being unavailable to take full part in future training or competition. • Article will not be restricted by muscle injury classification/grading as long as the injury has resulted in time-loss/absence • Articles which describe any criteria that is used to inform rehabilitation progression or clearance to return to play for any one of the four major muscle groups under investigation – this includes any element of rehabilitation and/or return to play. We are not focused solely on any particular milestone of the rehabilitation or RTP process.	• Any muscle injury that does not result in time loss • If the injury is a secondary injury and not the focus of the paper – No rehab information given in relation to the injury of interest for this scoping review • Any articles not available in full text • Any article not published in English

All aspects of rehabilitation process will be considered. • Any article which describes rehabilitation or return to play protocols • Both surgical and non-surgical rehabilitation strategies will be considered. • Studies published in the English language	

Data from included studies will be charted using a standardised data extraction form developed for the study using Microsoft Excel 2016 (Microsoft Corporation, Redmond, WA). The form will be used to record and assimilate extracted information on study characteristics as well as the criteria used to inform rehabilitation progression and return to play clearance. The charting form will be pre-tested by both independent reviewers (GD and RM) on a sample of articles to confirm consistency between reviewers and ensure that all relevant data are being captured. Owing to the iterative process of scoping reviews, the data-charting form will be continuously updated during the data extraction process. The characteristics of each full-text article will be charted independently by both reviewers. As described, any disagreement or discrepancies between reviews will be resolved through discussion or intervention via a third reviewer (AMcC).

Data Items

The following data items will be extracted

- Author(s)
- Year of publication
- Country of study origin
- Article type
- Level of evidence
- Aims/purpose
- Study population (age, sex, sport)
- Sample size
- Injury information (e.g. location, type, time-loss)
- Rehabilitation protocol (e.g. surgical or nonsurgical, criteria or time-based approach)
- Assessment criteria
- Assessment tools
- Specific criteria information (e.g. benchmarks, cut-offs, thresholds etc)

**Please note that owing to the iterative process of scoping reviews, the data-charting form may/will be continuously updated during the data extraction process.

27. Risk of bias (quality) assessment:

On account of the descriptive and exploratory nature of this scoping review, no appraisal of methodological quality or risk of bias will be performed on the articles included in this review. This approach is consistent with the guidance on scoping review conduct (Arskey and O'Malley, 2005; Peters et al., 2017).

28. Strategy for data synthesis:

Data will be summarised and tabulated according to the 13 data extraction categories outlined. Following data extraction, consensus will be used (among the review team members) to determine how best to group and categorise criteria.

Quantitative analysis will be conducted using descriptive methods (i.e. frequencies, summary statistics) where appropriate. Another appropriate technique commonly used for presenting data collected in scoping reviews is gap mapping. Based on the outcomes of this study, the research team will discuss and consider if this is a viable approach as part of our data synthesis. All strategies used for data synthesis will be supplemented by a narrative review describing included studies under the primary aims of the scoping review.

29. Analysis of subgroups or subsets:

It is possible that data extracted may be analysed and categorised in relation to specific muscle group injured, sport performed and/or criteria type.

30. Type and method of review:

Scoping Review

31. Language:

English

32. Country:

United Kingdom

33. Other registration details: N/A

34. Reference and/or URL for published protocol

The scoping review protocol will be submitted to the Open Science Framework for registration

35. Dissemination plans:

The scoping review is intended for publication in a sports science and medical peer reviewed journal upon completion. The results may also be used in international congress.

36. Keywords:

Return to play, Rehabilitation, Muscle Injury, Football, Soccer, Rugby

37. Current Review Status:

Ongoing

Appendix A.3.

The Peer Review of Electronic Search Strategies (PRESS) Checklist

(Chapter Four)

PRESS Guideline **— Search Submission & Peer Review Assessment**

SEARCH SUBMISSION: THIS SECTION TO BE FILLED IN BY THE SEARCHER

Searcher: Gordon Dunlop	Email: [redacted]	
Date submitted: 11/10/2019	Date requested by: 15/10/2019	*[Maximum = 5 working days]*

Scoping Review Title

Criteria informing rehabilitation progression and return to play clearance following lower limb muscle injury in 'football code' team sports: A Scoping Review

This search strategy is …

▯	My PRIMARY (core) database strategy — First time submitting a strategy for search question and database
	My PRIMARY (core) strategy — Follow-up review NOT the first time submitting a strategy for search question and database. If this is a response to peer review, itemize the changes made to the review suggestions
	SECONDARY search strategy— First time submitting a strategy for search question and database
	SECONDARY search strategy — NOT the first time submitting a strategy for search question and database. If this is a response to peer review, itemize the changes made to the review suggestions

Database

(i.e., MEDLINE,CINAHL…): *[mandatory]*

Medline, Cinahl, Psycinfo, SPORT Discus, Web of Science and Scopus

Interface

(i.e., Ovid, EBSCO…): *[mandatory]*

EBSCO

Research Question

(Describe the purpose of the search) *[mandatory]*

Consistent across team-based high-intensity football code sports such as soccer (i.e. football) and Australian Football League (AFL), the incidence of muscle re-injuries to the major muscle groups of the lower limbs (hamstring, quadriceps, adductors, and calf) remain high and thus has prompted greater interest in the area of RTP. In particular, the finding that a significant proportion of these recurrences occur 'early' (i.e. within 2months) following clearance to return to unrestricted training and match play has given rise to the viewpoint that inadequate rehabilitation and/or premature RTP may be possible risk factors contributing to re-injury.

Understanding what and how criteria are specifically progressed across rehabilitation to inform return to play (RTP) following an injury represents an important aspect of the decision-making process to ensure players/athletes are adequately prepared to return to unrestricted training and competition respectively.

It has been advocated that scoping reviews are particularly relevant to disciplines with emerging evidence such as rehabilitation, in which a lack of high-level studies makes it difficult to conduct more precise systematic reviews and perform meta-analyses (Levac et al., 2010). This difficulty is exacerbated when reviews are specifically directed toward investigating elite sporting populations (i.e. professional athletes) owing to the logistical difficulties of implementing high-level research (e.g. randomized-control trials) in performance settings (e.g. professional sports teams). Consequently, scoping reviews have emerged as a relatively new form of knowledge synthesis, with their conduct becoming increasingly more prominent in the fields such as rehabilitation and return to play (Phan et al., 2017; Burgi et al., 2018; Rambaud et al., 2018).

The purpose of this scoping review is to describe the criteria used in published research to progress lower limb muscle injury rehabilitation and inform return to play decisions in football-code team sports

PPC Format

(Outline the PPC for your question — i.e., Population, Concept, Context, — as applicable)

P	Professional team sport athletes participating in football code sports (Soccer, Australian Rules Football, Rugby Union, Rugby League and American Football
P	Types of criteria used and reported in published literature to help inform decision making in relation to rehabilitation progression and return to play clearance
C	This scoping review will be specifically centred around injury to the four major muscle groups of the lower limb i.e. hamstrings, quadriceps, adductors and calf muscles

Inclusion Criteria

(List criteria such as age groups, study designs, etc., to be included) *[optional]*

• Original Research Articles - prospective, retrospective intervention, observational studies and rehabilitation guidelines/protocols

• Articles relating to intermittent football code team-based sports:

Football (soccer) / Rugby (union/league codes) / Australian football league (AFL) / National football league (NFL)

• Both male and female populations will be included

• Articles that include participants of a professional academy standard or higher (snr professional). This should include Collegiate levels for American football players

• Any participants from populations under investigation who are undergoing rehabilitation practices for muscle injuries to any of the four major muscle groups of the lower limbs (i.e. hamstring, quadriceps, adductor muscles and calf).

• Muscle injuries will be considered to be a traumatic distraction or overuse injury to skeletal muscle tissue (including both first time and recurrent lesions) sustained by an athlete that results from training or competition participation and leads to the athlete being unavailable to take full part in future training or competition.

• Article will not be restricted by muscle injury classification/grading as long as the injury has resulted in time-loss/absence

• Articles which describe any criteria that is used to inform rehabilitation progression or clearance to return to play for any one of the four major muscle groups under investigation – this includes any element of rehabilitation and/or return to play. We are not focused solely on any particular milestone of the rehabilitation or RTP process. All aspects of rehabilitation process will be considered.

• Any article which describes rehabilitation or return to play protocols

• Both surgical and non-surgical rehabilitation strategies will be considered.

• Studies published in the English language

Exclusion Criteria

(List criteria such as study designs, date limits, etc., to be excluded) *[optional]*

• Systematic reviews, conference abstracts, narrative reviews, opinion pieces, magazine or newspaper articles and non-peer reviewed articles.

• Non-professional populations

• Articles involving surgery or discussing surgery techniques which then do not include post-intervention rehabilitation intervention protocols or criteria

• Articles whose focus is toward injury diagnosis (i.e. injury grading, clinical evaluation tests) without providing a prognosis outcome for RTP will not be included

• Articles which do not include any of the described team-sport populations under investigation

• Articles which do not include injuries to any of the four muscle groups under investigation

• Any muscle injury that does not result in time loss

• If the injury is a secondary injury and not the focus of the paper – No rehab information given in relation to the injury of interest for this scoping review

• Any articles not available in full text

• Any article not published in English

Was a search filter applied?

☐ Yes ☐ No ▯

If YES, which one(s) (e.g., Cochrane RCT filter, PubMed Clinical Queries filter)? Provide the source if this is a published filter. *[mandatory if YES to previous question — textbox]*

Other notes or comments you feel would be useful for the peer reviewer? ***[optional]***

Please copy and paste your search strategy here, exactly as run, including the number of hits per line. ***[mandatory]***

(Add more space, as necessary.)

Example of search strategy for the MEDLINE database

Please note that Line 1, 2 and 3 are connected with the Boolean operator 'AND' and line 4 with the Boolean operator 'NOT'

Line 1: football OR soccer OR AFL OR rugby OR NFL **(Hits = 22,395)**

AND

Line 2: manag* OR conserv* OR non-operative OR nonoperative OR surg* OR operative OR progress* OR "decision-making" OR clinical* OR criteri* OR therap* OR rehab* OR readaptation OR adaptation OR treat* OR convalescen* OR outcome* OR diagnosis OR prognosis OR return* to competit* OR return* to participation OR "return* to play" OR "return* to sport*" OR return* to train* OR “return* to run*” OR "time to return" OR "training fitness" OR "sport* participation" OR “patient-reported outcome*” OR athlete self-report* measure* OR (“return* to” AND (“pre-Injury level*” OR “preinjury level*” OR “pre injury level*”)) OR return* to perform* OR recovery of function OR functional recovery OR (MH “Diagnostic Imaging”) **(Hits = 12,851)**

AND

Line 3: hamstring OR "biceps femoris" OR semitendinosus OR semimembranosus OR quadriceps OR "rectus femoris" OR "vastus lateralis" OR "vastus medialis" OR "vastus intermedius" OR "anterior thigh pain" OR "posterior thigh pain" OR "calf muscle" OR gastrocnemius OR soleus OR "triceps surae" OR tibialis OR peroneus OR (adductor AND (injur* OR strain)) OR obturator OR gracilis OR "pectineus muscle" OR “adductor magnus” OR “adductor brevis” OR “adductor longus” OR (groin AND (injur* OR strain OR pain)) OR (muscle AND (injur* OR tear OR strain OR avulsion OR rupture)) OR (tendon AND (injur* OR tear OR avulsion OR rupture)) OR “avulsion Injur*” OR "upper leg*" OR "lower leg*” OR reinjur* OR re-injur* OR “recurr* injur*” OR “injury recurrence” OR (“sports medicine” AND (injur*)) OR (“inguinal canal” AND (injur*)) OR (MH "Athletic Injuries" AND (MW "TH" OR "SU" OR "RH" OR "PX")) OR (MH "Groin") OR (MH "Rupture" AND (MW "TH" OR "SU" OR "PX" OR "RH")) OR (MH "Fractures, Avulsion") OR (MH "Sprains and Strains" AND (MW "TU" OR "SU" OR "RH" OR PX")) OR (MH “Wounds and Injuries” AND (MW “RH” OR “SU” OR “PX” OR “TH”)) OR (MH “Pain” AND (MW “RH” OR “PX” OR “SU”)) OR (MH “Leg Injuries” AND (MW “RH” OR “PX” OR “SU” OR “TH”)) OR (MH "Inguinal Canal" AND (MW "SU" OR "IN")) OR (MH “Sports Medicine”) **(Hits = 3,072)**

NOT

Line 4: concussion OR ACL OR “anterior cruciate ligament” OR “anterior cruciate ligament reconstruction” **(Hits = 2442)**

PEER REVIEW ASSESSMENT: THIS SECTION TO BE FILLED IN BY THE REVIEWER

Reviewer: Laura Ennis	Email: [redacted]	Date completed: 14/10/2019

1. TRANSLATION

A ---No revisions	☐
B --- Revision(s) suggested	☐
C --- Revision(s) required	☐

If "B" or "C," please provide an explanation or example:

2. BOOLEAN AND PROXIMITY OPERATORS

A ---No revisions	☐
B --- Revision(s) suggested	☐
C --- Revision(s) required	☐

If "B" or "C," please provide an explanation or example:

☐ Using NOT to exclude articles about concussion and ACL injuries removes 300 results. Your justification for it is sound and after a quick look at them and I couldn't see anything relevant to your topic. I think your use of NOT here is fine and you should keep it. But I did want to note it as you might get some questions about excluding results.

☐ The PRESS recommends substituting NEAR operators for AND. However, given that this is a scoping review I'm not sure that this would save you much time.

3. SUBJECT HEADINGS

A ---No revisions	☐
B --- Revision(s) suggested	☐
C --- Revision(s) required	☐

If "B" or "C," please provide an explanation or example:

☐ I can't remember if you mentioned any exclusion criteria (beyond ACL-related injuries) but if you are going back a couple of decades then in MEDLINE the MeSH for "Athletic Injuries" was indexed as "Sport Medicine" prior to 1967, and "Groin" was indexed as "Inguinal Canal" prior to 1980. If you're going back that far you may need to include the older headings.

4. TEXT WORD SEARCHING

A ---No revisions	☐
B --- Revision(s)suggested	▯
C --- Revision(s) required	☐

If "B" or "C," please provide an explanation or example:

- Even broken up into Population, Concept and Context these are pretty hefty searches to do all at once. You could group each into smaller queries (this does make it easier to find any mistakes) but structuring searches this way is more personal preference (on the part of McGowan et al.) and not something you absolutely need to do.

5. SPELLING, SYNTAX, AND LINE NUMBERS

A ---No revisions	☐
B --- Revision(s)suggested	☐
C --- Revision(s) required	▯

If "B" or "C," please provide an explanation or example:

- Not a spelling error but I wonder if you missed out a truncation mark after return in "Return to Competit*" as all the other instances of return are phrased "Return* to play" "Return* to sport*" etc.

- Also, "patient reported outcome*" returns more results than "patient reported outcomes" But I don't know if the plural is important?

6. LIMITS AND FILTERS

A ---No revisions	☐
B --- Revision(s) suggested	▯
C --- Revision(s) required	☐

If "B" or "C," please provide an explanation or example:

- You've not mentioned any, but if you were going to put a timeframe around the search it might be good to note it in the protocol.

OVERALL EVALUATION (Note: If one or more "revision required" is noted above, the response below must be "revisions required".)

A ---No revisions	☐
B --- Revision(s) suggested	☐
C --- Revision(s) required	▯

Additional comments:

Appendix A.4.

Full search strategy across all databases screened

(Chapter Four)

Please note the Boolean operators ‘AND’ and ‘NOT’ were used to connect the different elements of the search strategy

MEDLINE Search Strategy

Population: football OR soccer OR AFL OR rugby OR NFL

AND

Concept: manag* OR conserv* OR non-operative OR nonoperative OR surg* OR operative OR progress* OR "decision-making" OR clinical* OR criteri* OR therap* OR rehab* OR readaptation OR adaptation OR treat* OR convalescen* OR outcome* OR diagnosis OR prognosis OR return* to competit* OR return* to participation OR "return* to play" OR "return* to sport*" OR return* to train* OR “return* to run*” OR "time to return" OR "training fitness" OR "sport* participation" OR “patient-reported outcome*” OR athlete self-report* measure* OR (“return* to” AND (“pre-injury level*” OR “preinjury level*” OR “pre injury level*”)) OR return* to perform* OR recovery of function OR functional recovery OR (MH “Diagnostic Imaging”)

AND

Context: hamstring OR "biceps femoris" OR semitendinosus OR semimembranosus OR quadriceps OR "rectus femoris" OR "vastus lateralis" OR "vastus medialis" OR "vastus intermedius" OR "anterior thigh pain" OR "posterior thigh pain" OR "calf muscle" OR gastrocnemius OR soleus OR "triceps surae" OR tibialis OR peroneus OR (adductor AND (injur* OR strain)) OR obturator OR gracilis OR "pectineus muscle" OR “adductor magnus” OR “adductor brevis” OR “adductor longus” OR (groin AND (injur* OR strain OR pain)) OR (muscle AND (injur* OR tear OR strain OR avulsion OR rupture)) OR (tendon AND (injur* OR tear OR avulsion OR rupture)) OR “avulsion Injur*” OR "upper leg*" OR "lower leg*” OR reinjur* OR re-injur* OR “recurr* injur*” OR “injury recurrence” OR (“sports medicine” AND (injur*)) OR (“inguinal canal” AND (injur*)) OR (MH "Athletic Injuries" AND (MW "TH" OR "SU" OR "RH" OR "PX")) OR (MH "Groin") OR (MH "Rupture" AND (MW "TH" OR "SU" OR "PX" OR "RH")) OR (MH "Fractures, Avulsion") OR (MH "Sprains and Strains" AND (MW "TU" OR "SU" OR "RH" OR PX")) OR (MH “Wounds and Injuries” AND (MW “RH” OR “SU” OR “PX” OR “TH”)) OR (MH “Pain” AND (MW “RH” OR “PX” OR “SU”)) OR (MH “Leg Injuries” AND (MW “RH” OR “PX” OR “SU” OR “TH”)) OR (MH "Inguinal Canal" AND (MW "SU" OR "IN")) OR (MH “Sports Medicine”)

NOT

concussion OR ACL OR “anterior cruciate ligament” OR “anterior cruciate ligament reconstruction”

CINAHL Search Strategy

Population: football OR soccer OR AFL OR rugby OR NFL

AND

Concept: manag* OR conserv* OR non-operative OR nonoperative OR surg* OR operative OR progress* OR "decision-making" OR clinical* OR criteri* OR therap* OR rehab* OR readaptation OR adaptation OR treat* OR convalescen* OR outcome* OR diagnosis OR prognosis OR return* to competit* OR return* to participation OR "return* to play" OR "return* to sport*" OR return* to train* OR “return* to run*” OR "time to return" OR "training fitness" OR "sport* participation" OR “patient-reported outcome*” OR athlete self-report* measure* OR (“return* to” AND (“pre-Injury level*” OR “preinjury level*” OR “pre injury level*”)) OR return* to perform* OR recovery of function OR functional recovery OR (MH “Sports Re-Entry”) OR (MH “Recovery/ST/PF/EV/PH")

AND

Context: hamstring OR "biceps femoris" OR semitendinosus OR semimembranosus OR quadriceps OR "rectus femoris" OR "vastus lateralis" OR "vastus medialis" OR "vastus intermedius" OR "anterior thigh pain" OR "posterior thigh pain" OR "calf muscle" OR gastrocnemius OR soleus OR "triceps surae" OR tibialis OR peroneus OR (adductor AND (injur* OR strain)) OR obturator OR gracilis OR "pectineus muscle" OR “adductor magnus” OR “adductor brevis” OR “adductor longus” OR (groin AND (injur* OR strain OR pain)) OR (muscle AND (injur* OR tear OR strain OR avulsion OR rupture)) OR (tendon AND (injur* OR tear OR avulsion OR rupture)) OR “avulsion Injur*” OR "upper leg*" OR "lower leg*” OR reinjur* OR re-injur* OR “recurr* Injur*” OR “injury recurrence” OR (MH "Football Injuries/RH/SU/TH/PF") OR (MH "Soccer Injuries/RH/SU/TH/PF") OR (MH "Rugby Injuries/RH/SU/TH/PF") OR (MH "Groin") OR (MH "Athletic Injuries/SU/RH/PF/TH") OR (MH "Soft Tissue Injuries") OR (MH "Sprains and Strains/TH/SU/RH/PF") OR (MH "Avulsion Fractures") OR (MH "Rupture") OR (MH "Lower Extremity/IN") OR (MH "Pain/TH/SU/RH/PF/DI") OR (MH "Pain Management")

NOT

concussion OR ACL OR “anterior cruciate ligament” OR “anterior cruciate ligament reconstruction”

SPORTSDiscus Search Strategy

Population: football OR soccer OR AFL OR rugby OR NFL

AND

Concept: manag* OR conserv* OR non-operative OR nonoperative OR surg* OR operative OR progress* OR "decision-making" OR clinical* OR criteri* OR therap* OR rehab* OR readaptation OR adaptation OR treat* OR convalescen* OR outcome* OR prognosis OR diagnosis OR return* to competit* OR return* to participation OR "return* to play" OR "return* to sport*" OR return* to train* OR “return* to run*” OR "time to return" OR "training fitness" OR "sport* participation" OR “patient-reported outcome*” OR athlete self-report* measure* OR (“return* to” AND (“pre-Injury level*” OR “preinjury level*” OR “pre injury level*”)) OR return* to perform* OR recovery of function OR functional recovery OR (DE “DIAGNOSTIC imaging”)

AND

Context: hamstring OR "biceps femoris" OR semitendinosus OR semimembranosus OR quadriceps OR "rectus femoris" OR "vastus lateralis" OR "vastus medialis" OR "vastus intermedius" OR "anterior thigh pain" OR "posterior thigh pain" OR "calf muscle" OR gastrocnemius OR soleus OR "triceps surae" OR tibialis OR peroneus OR (adductor AND (injur* OR strain)) OR obturator OR gracilis OR "pectineus muscle" OR “adductor magnus” OR “adductor brevis” OR “adductor longus” OR (groin AND (injur* OR strain OR pain)) OR (muscle AND (injur* OR tear OR strain OR avulsion OR rupture)) OR (tendon AND (injur* OR tear OR avulsion OR rupture)) OR “avulsion injur*” OR "upper leg*" OR "lower leg*” OR reinjur* OR re-injur* OR “recurr* injur*” OR “injury recurrence” OR (DE "PAIN management") OR (SU "PAIN") OR (DE "AVULSION fractures") OR (DE "RUPTURE of organs, tissues, etc.") OR (DE "LEG injuries") OR (DE "OVERUSE injuries") OR (DE "SOFT tissue injuries") OR (DE "FOOTBALL injuries") OR (DE "RUGBY football injuries") OR (DE "SOCCER injuries")

NOT

concussion OR ACL OR “anterior cruciate ligament” OR “anterior cruciate ligament reconstruction”

Psycinfo Search Strategy

Population: football OR soccer OR AFL OR rugby OR NFL OR sport

AND

Concept: manag* OR conserv* OR non-operative OR nonoperative OR surg* OR operative OR progress* OR "decision-making" OR clinical* OR criteri* OR therap* OR rehab* OR readaptation OR adaptation OR treat* OR convalescen* OR outcome* OR prognosis OR diagnosis OR return* to competit* OR return* to participation OR "return* to play" OR "return* to sport*" OR return* to train* OR “return* to run*” OR "time to return" OR "training fitness" OR "sport* participation" OR “patient-reported outcome*” OR athlete self-report* measure* OR (“return* to” AND (“pre-Injury level*” OR “preinjury level*” OR “pre injury level*”)) OR return* to perform* OR recovery of function OR functional recovery OR (MJ “athletic performance”)

AND

Context: hamstring OR "biceps femoris" OR semitendinosus OR semimembranosus OR quadriceps OR "rectus femoris" OR "vastus lateralis" OR "vastus medialis" OR "vastus intermedius" OR "anterior thigh pain" OR "posterior thigh pain" OR "calf muscle" OR gastrocnemius OR soleus OR "triceps surae" OR tibialis OR peroneus OR (adductor AND (injur* OR strain)) OR obturator OR gracilis OR "pectineus muscle" OR “adductor magnus” OR “adductor brevis” OR “adductor longus” OR (groin AND (injur* OR strain OR pain)) OR (muscle AND (injur* OR tear OR strain OR avulsion OR rupture)) OR (tendon AND (injur* OR tear OR avulsion OR rupture)) OR “avulsion Injur*” OR "upper leg*" OR "lower leg*” OR reinjur* OR re-injur* OR “recurr* injur*” OR “injury recurrence” OR (MJ "Pain") OR (MJ "Injuries")

NOT

concussion OR ACL OR “anterior cruciate ligament” OR “anterior cruciate ligament reconstruction”

Web of Science Search Strategy

Population: football OR soccer OR AFL OR rugby OR NFL

AND

Concept: manag* OR conserv* OR non-operative OR nonoperative OR surg* OR operative OR progress* OR "decision-making" OR clinical* OR criteri* OR therap* OR rehab* OR readaptation OR adaptation OR treat* OR convalescen* OR outcome* OR prognosis OR diagnosis OR return* to competit* OR return* to participation OR "return* to play" OR "return* to sport*" OR return* to train* OR "return* to run*" OR "time to return" OR "training fitness" OR "sport* participation" OR "patient reported outcome*" OR athlete self-report* measure* OR ("return* to" AND ("pre-Injury level*" OR "preinjury level*" OR "pre injury level*")) OR return* to perform* OR recovery of function OR functional recovery

AND

Context: hamstring OR "biceps femoris" OR semitendinosus OR semimembranosus OR quadriceps OR "rectus femoris" OR "vastus lateralis" OR "vastus medialis" OR "vastus intermedius" OR "anterior thigh pain" OR "posterior thigh pain" OR "calf muscle" OR gastrocnemius OR soleus OR "triceps surae" OR tibialis OR peroneus OR (adductor AND (injur* OR strain)) OR obturator OR gracilis OR "pectineus muscle" OR "adductor magnus" OR "adductor brevis" OR "adductor longus" OR (groin AND (injur* OR strain OR pain)) OR (muscle AND (injur* OR tear OR strain OR avulsion OR rupture)) OR (tendon AND (injur* OR tear OR avulsion OR rupture)) OR "avulsion Injur*" OR "upper leg*" OR "lower leg*" OR reinjur* OR re-injur* OR "recurr* Injur*" OR "injury recurrence"

NOT

concussion OR ACL OR "anterior cruciate ligament" OR "anterior cruciate ligament reconstruction"

Scopus Search Strategy

POPULATION: (TITLE-ABS-KEY (football OR soccer OR AFL OR rugby OR NFL)

AND

CONCEPT: TITLE-ABS-KEY (manag* OR conserv* OR non-operative OR nonoperative OR surg* OR operative OR progress* OR "decision-making" OR clinical* OR criteri* OR therap* OR rehab* OR readaptation OR adaptation OR treat* OR convalescen* OR outcome* OR prognosis OR diagnosis OR “return* to competit*” OR “return* to participation” OR "return* to play" OR "return* to sport*" OR “return* to train*” OR “return* to run*” OR "time to return" OR "training fitness" OR "sport* participation" OR “patient reported outcome*” OR “athlete self-report* measure*” OR “return* to pre-injury level*” OR “return* to preinjury level*” OR “return* to pre injury level*” OR “return* to perform*” OR “recovery of function” OR “functional recovery”)

AND

CONTEXT: TITLE-ABS-KEY (*hamstring* OR *"biceps femoris"* OR *semitendinosus* OR *semimembranosus* OR *quadriceps* OR *"rectus femoris"* OR *"vastus lateralis"* OR *"vastus medialis"* OR *"vastus intermedius"* OR *"anterior thigh pain"* OR *"posterior thigh pain"* OR *"calf muscle"* OR *gastrocnemius* OR *soleus* OR *"triceps surae"* OR tibialis OR peroneus OR *"adductor injur*"* OR “adductor strain” OR *obturator* OR *gracilis* OR *"pectineus muscle"* OR “adductor magnus” OR “adductor brevis” OR “adductor longus” OR *"groin injur*"* OR *"groin strain"* OR *"groin pain"* OR *"muscle injur*"* OR *"muscle avulsion"* OR *"muscle tear"* OR *"muscle strain"* OR *"muscle rupture"* OR *"tendon injur*"* OR *"tendon tear"* OR *"tendon avulsion"* OR *"tendon rupture"* OR *"avulsion injur*"* OR *"upper leg"* OR *"lower leg"* OR reinjur* OR re-injur* OR “recurr* Injur*” OR “injury recurrence”)

NOT

TITLE-ABS-KEY (concussion OR ACL OR “anterior cruciate ligament” OR “anterior cruciate ligament reconstruction”)

Appendix A.5.

Extracted data from studies included for review

(Chapter Four)

Author(s)	Year	Origin	Study Design	Level of Evidence	Study Aim(s)	Population Demographics	Injury Information	Rehabilitation Programme	Assessment Criteria
Bass	1966	United Kingdom	Retrospective cohort study	IV	To describe rehabilitation after soft tissue trauma	**Sport:** Football **Level:** Professional **Total Sample:** 190 Injuries: *n*=190 **Sex:** Male **Age:** Not stated	**Muscle Group:** Common Injuries Muscle injuries (n=72) Hamstrings (n=17) Intramuscular - 2 Intermuscular -15 Quadriceps (n=28) Intramuscular - 2 Intermuscular - 26 Adductors (n=10) Intramuscular - 0 Intermuscular - 10 Calf (n=13) Intramuscular - 2 Intermuscular - 11 **Specific Muscle(s) Involved:** Not stated **Diagnosis Approach:** Clinical Symptoms and Assessment Tests: Intramuscular Diagnosis: (i) Localized haematoma (ii) Persisting swelling (iii) Persisting muscle weakness	**Treatment Approach**: Non-surgical **Domain(s) of Rehabilitation:** Physical Domain (i) Clinical (ii) Functional **Stage(s) of Recovery:** RTP **RTS decision-making guidelines:** 1. Complete recovery from injury **Decision-making approach:** Not stated	**Criteria Informing RTP:** *Clinical Examination / Evaluation* **Range of Motion (ROM)** Full range of movement Full extensibility of the muscle *Assessment Method/Tools/Tests Used* Not stated *Strength Tests* **Method of Strength Test not clearly stated** Full recovery of power of the muscle *Assessment Method/Tools/Tests Used* Not stated *Functional/Performance Based Criteria* **Non-Specific Performance-Based Criteria** Restoration of normal functional movement pattern *Assessment Method/Tools/Tests Used* Not stated **Post RTP follow up:** Not stated

							Intermuscular Diagnosis (after 48-72hrs): (i) Superficial bruising (ii) Drastic reduction in swelling (iii) Recovery of muscle strength (iv) Evidence of tracking **Imaging Performed**: No **Injury Grading:** Not stated **Time to RTP:** Hamstrings Intramuscular - 57 Intermuscular - 14 Quadriceps Intramuscular – 22.5 Intermuscular – 7.9 Adductors Intermuscular – 13.4 Calf Intramuscular - 14 Intermuscular – 5.7 **Injury Recurrences:** Not stated		

Heiser et al.,	1984	USA	Retrospective cohort study	IV	To review the number of hamstring injuries the 5-year period prior to using isokinetic dynamometry (IKD) and compare this to the most recent period in which IKD was utilized for muscle imbalance detection and hamstring strain rehabilitation	**Sport:** American Football **Level:** Collegiate **Total Sample:** *n*=1098 Injuries: *n*=47 Group 1: Injuries (*n*=41) Group 2: Injuries (*n*=6) **Sex:** Male **Age:** Not stated	**Muscle Group:** Hamstring **Specific Muscle(s) Involved:** Not stated **Diagnosis Approach:** Clinical Symptoms and Assessment Tests: (i) Sudden onset of pain in posterior thigh (ii) Presence and localised pain on palpation (iii) Palpable mass/defect (iv) Swelling **Imaging Performed**: No **Injury Grading:** Not stated **Time to RTP:** Group 1: Non IKD Treatment Approx. 14 days Group 2: IKD Treatment Approx. 14 days **Injury Recurrences:** 13 Group 1: Non IKD Treatment (13) Group 2: IKD Treatment (0)	**Treatment Approach**: Non-surgical Group 1: Rehabilitation programme Group 2: Rehabilitation programme + Isokinetic evaluation **Domain(s) of Rehabilitation:** Physical Domain (i) Clinical (ii) Functional **Stage(s) of Recovery:** Return to Participation RTP **RTS decision-making guidelines:** Group 1 **Return to Play** 1. Ability to run at 'near full' speed and display adequate agility Group 2 **Return to Running** 1. Hamstring strength ≥ 70% pre-injury strength **Return to Play** 1. Ability to run at 'near full' speed and display adequate agility 2. Isokinetic evaluation **Decision-making approach:** Not stated	**Criteria Informing Rehabilitation Progression:** *Strength Tests* **Isokinetic (Group 2 Only)** Hamstring strength (contraction type not specified) Peak torque ≥ 70% of pre-injury levels (3 reps - 60 /s) (Players must achieve this to be cleared to return to run) *Assessment Method/Tools/Tests Used* IKD **Criteria Informing RTP:** *Strength Tests* **Isokinetic (Group 2 Only)** Hamstring strength (contraction type not specified) Peak torque ≥ 95% of pre-injury level (at 60 /s testing speed) H:Q ratio ≥ 0.55 (at 60 /s testing speed) *Assessment Method/Tools/Tests Used* IKD *Functional/Performance Based Criteria* **High Speed Running / Sprinting** Achieve near full running speed *Assessment Method/Tools/Tests Used* Patient rated/determined running speeds **Agility** Demonstrate adequate agility *Assessment Method/Tools/Tests Used* Not stated **Post RTP follow up:** Not stated

Herrington	2000	United Kingdom	Case series	IV	A case report of the treatment strategy used for patients returning to sport in less than 14 days following hamstring muscle strains	**Sport:** Rugby League **Level:** Professional **Total Sample:** *n*=5 Injuries: *n*=5 **Sex:** Male **Age:** Not stated	**Muscle Group:** Hamstring **Specific Muscle(s) Involved:** Biceps Femoris (*n*=2) Semitendinosus (*n*=not stated) Semimembranosus (*n*=not stated) **Diagnosis Approach:** Clinical Symptoms and Assessment Tests: (i) Pain and limited single leg raise (ii) Pain on knee extension with hip flexed to 90 (iii) Pain and weakness on resisted knee flexion (iv) Presence and localised pain on palpation (v) Senitizing tests for nerve involvement (e.g., slump test and SLR) **Imaging Performed**: No **Injury Grading:** Not stated **Time to RTP:** 10 days (2 players) 14 days (3 players) **Injury Recurrences:** 0	**Treatment Approach**: Non-surgical **Domain(s) of Rehabilitation:** Physical Domain (i) Clinical (ii) Functional **Stage(s) of Recovery:** Return to Participation RTP **RTS decision-making guidelines:** 1. Asymptomatic completion of progressive running programme 2. Pass a RTP fitness test **Decision-making approach:** Not Stated	**Criteria Informing Rehabilitation Progression:** *Clinical Examination / Evaluation* **Pain** Pain during all running activities (VAS ≤1) (+) Pain during max speed sprinting (VAS ≤1) (+) *Assessment Method/Tools/Tests Used* VAS (0-10) *Functional/Performance Based Criteria* **High Speed Running / Sprinting** Sprint at 100% max speed (Rolling start running, speed progressively increased) *Assessment Method/Tools/Tests Used* Patient rated/determined running speeds **Completion of a Specific Programme** Progressive running programme **Criteria Informing RTP:** *Clinical Examination / Evaluation* **Range of Motion (ROM)** Full straight leg raise ROM Full active knee extension ROM (hip flexion 90) *Assessment Method/Tools/Tests Used* Not stated *Strength Tests* **Isometric** Equal strength between limbs on manually resisted isometric knee flexion *Assessment Method/Tools/Tests Used* Manual assessment of strength

									<u>*Functional/Performance Based Criteria*</u> **High Speed Running / Sprinting** Perform maximal sprint from a standing start Change sprint speed from 70-100% mid run <u>*Assessment Method/Tools/Tests Used*</u> Patient rated/determined running speeds **Agility** Side-step and change direction at max speed <u>*Assessment Method/Tools/Tests Used*</u> Not stated **Completion of a Specific Programme** Complete a specific RTP clearance test – Running protocol **Post RTP follow up:** Not stated

Slavotinek et al.,	2002	Australia	Prospective cohort study	III	To examine the relationships between MRI measurements of the extent of hamstring injury and the amount of time lost from competition in a group of athletes	**Sport:** Australian Football League **Level:** Professional **Total Sample:** *n*=37 Injuries: *n*=37 **Sex:** Male **Age: (Median)** 24 (Range 17-32)	**Muscle Group:** Hamstrings **Specific Muscle(s) Involved:** Biceps Femoris (n=26) Semitendinosus (n=15) Semimembranosus (n=2) Combined injuries BF + ST (n=11) **Diagnosis Approach:** Clinical Symptoms and Assessment Tests: (i) Current pain - VAS pain scale (0-10) **Imaging Performed**: Yes Imaging Technique: MRI **Injury Grading:** Not stated **Time to RTP (Median):** Hamstring injury 27 (Range 13-48) **Injury Recurrences:** Not stated	**Treatment Approach**: Non-surgical **Domain(s) of Rehabilitation:** Physical Domain (i) Clinical **Stage(s) of Recovery:** RTP **RTS decision-making guidelines:** 1. Asymptomatic completion of a rehabilitation programme **Decision-making approach:** Not stated	**Criteria Informing RTP:** *Clinical Examination / Evaluation* **Pain** Rehabilitation progressed according to pain levels (+) *Assessment Method/Tools/Tests Used* (VAS, 0-10) *Functional/Performance Based Criteria* **Completion of a Specific Programme** Rehabilitation programme (Predefined protocol involving graduated mobilisation (walking/stretching/physiotherapy) and activity) **Post RTP follow up:** Not stated

Cross et al.,	2004	Australia	Causal-comparative study	IV	To investigate the relationship between the MRI findings of a series of clinical quadriceps strain injuries and the recovery interval of those injuries	**Sport:** Australian Football League **Level:** Professional **Total Sample:** *n*=40 Injuries: *n*=25 (Involving 18 players) **Sex:** Male **Age: Mean** 23 (Range 18–33)	**Muscle Group:** Quadriceps **Specific Muscle(s) Involved:** Rectus Femoris (n=15) - *Rectus Femoris central tendon (7)* - *Rectus Femoris Peripheral area (8)* Vastus Intermedius (n=6) Vastus Lateralis (n=1) Negative MRI cases (n=3) **Diagnosis Approach:** Clinical Symptoms and Assessment Tests: (i) Experienced symptoms of pain, ache or tightness in anterior thigh during training or match-play (ii) Tenderness over anterior thigh on clinical examination **Imaging Performed**: Yes Imaging Technique: MRI **Injury Grading:** Not stated **Time to RTP (SD):** All Injury Types 13.1(12) Rectus Femoris 18.7(12.7) - *Rectus Femoris with central tendon disruption* *30 (8.9)* - *Rectus Femoris injury to peripheral area* 8.8 (3.5) Vastus Lateralis 5	**Treatment Approach**: Non-surgical **Domain(s) of Rehabilitation:** Physical Domain (i) Clinical (ii) Functional **Stage(s) of Recovery:** Return to Participation RTP **RTS decision-making guidelines:** **Return to training:** 1.Pain free full passive range of motion (prone knee flexion) and single leg hop performance 2. Asymptomatic completion of standardised 4-stage running and kicking rehabilitation programme: **Return to play**: 1. Pain free completion of full team training 2. Display full function during session (no limitations) 3. Consultation between supervising medical team gave definitive clearance for RTP **Decision-making approach:** Shared	**Criteria Informing Rehabilitation Progression:** *Clinical Examination / Evaluation* **Pain (**Emphasis on pain free exercise at all times) Pain free full passive range of motion (+) Pain free single leg hop test (3x10reps) (+) Pain free running (+) Pain free sport specific performance (+) Pain free completion of rehabilitation programme (i e , to pass from one stage to another the athlete must be pain free) *Assessment Method/Tools/Tests Used* Pain - Patient feedback **Range of Motion (ROM)** Full passive range of motion (prone knee flexion) – (compared against contralateral side) *Assessment Method/Tools/Tests Used* Not stated *Functional/Performance Based Criteria* **Low / Moderate Speed Running (Activity)** Jogging 2x 10mins Striding (Interval running) – 80m at 40-60% max speed (3x5reps) **High Speed Running / Sprinting** Sprinting – 30m at (90-100% max speed) (3x5reps) *Assessment Method/Tools/Tests Used* Not stated **Agility** Sport specific running drills (e.g., rapid change of direction, figure-8 drills, shuttle runs) 60-80m (90-100% intensity) (3x5reps) *Assessment Method/Tools/Tests Used* Not stated **Hop Test**

							Vastus Intermedius 4.2(2.1) Negative MRI 5.7(3.8) **Injury Recurrences:** 0		Single leg hops test (3x10 reps) *Assessment Method/Tools/Tests Used* Single leg hop test **Completion of a Specific Programme** Progressive Running Programme Sport Specific Functional Field Testing - (Staged kicking prog) **Criteria Informing RTP:** *Clinical Examination / Evaluation* **Pain** Pain free completion of full team training (+) *Assessment Method/Tools/Tests Used* Pain - Patient feedback *Functional/Performance Based Criteria* **Non-Specific Performance-Based Criteria** Complete full team training session Demonstrate full function during training session - (Observational – no specific functional tests used) **Post RTP follow up:** Not stated

Gibbs et al.,	2004	Australia	Prospective cohort study	III	The purpose of this study was to use MRI to classify acute grade 1 hamstring muscle strains in Australian Rules footballers to determine if it was accurate in predicting the recovery time for each injury and also able to predict those that would recur within the same season	**Sport:** Australian Football League **Level:** Professional **Total Sample:** *n*=31 Injuries: *n*=31 **Sex:** Male **Age:** (Range 18-33)	**Muscle Group:** Hamstring **Specific Muscle(s) Involved:** Biceps Femoris Semitendinosus Semimembranosus **Diagnosis Approach:** Clinical Symptoms and Assessment Tests: (i) Presence and localised pain on palpation (ii) Pain on SLR (iii) Pain on resisted prone knee flexion **Imaging Performed**: Yes Imaging Technique: MRI **Injury Grading:** 14 injuries showed no abnormality on MRI despite clinical symptoms 17 Grade 1 Injuries **Time to RTP (SD):** 14 MRI negative injury cases: 6.6 (8.23) 17 MRI positive injury cases: 20.3 (52.3) **Injury Recurrences:** 6 Biceps Femoris (4) Semitendinosus (1) Combined re-injuries - BF + ST (n=1)	**Treatment Approach**: Non-surgical **Domain(s) of Rehabilitation:** Physical Domain (i) Clinical (ii) Functional **Stage(s) of Recovery:** RTP **RTS decision-making guidelines:** 1. Asymptomatic completion of rehabilitation programme Standardised physiotherapy programme + progressive running programme 2. Ability to sprint at max speed 3. Perform sport specific full speed activities **Decision-making approach:** Not stated	**Criteria Informing RTP:** *Clinical Examination / Evaluation* **Pain** Pain free during light stretching activities Pain free during isometric hamstring exercises Pain free range of movement Pain free hamstring strengthening Pain free walking Pain free jogging Pain free variable running pace Pain free interval running (with increasing speed) Pain free linear max speed sprinting (+) *Assessment Method/Tools/Tests Used* Pain – Patient feedback *Functional/Performance Based Criteria* **High Speed Running / Sprinting** Achieve max sprint speed *Assessment Method/Tools/Tests Used* Not stated **Agility** Controlled full speed activities whist changing direction, kicking, jumping and chasing a rolling ball *Assessment Method/Tools/Tests Used* Not stated **Completion of a Specific Programme** Progressive running programme (+) **Post RTP follow up:** Not stated

Wright-Carpenter et al ,	2004	Germany	Prospective cohort study	III	A preliminary study was conducted on muscle strain injuries in professional sportsmen receiving either 1) autologous conditioned serum or 2) actovegin /traumeel treatment as a control. Assessment of recovery from injury was done by: 1) sport professionals' ability to participate to 100% under competition conditions in their respective sport and 2) MRI analysis	**Sport:** Multi-Sport including Football **Level:** Professional **Total Sample:** *n*=29 Injuries: *n*=29 Injuries involving footballers (*n*=16) **Sex:** Male **Age:** Not stated	**Muscle Group:** Hamstring (*n*=11) Adductor (*n*=10) Rectus femoris (*n*=1) Gastrocnemius (*n*=2) Iliopsoas (*n*=3) Gluteus (*n*=1) Abdominal oblique (*n*=1) **Specific Muscle(s) Involved:** Not stated **Diagnosis Approach:** Clinical Symptoms and Assessment Tests: Not stated Imaging Performed: Yes Imaging Technique: MRI **Injury Grading:** Not stated **Time to RTP (SD):** 22.3 (1.2) Autologous conditioned serum 16.6 (0.9) Actovegin / Traumeel control group 22.3 (1.2) **Injury Recurrences:** Not stated	**Treatment Approach**: Non-surgical and injection therapy Group 1: Autologous conditioned serum (ACS) (5ml – 2.5ml ACS + 2ml Saline) Group 2: Actovegin / Trameel control group (5ml) **Domain(s) of Rehabilitation:** Physical Domain (i) Clinical (ii) Functional Non-Physical domain (i) Psychological **Stage(s) of Recovery:** RTP **RTS decision-making guidelines:** 1. Asymptomatic completion of a standardised rehabilitation programme 2 Isokinetic evaluation to confirm muscle strength imbalances had been corrected and strength of injured limb has been restored to ≥ 90% of unaffected limb 3. Subjective judgement by athlete that they are ready to return to competition **Decision-making approach:** Shared	**Criteria Informing RTP:** *Clinical Examination / Evaluation* **Pain** Pain-free completion of rehabilitation programme (+) (Exercise allowed in a pain-free range) *Assessment Method/Tools/Tests Used* Pain – Patient feedback *Strength Tests* **Isokinetic** (compared to uninjured limb) ≤10% strength asymmetry in strength between legs *Assessment Method/Tools/Tests Used* IKD Patient Report **Subjective Statements** Demonstrates readiness to RTP and ability to participate to 100% under competition conditions *Assessment Method/Tools/Tests Used* No tool used – subjective feedback *Imaging* MRI – performed between the 14th – 16th day injury to evaluate restitution of muscle tissue *Functional/Performance Based Criteria* **Completion of a Specific Programme** Rehabilitation programme **Post RTP follow up:** Not stated

Verrall et al ,	2006	Australia	Prospective cohort study	III	To evaluate the anthropometric characteristics, convalescent interval, clinical features and MRI measurements of an initial hamstring muscle strain injury to establish factors that may be predictive of recurrent injury.	**Sport:** Australian Football League **Level:** Professional **Total Sample:** *n*=162 Injuries: *n*=30 **Sex:** Male **Age: Mean (SD)** 23.6 (3.2)	**Muscle Group:** Hamstring **Specific Muscle(s) Involved:** Biceps Femoris (n=26) **Diagnosis Approach:** Clinical Symptoms and Assessment Tests: Presence/Absence of: (i) Swelling (ii) Visible bruising (iii) Posterior thigh tenderness (iv) Pain on resisted hamstring contraction - hip flexed 30 (athlete supine) (v) MMT isometric knee flexion at 0 and 10 flexion – positive test recorded if athlete experienced pain in injured area (vi) Presence and localised pain on palpation (vii) Pain experienced with injury (VAS scale, 0-10) **Imaging Performed**: Yes Imaging Technique: MRI **Injury Grading:** Not stated **Time to RTP:** Not stated **Injury Recurrences:** 19	**Treatment Approach**: Non-surgical **Domain(s) of Rehabilitation:** Physical Domain (i) Clinical (ii) Functional **Stage(s) of Recovery:** Return to Participation RTP **RTS decision-making guidelines:** **Returning to training** 1. Pain-free completion of running and stretching programmes Running programme (and criteria) required to be completed ~ 2 to 3 times before being cleared to return to training 2. Asymptomatic clinical examination **Returning to play:** 1. Complete 1 week of full training **Decision-making approach:** Isolated Stakeholder: Sports Physician	**Criteria Informing Rehabilitation Progression:** *Clinical Examination / Evaluation* Satisfactory Clinical Exam (asymptomatic) **Pain** Ability to walk pain free Pain free passive hamstring stretches Pain free active hamstring stretches *Assessment Method/Tools/Tests Used* (VAS 0-10) *Strength Tests* **Method of testing not clearly stated:** No detectable difference clinically between injured and uninjured limb strength *Assessment Method/Tools/Tests Used* Manual assessment of strength *Functional/Performance Based Criteria* **Low / Moderate Speed Running (Activity)** 4x500m continuous jogging 4x500m interval running (70% max speed) *Assessment Method/Tools/Tests Used* Not stated **High Speed Running / Sprinting** 80-90% max speed (5x40m (2 sets)) 80-90% max speed (10x40m (2 sets)) Accelerations 5x40m (2 sets) stationery starting position 10x40m (2sets) crouched starting position Decelerations 90% max speed (10x40m + 20m breaking distance) 90% max speed (10x40m + 10m breaking distance)

							12 – same season 7 – subsequent season			*<u>Assessment Method/Tools/Tests Used</u>* Not stated **Completion of a Specific Programme** Progressive Running Programme Progressive Stretching Programme (eccentric emphasis) **Criteria Informing RTP:** *<u>Functional/Performance Based Criteria</u>* **Non-Specific Performance-Based Criteria** Complete 1 full week of training **Post RTP follow up:** *<u>Follow Up Period</u>* 2 season follow up – only re-injury occurrences were registered

Fuller & Walker	2006	United Kingdom	Prospective cohort study	III	To determine whether quantified, auditable records of functional rehabilitation can be generated using subjective assessments of players' performance in fitness tests routinely used in professional football.	**Sport:** Football **Level:** Professional **Total Sample:** *n*=118 Injuries: *n*=118 (Involving 55 players) **Sex:** Male **Age:** Not stated	**Muscle Group:** Common muscle injuries reported Groin strain (11) Thigh strain (26) Lower leg strain (11) **Specific Muscle(s) Involved:** Not stated **Diagnosis Approach:** Clinical Symptoms and Assessment Tests: Not stated **Imaging Performed**: No **Injury Grading:** Not stated **Time to RTP (95% CI):** Stage 1: Pre-Functional Groin 4.6 (2.4–6.9) Thigh 10.9 (7.9–13.9) Lower Leg 12.3 (5.7–18.9) Stage 2: Functional Groin 3.9 (2.7-5.1) Thigh 7.5 (3.9-11.1) Lower Leg 8.9 (3.5-14.3) Stage 3: RTP Groin 8.5 (5.9-11.1) Thigh 18.4 (13.1-23.7) Lower Leg 21 2 (11 5-30 9) **Injury Recurrences:** 7	**Treatment Approach**: Non-surgical **Domain(s) of Rehabilitation:** Physical Domain (i) Clinical (ii) Functional **Stage(s) of Recovery:** Return to Participation RTP **RTS decision-making guidelines:** 1. Asymptomatic completion of 2 stage rehabilitation programme: Pre functional + functional staged programmes 2. Players achieved a recovery score of 100% - accumulative points-based score **Decision-making approach:** Shared	**Criteria Informing Rehabilitation Progression:** *Clinical Examination / Evaluation* **Satisfactory Clinical Exam** Confirmation of complete tissue healing Capability of undertaking full weight-bearing exercises *Assessment Method/Tools/Tests Used* Not stated **Pain** Pain free completion of pre-functional stage of rehabilitation programme *Assessment Method/Tools/Tests Used* Pain – Patient feedback **Criteria Informing RTP:** *Clinical Examination / Evaluation* **Pain** Pain free completion of conditioning programme Pain-free when moving in all directions and at all running speeds Pain free demonstration of sport specific skills (e.g., technical proficiency) Pain free demonstration of match pace activities performed at normal match speed *Assessment Method/Tools/Tests Used* Pain – Patient feedback **Effusion/Swelling** None *Functional/Performance Based Criteria* **Quality of motion** Display normal gait during rehabilitation exercises

									Assessment Method/Tools/Tests Used Observational **Predetermined Benchmark** Subjective performance evaluation by coach/physio (rating scale 0-6). Scale considered players normal uninjured capabilities. The minimum accepted assessment score was 3 (i.e., good). Within the phases of the rehabilitation programme: Phase 1: Fitness Phase 2: Ball and Match Skills Phase 3: Match pace football Players required to score ≥3 in two exercises for each element of each phase (phases 1 and 2 only) Players progressed to phase 2 when they had successfully completed all elements of phase 1. They progressed to phase 3 when they had successfully completed all elements of phase 2. For each successfully completed exercise within each element a recovery score of 5% was awarded for phases 1 and 2. Phase 3 comprised only 1 element and its successful completion awarded a recovery score of 10% An accumulated recovery score of 100% was required to RTP *Assessment Method/Tools/Tests Used* Subjective assessment scale (6-point scale) (Scale benchmarked against normal uninjured capabilities i e , score of 6) **Completion of a Specific Programme** Conditioning programme Sport-specific skills programme (with ball) - displaying technical proficiency in all tasks **Non-Specific Performance-Based Criteria** Complete sport-specific match activities at normal match speed

									Post RTP follow up: Not stated

Verrall et al ,	2006	Australia	Prospective cohort study	III	To determine if there is any decrease in playing performance of athletes following return to sport after recovery from hamstring muscle strain injury	**Sport:** Australian Football League **Level:** Professional **Total Sample:** *n*=13 Injuries: *n*=13 **Sex:** Male **Age:** Not stated	**Muscle Group:** Hamstring **Specific Muscle(s) Involved:** Not stated **Diagnosis Approach:** Clinical Symptoms and Assessment Tests: (i) Acute onset of pain in posterior thigh **Imaging Performed**: Yes Imaging Technique: MRI **Injury Grading:** Not stated **Time to RTP:** Not stated **Injury Recurrences:** Not stated	**Treatment Approach**: Not stated **Domain(s) of Rehabilitation:** Physical Domain (i) Functional **Stage(s) of Recovery:** Return to performance **RTS decision-making guidelines:** Not stated **Decision-making approach:** Not stated	**Post RTP follow up:** *Follow Up Period* 2 competitive matches post return to play clearance *Functional/Performance Based Criteria* **Non-Specific Performance-Based Criteria** Coach subjective match performance rating (1-10) (Recorded for mean 2 games after RTP) Compared against the mean 2 game rating prior to injury and also against the mean entire season rating) *Assessment Method/Tools/Tests Used* Subjective performance rating scale (1-10)

Balius et al.,	2009	Spain	Casual comparative study	IV	To establish whether a correlation exists between the level and degree of rectus femoris central tendon injury and the amount of time that an athlete is unable to participate in sport.	**Sport:** Football **Level:** Professional **Total Sample:** *n*=35 Injuries: *n*=35 **Sex:** Male **Age: Mean (SD)** 24.14 (5.92)	**Muscle Group:** Quadriceps **Specific Muscle(s) Involved:** Rectus Femoris **Diagnosis Approach:** Clinical Symptoms and Assessment Tests: (i) Acute pain in the anterior thigh during physical soccer activity **Imaging Performed**: Yes Imaging Technique: Ultrasound **Injury Grading:** 14 Grade 1 Injuries 20 Grade 2 Injuries 1 Grade 3 Injury **Time to RTP (SD):** Grade 1: 27.7 (7.9) Grade 2: 46.8 (13.4) Proximal location: 45.1 (14.1) Grade 1 Proximal location 32.3 (8.5) Grade 2 Proximal location 48.7 (13.4) Distal location: 32.9 (13.1) Grade 1 Distal location 25.9 (7.3)	**Treatment Approach**: Non-surgical **Domain(s) of Rehabilitation:** Physical Domain (i) Clinical (ii) Functional **Stage(s) of Recovery:** Return to Participation RTP **RTS decision-making guidelines:** **Return to training:** 1.Pain free full passive range of motion (prone knee flexion) and single leg hop performance 2. Asymptomatic completion of standardised 4-stage running and kicking rehabilitation programme: **Return to play**: 1. Pain free completion of full team training 2. Display full function during session (no limitations) 3. Consultation between supervising medical team gave definitive clearance for RTP **Decision-making approach:** Shared	**Criteria Informing Rehabilitation Progression:** *Clinical Examination / Evaluation* **Pain** Pain free full passive range of motion (+) Pain free single leg hop test (3x10reps) (+) Pain free running (+) Pain free sport specific performance (+) Pain free completion of rehabilitation programme (i e , to pass from one stage to another the athlete must be pain free) *Assessment Method/Tools/Tests Used* Pain - Patient feedback **Range of Motion (ROM)** Full passive range of motion (prone knee flexion) – (compared against contralateral side) *Assessment Method/Tools/Tests Used* Not stated *Functional/Performance Based Criteria* **Low / Moderate Speed Running (Activity)** Jogging 2x 10mins Interval running – 80m at 40-60% max speed (3x5reps) **High Speed Running / Sprinting** Sprinting – 30m at (90-100% max speed) (3x5reps) *Assessment Method/Tools/Tests Used* Not stated **Agility** Sport specific running drills (e.g., change of direction, figure-8 drills) 60-80m (90-100% intensity) (3x5reps) *Assessment Method/Tools/Tests Used* Not stated **Hop test** Single leg hop test (3x10reps)

							Grade 2 Distal location 42.9 (13.5) **Injury Recurrences:** 0		*Assessment Method/Tools/Tests Used* Single leg hop test **Completion of a Specific Programme** Progressive Running Programme Sport Specific Functional Field Testing - (Staged kicking prog) **Criteria Informing RTP:** *Clinical Examination / Evaluation* **Pain** Pain free completion of full team training (+) *Assessment Method/Tools/Tests Used* Pain - Patient feedback *Functional/Performance Based Criteria* **Non-Specific Performance-Based Criteria** Complete full team training session Demonstrate full function during training session - (Observational – no specific functional tests used) **Post RTP follow up:** Not stated

Pedret et al.,	2011	Spain	Case series	IV	To present the injury pattern, clinical presentation, diagnosis and outcome of gracilis muscle ruptures	**Sport:** Multi-sport including Football **Level:** Professional **Total Sample:** *n*=7 Injuries: *n*=7 Injuries involving Footballers (*n*=2) **Sex:** Male (*n*=4) Female (*n*=3) **Age: Mean (SD)** 26.3 (6.0)	**Muscle Group:** Adductor **Specific Muscle(s) Involved:** Gracilis **Diagnosis Approach:** Clinical Symptoms and Assessment Tests: (i) Presence and localised pain on palpation (ii) Functional limitation of internal rotation and adduction of leg **Imaging Performed**: Yes Imaging Technique: Ultrasound / MRI **Injury Grading:** Not stated **Time to RTP (SD):** 35.6(5.7) (Range 30-45) **Injury Recurrences:** 0	**Treatment Approach**: Non-surgical **Domain(s) of Rehabilitation:** Physical Domain (i) Clinical (ii) Functional **Stage(s) of Recovery:** Return to Participation RTP **RTS decision-making guidelines:** 1. Asymptomatic, Completion of 4-stage rehabilitation programme: Running programme and Sport-specific functional field testing **Decision-making approach:** Isolated Stakeholder: Sports Physician	**Criteria Informing Rehabilitation Progression:** *Clinical Examination / Evaluation* **Pain** Pain free ROM *Assessment Method/Tools/Tests Used* Pain – Patient feedback **Criteria Informing RTP:** *Clinical Examination / Evaluation* **Pain** Pain free execution of all rehabilitation programme exercises (To pass from one stage to the next, athlete had to be pain-free) *Assessment Method/Tools/Tests Used* Pain – Patient feedback **Range of Motion (ROM)** Full Active range of motion similar to uninjured leg (Supine 90/90 position assessment) *Assessment Method/Tools/Tests Used* Inclinometer *Functional/Performance Based Criteria* **Hop test** No difference between legs - distance *Assessment Method/Tools/Tests Used* Single leg hop test (triple jump) **Completion of a Specific Programme** Sport-specific functional field testing (asymptomatic) **Post RTP follow up:** *Follow Up Period*

									Average follow up of 12 months (Range 4-48 months) whereby re-injury occurrences were registered.

Lee et al.,	2011	United Kingdom	Case series	IV	A report of the experience using Actovegin to treat muscle injuries	**Sport:** Football **Level:** Professional **Total Sample:** *n*=11 Injuries: *n*=11 **Sex:** Male **Age: Mean** 23	**Muscle Group:** Hamstring **Specific Muscle(s) Involved:** Biceps Femoris **Diagnosis Approach:** Clinical Symptoms and Assessment Tests: Not stated **Imaging Performed**: Yes Imaging Technique: MRI **Injury Grading:** **(Only G1/2 injuries considered)** 8 Grade 1 Injuries 3 Grade 2 Injuries **Time to RTP:** **Grade 1 Injuries** Group 1: Control 20 (Range 16-26) Group 2: Actovegin Treatment 12 (Range 9-15) **Grade 2 Injuries** Group 1: Control No injury cases Group 2: Actovegin Treatment 18.67 (Range 13-26) **Injury Recurrences:** 0	**Treatment Approach**: Non-surgical / Injection therapy Group 1: No Injection (control) Group 2: 3x 2mL Intramuscular injections of Actovegin 1st Injection: Post MRI confirmed injury 2nd Injection – 24hrs after 1st injection 3rd Injection – 24hrs after 2nd injection **Domain(s) of Rehabilitation:** Physical Domain (i) Clinical (ii) Functional **Stage(s) of Recovery:** Return to Participation RTP **RTS decision-making guidelines:** 1. Asymptomatic completion of 4-stage rehabilitation programme 2. Pass a RTP test protocol 3. Supervising physio gave the definitive clearance for RTP **Decision-making approach:** Isolated Stakeholder: Physiotherapist	**Criteria Informing Rehabilitation Progression:** *Clinical Examination / Evaluation* **Pain** Pain-free modified practice (minus high-speed manoeuvres) (+) Perform all rehabilitation activities pain-free *Assessment Method/Tools/Tests Used* Pain – Patient feedback **Range of Motion (ROM** Mobilise hamstring to full range *Assessment Method/Tools/Tests Used* Not stated *Functional/Performance Based Criteria* **Low / Moderate Speed Running (Activity)** Perform modified practice (without limitation or restriction) *Assessment Method/Tools/Tests Used* Not stated **Criteria Informing RTP:** *Clinical Examination / Evaluation* **Pain** Perform all rehabilitation activities pain *Assessment Method/Tools/Tests Used* Pain – Patient feedback *Functional/Performance Based Criteria* **Completion of a Specific Programme** Complete a specific RTP clearance test (e g , sudden movement + stop-start running and cutting drills (with/without ball), Nordic curls and swiss ball stabilisation with trunk rotation) **Post RTP follow up:** Not stated

Cohen et al.,	2011	USA	Retrospective cohort study	IV	To correlate time for return to play in professional football players with MRI findings after acute hamstring strains and to create an MRI scoring scale predictive of return to sports	**Sport:** American Football **Level:** Professional **Total Sample:** *n*=43 Injuries: *n*=43 (Involving 38 players) **Sex:** Male **Age: Mean (SD)** 26.7 (3.4) (Range 22-35)	**Muscle Group:** Hamstring **Specific Muscle(s) Involved:** Biceps Femoris (Long head) (*n*=25) Biceps Femoris (Short Head) (*n*=5) Semimembranosus (*n*=13) Semitendinosus (*n*=12) **Diagnosis Approach:** Clinical Symptoms and Assessment Tests: Not stated **Imaging Performed**: Yes Imaging Technique: MRI **Injury Grading:** 2 Grade 0 Injuries 14 Grade 1 Injuries 18 Grade 2 Injuries 9 Grade 3 Injuries **Time to RTP: Practices missed** Overall, 11.3(6.5) practices **Games Missed** Overall, 2.6(3.1) games Grade 0 – 0 Grade 1 – 1.1 (Range 0-4) Grade 2 – 1.7 (Range 0-3) Grade 3 – 6.4 (Range 3-16) **Injury Recurrences:** 8 Those occurring in the same season (*n*=5)	**Treatment Approach**: Non-surgical **Domain(s) of Rehabilitation:** Physical Domain (i) Clinical (ii) Functional Non-Physical Domain (i) Psychological **Stage(s) of Recovery:** Return to Participation RTP **RTS decision-making guidelines:** 1. Completion of stretching and strengthening programme 2. Completion of a progressive agility and trunk stabilisation programme 3. Pass a RTP Functional testing protocol **Decision-making approach:** Not stated	**Criteria Informing Rehabilitation Progression:** *Clinical Examination / Evaluation* **Pain** Demonstrate normal walking stride without pain Pain free high knee march *Assessment Method/Tools/Tests Used* Pain - Patient feedback *Functional/Performance Based Criteria* **Completion of a Specific Programme** Stretching and strengthening programme Progressive agility and trunk stabilisation programme **Criteria Informing RTP:** *Clinical Examination / Evaluation* **Pain** No pain on palpation Pain free sprinting (+) *Assessment Method/Tools/Tests Used* Pain - Patient feedback Palpation *Strength Tests* **Isometric** Full strength (5/5) during manual strength test to resist knee flexion when in prone position *Assessment Method/Tools/Tests Used* Manual assessment of strength

							Those occurring in a subsequent season (*n*=3)		<u>Patient Report</u> **Subjective Statements** Demonstrate readiness to RTP after completing agility and running tests *<u>Assessment Method/Tools/Tests Used</u>* No tool stated - Patient feedback *<u>Functional/Performance Based Criteria</u>* **High Speed Running / Sprinting** 40yard Sprint test *<u>Assessment Method/Tools/Tests Used</u>* Not stated **Hop test** (Comparison of injured and uninjured limbs) Unilateral Hop height test Unilateral Hop distance test Unilateral 4 hop cross over test *<u>Assessment Method/Tools/Tests Used</u>* Single leg hop test **Completion of a Specific Programme** RTP test protocol **Post RTP follow up:** Not stated

Kilcoyne et al ,	2011	USA	Retrospective case series	IV	To present the outcomes of a novel rehabilitation protocol for the treatment of proximal hamstring strains in intercollegiate sporting population and to determine any significant differences in the rate of re-injury and time to return to sport based on patient and injury characteristics	**Sport:** Multi-Sport including American Football and Rugby **Level:** Collegiate **Total Sample:** *n*=48 Injuries: *n*=48 Injuries involving American footballers (*n*=12) and Rugby players (*n*=9) **Sex:** Male (40) Female (8) **Age:** Range 18-25	**Muscle Group:** Hamstring **Specific Muscle(s) Involved:** Biceps Femoris (*n*=25) Semimembranosus (*n*=20) Not specified (*n*=3) **Diagnosis Approach:** Clinical Symptoms and Assessment Tests: (i) Sudden posterior thigh pain while running or jumping (ii) Physical disability (iii) Pain with resisted prone knee flexion (iv) Presence and localised pain on palpation Imaging Performed: No **Injury Grading:** 30 Grade 1 Injuries 18 Grade 2 Injuries **Time to RTP (Range):** 11.9 (5-23) **Injury Recurrences:** 3 All 3 re-injuries occurred in biceps femoris	**Treatment Approach**: Non-surgical **Domain(s) of Rehabilitation:** Physical Domain (i) Clinical (ii) Functional **Stage(s) of Recovery:** Return to participation RTP **RTS decision-making guidelines:** 1. Equivalent hamstring strength between injured and uninjured leg 2. Equivalent hamstring range of motion between injured and uninjured leg 3. Pain free during all rehab drills including sprinting **Decision-making approach:** Not stated	**Criteria Informing Rehabilitation Progression:** *Clinical Examination / Evaluation* **Pain** Pain-free completion of all rehabilitation exercises Pain free range of motion (+) Sprinting drills (forward, backward runs) ($\leq$ 2 VAS) *Assessment Method/Tools/Tests Used* VAS (0-10) **Range of Motion (ROM)** Achieve ≥ 60 inches (from the floor) in progressive static elevated stretching (minimum height 48 inches) *Assessment Method/Tools/Tests Used* Not stated *Strength Tests* **Isokinetic** (Performed on injured + uninjured leg) Performed until strength equivalent between limbs Protocol 1: High speed 300 /s knee flexion / extension for 90 secs Protocol 2: Power/Speed 90 /s knee flexion / extension for 15 secs each 180 /s knee flexion / extension for 15 secs each 240 / knee flexion / extension for 15 secs each 120 / knee flexion / extension for 15 secs each 300 /s knee flexion / extension to burnout *Assessment Method/Tools/Tests Used* IKD *Functional/Performance Based Criteria* **High Speed Running / Sprinting**

									Perform sport specific running drills at 90% max speed *Assessment Method/Tools/Tests Used* Patient rated/determined running speeds **Completion of a Specific Programme** Progressive running programme Plyometric programme **Criteria Informing RTP:** *Clinical Examination / Evaluation* **Pain** Pain free completion of rehabilitation exercises Pain free sprinting (+) *Assessment Method/Tools/Tests Used* VAS (0-10) **Range of Motion (ROM)** Symmetrical hamstring range of motion between injured and uninjured limb *Assessment Method/Tools/Tests Used* Not stated *Strength Tests* **Isokinetic** Symmetrical hamstring strength between injured and uninjured limb *Assessment Method/Tools/Tests Used* IKD *Functional/Performance Based Criteria* **High Speed Running / Sprinting** 4-6 Rolling start sprints at 90-95% max speed (100 yd)

									Assessment Method/Tools/Tests Used Patient rated/determined running speeds **Post RTP follow up:** *Follow Up Period* Follow up performed wherein reinjuries were registered – period of follow up not stated

Gurovich	2012	USA	Case study	IV	The purpose of this case report is to present a different approach to muscle injury rehabilitation	**Sport:** Football **Level:** Professional **Total Sample:** *n*=1 Injuries: *n*=1 **Sex:** Male **Age:** 17	**Muscle Group:** Quadriceps **Specific Muscle(s) Involved:** Vastus Intermedius **Diagnosis Approach:** Clinical Symptoms and Assessment Tests: Pain reported using VAS (0-10) pain scale (i) Presence and localised pain on palpation (ii) Pain on passive mobilisation with 90 knee flexion and active knee extension **Imaging Performed**: Yes Imaging Technique: Ultrasound **Injury Grading:** Not stated **Time to RTP:** 35 days **Injury Recurrences:** 0	**Treatment Approach**: Non-surgical **Domain(s) of Rehabilitation:** Physical Domain (i) Clinical (ii) Functional **Stage(s) of Recovery:** Return to Participation RTP **RTS decision-making guidelines:** 1. Completion of a 5-phase rehabilitation programme 2. ≥ 95% knee extension strength symmetry between limbs 3. Complete 1 week of full team training sessions without compliant **Decision-making approach:** Not stated	**Criteria Informing Rehabilitation Progression:** *Clinical Examination / Evaluation* **Pain** Pain free passive range of motion (+) *Assessment Method/Tools/Tests Used* VAS (0-10) **Range of Motion (ROM)** Full passive range of motion *Assessment Method/Tools/Tests Used* Inclinometer *Strength Tests* **Method of Strength Test not clearly stated** 95% knee extension strength symmetry between injured and uninjured limbs *Assessment Method/Tools/Tests Used* Open kinetic chain exercise machine (isotonic single leg extension) *Imaging* Ultrasound – Evaluation of injury healing **Criteria Informing RTP:** *Imaging* Ultrasound *Functional/Performance Based Criteria* **Non-Specific Performance-Based Criteria** Complete 1 week of full team training sessions without compliant

									Post RTP follow up: *Follow Up Period* 12 months periodic follow up *Clinical Examination / Evaluation* **Satisfactory Clinical Exam** Player demonstrates no significant physical problems at 1 year follow up *Imaging* Ultrasound (performed at 12 months)

Askling et al ,	2013	Sweden	RCT	II	To compare the effectiveness of two rehabilitation protocols after acute hamstring injury by evaluating time needed to return to full participation in football team-training and availability for match selection. Other aims were to study possible correlations between injury type, location, size, palpation pain and time to return.	**Sport:** Football **Level:** Professional **Total Sample:** *n*=75 Injuries: *n*=75 **Sex:** Male (*n*=69) Female (*n*=6) **Age: Mean (SD)** Group 1: L-Protocol 25(5) (Range 16-37) Group 2: C-Protocol 25(6) (Range 15-37)	**Muscle Group:** Hamstring **Specific Muscle(s) Involved:** Biceps Femoris (long head) (n=52) Semimembranosus (n=16) **Diagnosis Approach:** Clinical Symptoms and Assessment Tests: (i) Presence and localised pain on palpation (ii) Manual assessment of strength and flexibility (comparison to contralateral limb) Pain reported using VAS (0-10) pain scale **Imaging Performed**: Yes Imaging Technique: MRI **Injury Grading:** Not stated **Time to RTP (SD) (Range):** Group 1 L-Protocol 28(15) (Range 8-58) Group 2 C-Protocol 51(21) (Range 12-94) **Injury Recurrences:** 1 Group 2: C-Protocol: 1	**Treatment Approach**: Non-surgical Group 1: L-Protocol (exercises specifically aimed at loading hamstrings during lengthening and mainly during eccentric muscle actions) Group 2: C-Protocol (Conventional hamstring exercises with less emphasis on lengthening) **Domain(s) of Rehabilitation:** Physical Domain (i) Clinical (ii) Functional **Stage(s) of Recovery:** RTP **RTS decision-making guidelines:** 1. Pain free completion of rehabilitation programme: Either L-protocol or C-Protocol 2. Asymptomatic clinical examination 3. Askling H-test performed without insecurity **Decision-making approach:** Shared	**Criteria Informing RTP:** *Clinical Examination / Evaluation* Satisfactory Clinical Exam (asymptomatic) **Pain** No pain on palpation Pain free completion of rehabilitation programme (No pain provocation was allowed) *Assessment Method/Tools/Tests Used* Palpation Pain – Patient Feedback **Range of Motion (ROM)** Passive SLR comparable to contralateral leg Dynamic flexibility H-Test (display no insecurity) – Performed once clinically asymptomatic *Assessment Method/Tools/Tests Used* Manual assessment of flexibility Askling H-test *Strength Tests* **Isometric** Strength comparable to contralateral leg *Assessment Method/Tools/Tests Used* Manual assessment of strength *Functional/Performance Based Criteria* **Completion of a Specific Programme** Rehabilitation programme: L-Protocol (Emphasis on lengthening exercises – eccentric focus) Rehabilitation programme: C-Protocol (Conventional prog, less emphasis on lengthening exercises)

									Post RTP follow up: *Follow Up Period* 12 months periodic follow up – whereby re-injury occurrences were registered

Rettig et al.,	2013	USA	Case control study	IV	To investigate the effects of the addition of PRP to rehabilitation in the treatment of acute hamstring injuries in professional national football league players and to report the time to RTP	**Sport:** American Football **Level:** Professional **Total Sample:** *n*=10 Injuries: *n*=10 **Sex:** Male **Age: Median** Group 1: PRP 23 (Range 22-27) Group 2: Non-PRP 26 (Range 22-28)	**Muscle Group:** Hamstring **Specific Muscle(s) Involved:** Biceps Femoris (long head) (*n*=8) Semimembranosus (*n*=2) **Diagnosis Approach:** Clinical Symptoms and Assessment Tests: Not stated **Imaging Performed**: Yes Imaging Technique: MRI **Injury Grading:** Group 1: PRP Treatment 2 Grade 1 Injuries 3 Grade 2 Injuries Group 2: Non-PRP Treatment 2 Grade 1 Injuries 3 Grade 2 Injuries **Time to RTP (Median):** Group 1: PRP Treatment 20 (Range 16-30) Group 2: Non-PRP Treatment 17 (Range 8-81) **Injury Recurrences:** 0	**Treatment Approach**: Non-surgical + PRP Group 1: Platelet-rich plasma Group 2: No injection **Domain(s) of Rehabilitation:** Physical Domain (i) Clinical (ii) Functional **Stage(s) of Recovery:** Return to Participation RTP **RTS decision-making guidelines:** 1. Asymptomatic completion of 4 stage rehabilitation programme: Progressive running programme + Sport-specific functional field testing **Decision-making approach:** Not stated	**Criteria Informing Rehabilitation Progression:** *Clinical Examination / Evaluation* **Pain** Pain free during low/moderate activity (2 consecutive days) (+) Run/Sprint without pain or hesitation (+) Pain free completion of functional field testing (+) *Assessment Method/Tools/Tests Used* Pain – Patient feedback *Functional/Performance Based Criteria* **Low / Moderate Speed Running (Activity)** Cross trainer 2x 20-30mins without limitation/set back *Assessment Method/Tools/Tests Used* Cross trainer - elliptical **High Speed Running / Sprinting** Treadmill – progressive speed interval training Work:Rest Intervals - 20s:20s (7 to 10 mph - 0.5 mph speed increments) - 10s:15s (10 to 14 mph - 0.5 mph speed increments) Run:Walk Intervals - 60s:60s (15min duration) (Running speed ~7-10mph / walking speed 3.5mph) *Assessment Method/Tools/Tests Used* Treadmill **Completion of a Specific Programme** Progressive Treadmill running programme Sport Specific Functional Field Testing (running based) **Criteria Informing RTP:** *Functional/Performance Based Criteria* **Completion of a Specific Programme**

									Sport Specific Functional Field Testing (position specific) **Non-Specific Performance-Based Criteria** Progressive resumption of full team training **Post RTP follow up:** *Follow Up Period* 6 month follow up period

Corazza et al ,	2013	Italy	Retrospective cohort study	IV	To evaluate MRI and Ultrasound in the assessment of both acute phases and the healing phase of thigh muscles indirect injuries in a cohort of professional soccer players. Further, we investigated the association between the extent of thigh muscle tears and the amount of time lost from competition	**Sport:** Football **Level:** Professional **Total Sample:** *n*=84 Injuries: *n*=27 **Sex:** Male **Age: Mean (SD)** 27.1 (4) (Range 18-35)	**Muscle Group:** Hamstrings (*n*=13) Adductors (*n*=6) Quadriceps (*n*=8) **Specific Muscle(s) Involved:** Not stated **Diagnosis Approach:** Clinical Symptoms and Assessment Tests: (i) Occurrence of a 'snap' feeling followed by (or not) a loss of function during sport activity (ii) Dull/sharp pain sensation in thigh (iii) Stretch-induced worsening of pain (iv) Muscle contraction worsening of pain (v) Presence of visible haematoma (vi) Palpable defect **Imaging Performed**: Yes Imaging Technique: MRI / Ultrasound **Injury Grading:** 2 Grade 0 Injuries 10 Grade 1 Injuries 15 Grade 2 Injuries **Time to RTP (SD):** Overall: 20 (9) (Range 6-46) Grade 0 Injuries: 5(1)	**Treatment Approach**: Non-surgical **Domain(s) of Rehabilitation:** Physical Domain (i) Clinical (ii) Functional **Stage(s) of Recovery:** Return to Participation RTP **RTS decision-making guidelines:** 1.Completion of rehabilitation programme 2 Imaging (MRI + Ultrasound) confirmation of injury healing 3. Asymptomatic functional testing 4. Correction of strength imbalances **Decision-making approach:** Not stated	**Criteria Informing Rehabilitation Progression:** *Clinical Examination / Evaluation* **Pain** Demonstrate normal walking stride/gait without pain Very low speed running without pain (+) Pain free sub-maximal isometric contraction (+) Pain free full strength isometric contraction (+) Pain free forward / backward running (50% max speed) (+) Pain free bike Pain free passive range of motion Pain free pool activities *Assessment Method/Tools/Tests Used* Pain – Patient feedback *Strength Tests* **Isometric** Submaximal (50-70% resistance) manual strength test in prone knee flexion (90 knee flexion) *Assessment Method/Tools/Tests Used* Manual assessment of strength Full strength (5/5) during 1 rep maximal effort manual strength test in prone knee flexion (90 knee flexion) *Assessment Method/Tools/Tests Used* Manual assessment of strength *Imaging* MRI Ultrasound (evaluation of contralateral thigh also performed) *Functional/Performance Based Criteria* **Low / Moderate Speed Running (Activity)** Perform very low speed running Forward + backward running at 50% max speed

							Grade 1 Injuries: 13(5) Grade 2 Injuries 25(9) **Injury Recurrences:** 4 Hamstring (*n*=1) Adductors (*n*=1) Quadriceps (*n*=2)		*Assessment Method/Tools/Tests Used* Not stated **Completion of a Specific Programme** Progressive agility and trunk stability programme **Criteria Informing RTP:** *Clinical Examination / Evaluation* **Pain** Pain free full range of motion (+) Pain free full-speed running (+) Pain free sport specific movements/actions (+) Full strength without pain (+) *Assessment Method/Tools/Tests Used* Pain - Patient feedback **Range of Motion (ROM)** Full range of motion *Assessment Method/Tools/Tests Used* Not stated *Strength Tests* **Isometric** Manual strength testing - 4 consecutive max effort reps in prone knee flexion (90 and 15 flexion) *Assessment Method/Tools/Tests Used* Manual assessment of strength **Isokinetic** <5% bilateral deficit in H:Q ratio – (eccentric hamstrings 30 /s / concentric quadriceps 240 /s) *Assessment Method/Tools/Tests Used* IKD

									Bilateral symmetry in knee flexion angle of peak concentric knee flexion torque at 60 /s *Assessment Method/Tools/Tests Used* IKD *Imaging* MRI Ultrasound (evaluation of contralateral thigh also performed) *Functional/Performance Based Criteria* **High Speed Running / Sprinting** Achieve full speed sprinting *Assessment Method/Tools/Tests Used* Not stated **Non-Specific Performance-Based Criteria** Unhindered functional sports-specific testing *Assessment Method/Tools/Tests Used* Not stated **Post RTP follow up:** *Follow Up Period* 2 month follow up wherein reinjuries were registered

Silder et al.,	2013	USA	RCT	II	To monitor clinical and morphological changes during the course of rehabilitation in individuals with acute hamstring strain injuries and to determine if differences in outcomes may exist between the 2 progressive rehabilitation programs. The rehabilitation programs utilized were a modified PATS program30 and a progressive running and eccentric strengthening (PRES) program	**Sport:** Multi-Sport Including American Football **Level:** Collegiate **Total Sample:** *n*=29 Injuries: *n*=29 **Sex:** Male (n=19) Female (n=5) **Age: Mean (SD)** 24(9)	**Muscle Group:** Hamstring **Specific Muscle(s) Involved:** Biceps Femoris (*n*=20) Semimembranosus (*n*=4) Semitendinosus (*n*=2) No indication of injury on MRI (*n*=3) **Diagnosis Approach:** Clinical Symptoms and Assessment Tests: (i) Pain with sport activity/running (ii) Presence and localised pain on palpation (iii) Pain on passive straight leg raise (iv) Weakness with resisted knee flexion (v) Pain with resisted knee flexion (vi) Posterior thigh pain with sports/running **Imaging Performed**: Yes Imaging Technique: MRI **Injury Grading:** Not stated **Time to RTP (SD):** Group 1 (PRES): 28.8 (11.4) (Range 13-49) Group 2 (PATS): 25.2 (6.3) (Range 17-37)	**Treatment Approach**: Non-surgical Group 1 (PRES) Group 2 (PATS) **Domain(s) of Rehabilitation:** Physical Domain (i) Clinical (ii) Functional Non-Physical Domain (i) Psychological **Stage(s) of Recovery:** Return to Participation RTP Return to Performance **RTS decision-making guidelines:** PRES Group 1. Complete a progressive running and eccentric strengthening programme 2. Score 5/5 on isometric strength testing in various knee positions 3. Demonstrated max speed sprinting without apprehension 4. Clinical examination + MRI PATS Group 1. Complete a progressive agility and trunk stabilisation programme 2. Score 5/5 on isometric strength testing in various knee positions	PRES Group **Criteria Informing Rehabilitation Progression:** *Clinical Examination / Evaluation* **Pain** Pain free isometric contraction (90 flexion) (+) *Assessment Method/Tools/Tests Used* Pain – Patient feedback **Satisfactory Clinical Exam** Normal walking stride + stance time compared to uninjured leg Jog forward and backward with same stride length and stance time compared to uninjured leg *Assessment Method/Tools/Tests Used* Visual assessment by treating physio *Strength Tests* **Isometric** Demonstrate 4/5 strength on isometric manual muscle testing (90 flexion) *Assessment Method/Tools/Tests Used* Manual assessment of strength Demonstrate 5/5 strength on isometric manual muscle testing in prone with: - 90 knee flexion with tibia in neutral position - 90 knee flexion with tibia internally rotated - 90 knee flexion with tibia externally rotated *Assessment Method/Tools/Tests Used* Manual assessment of strength

							Injury Recurrences: 4	3. Demonstrated max speed sprinting without apprehension 4. Clinical examination + MRI **Decision-making approach:** Isolated Stakeholder: Physiotherapist	**Criteria Informing RTP:** *Clinical Examination / Evaluation* **Pain** No pain on palpation *Assessment Method/Tools/Tests Used* Pain – Patient feedback *Strength Tests* **Isometric** Score 5/5 manual muscle testing on 4 consecutive reps performed in various knee positions: Prone with hip in 0 of flexion and knee flexed at 15 - 15 knee flexion with tibia in neutral position - 15 knee flexion with tibia internally rotated - 15 knee flexion with tibia externally rotated - Prone with hip in 0 of flexion and knee flexed at 90 - 90 knee flexion with tibia in neutral position - 90 knee flexion with tibia internally rotated - 90 knee flexion with tibia externally rotated *Assessment Method/Tools/Tests Used* Manual assessment of strength Patient Report **Subjective Statements** Demonstrate readiness to RTP – no apprehension (+) *Assessment Method/Tools/Tests Used* No tool stated – Patient subjective feedback *Functional/Performance Based Criteria* **High Speed Running / Sprinting** Achieve max speed (sprint test) (no apprehension)

									<u>Assessment Method/Tools/Tests Used</u> Not stated **Completion of a Specific Programme** Progressive running and eccentric strengthening programme **Post RTP follow up:** *<u>Follow Up Period</u>* Periodic follow up over 12 months wherein any re-injuries were reported *<u>Clinical Examination / Evaluation</u>* **Pain** No pain on palpation Pain provocation on range of motion tests (+) Pain provocation on strength tests (+) *<u>Assessment Method/Tools/Tests Used</u>* Pain – Patient feedback **Range of Motion (ROM)** (compared to injured side) Passive straight leg raise (in full knee extension) Active knee extension (Hip in 90 flexion) - Joint angle recorded at point of discomfort/pain Passive knee extension (Hip in 90 flexion) - Joint angle recorded at point of discomfort/pain *<u>Assessment Method/Tools/Tests Used</u>* Not stated *<u>Strength Tests</u>* **Isometric** (compared to injured side) Isometric manual muscle testing – strength recorded using standard (0-5) grading scale. Tests performed:

									Prone with hip in 0 of flexion and knee flexed at 15 Prone with hip in 0 of flexion and knee flexed at 90 - 90 knee flexion with tibia in neutral position - 90 knee flexion with tibia internally rotated - 90 knee flexion with tibia externally rotated Isometric hip extension strength assessed with knee at 0 and 90 knee flexion. Strength recorded using standard (0-5) grading scale *Assessment Method/Tools/Tests Used* Manual assessment of strength *Imaging* MRI Measurements: Craniocaudal injury length CSA of injury as % of total CSA Mediolateral width of total injured area Anterior/posterior depth of total injured area T2 hyperintensity at injury location Site of injury (involved muscle(s) Location of injury (proximal, middle, distal MTJ) Patient Report **Subjective Statements** As part of clinical exam players asked: (1) If they were back to their pre-injury level of performance? If not, was hamstring injury a limiting factor (2) If they had any remaining symptoms (3) Felt hamstring symptoms during running *Assessment Method/Tools/Tests Used* No tool stated – Patient subjective feedback

									<u>PATS Group</u> **Criteria Informing Rehabilitation Progression:** <u>*Clinical Examination / Evaluation*</u> **Pain** Pain free isometric contraction (90 flexion) (+) <u>*Assessment Method/Tools/Tests Used*</u> Pain – Patient feedback **Satisfactory Clinical Exam** Normal walking stride + stance time compared to uninjured leg Jog forward and backward with same stride length and stance time compared to uninjured leg <u>*Assessment Method/Tools/Tests Used*</u> Visual assessment by treating physio <u>*Strength Tests*</u> **Isometric** Demonstrate 4/5 strength on isometric manual muscle testing (90 flexion) <u>*Assessment Method/Tools/Tests Used*</u> Manual assessment of strength Demonstrate 5/5 strength on isometric manual muscle testing in prone with: - 90 knee flexion with tibia in neutral position - 90 knee flexion with tibia internally rotated - 90 knee flexion with tibia externally rotated <u>*Assessment Method/Tools/Tests Used*</u> Manual assessment of strength

									Criteria Informing RTP: *Clinical Examination / Evaluation* **Pain** No pain on palpation *Assessment Method/Tools/Tests Used* Pain – Patient feedback *Strength Tests* **Isometric** Score 5/5 manual muscle testing on 4 consecutive reps performed in various knee positions: Prone with hip in 0 of flexion and knee flexed at 15 - 15 knee flexion with tibia in neutral position - 15 knee flexion with tibia internally rotated - 15 knee flexion with tibia externally rotated - Prone with hip in 0 of flexion and knee flexed at 90 - 90 knee flexion with tibia in neutral position - 90 knee flexion with tibia internally rotated - 90 knee flexion with tibia externally rotated *Assessment Method/Tools/Tests Used* Manual assessment of strength Patient Report **Subjective Statements** Demonstrate readiness to RTP – no apprehension (+) *Assessment Method/Tools/Tests Used* No tool stated – Patient subjective feedback *Functional/Performance Based Criteria* **High Speed Running / Sprinting** Achieve max speed (sprint test) (no apprehension)

									<u>Assessment Method/Tools/Tests Used</u> Not stated **Completion of a Specific Programme** Progressive agility and trunk stabilisation programme **Post RTP follow up:** *<u>Follow Up Period</u>* Periodic follow up over 12 months wherein any re-injuries were reported *<u>Clinical Examination / Evaluation</u>* **Pain** Localised pain on palpation Pain provocation on range of motion tests (+) Pain provocation on strength tests (+) *<u>Assessment Method/Tools/Tests Used</u>* Pain – Patient feedback **Range of Motion (ROM)** (compared to injured side) Passive straight leg raise (in full knee extension) Active knee extension (Hip in 90 flexion) - Joint angle recorded at point of discomfort/pain Passive knee extension (Hip in 90 flexion) - Joint angle recorded at point of discomfort/pain *<u>Assessment Method/Tools/Tests Used</u>* Not stated *<u>Strength Tests</u>* **Isometric** (compared to injured side) Isometric manual muscle testing – strength recorded using standard (0-5) grading scale. Tests performed:

									Prone with hip in 0 of flexion and knee flexed at 15 Prone with hip in 0 of flexion and knee flexed at 90 - 90 knee flexion with tibia in neutral position - 90 knee flexion with tibia internally rotated - 90 knee flexion with tibia externally rotated Isometric hip extension strength assessed with knee at 0 and 90 knee flexion. Strength recorded using standard (0-5) grading scale *Assessment Method/Tools/Tests Used* Manual assessment of strength *Imaging* MRI Measurements: Craniocaudal injury length CSA of injury as % of total CSA Mediolateral width of total injured area Anterior/posterior depth of total injured area T2 hyperintensity at injury location Site of injury (involved muscle(s) Location of injury (proximal, middle, distal MTJ) Patient Report **Subjective Statements** As part of clinical exam players asked: (1) If they were back to their pre-injury level of performance? If not, was hamstring injury a limiting factor (2) If they had any remaining symptoms (3) Felt hamstring symptoms during running *Assessment Method/Tools/Tests Used* No tool stated – Patient subjective feedback

Tol et al.,	2014	Qatar	Prospective study of a cohort of participants in a larger RCT	III	To evaluate isokinetic variables in a cohort of MRI-positive hamstring-injured professional football players who had completed a six-stage rehabilitation programme including functional sports-specific rehabilitation.	**Sport:** Football **Level:** Professional **Total Sample:** *n*=52 Injuries: *n*=52 **Sex:** Male **Age: Mean** 24.9 (Range 18-38)	**Muscle Group:** Hamstring **Specific Muscle(s) Involved:** Not stated **Diagnosis Approach:** Clinical Symptoms and Assessment Tests: (i) Acute onset of posterior thigh pain **Imaging Performed**: Yes Technique: MRI **Injury Grading:** **(Only G1/2 injuries considered)** 27 Grade 1 Injuries 25 Grade 2 Injuries **Time to RTP:** 21 (Range 7-43) **Injury Recurrences:** 6	**Treatment Approach**: Non-surgical + PRP Therapy Group 1: 3 mL Platelet-rich plasma Group 2: 3 mL Platelet-poor plasma Group 3: No injection **Domain(s) of Rehabilitation:** Physical Domain (i) Clinical (ii) Functional Non-Physical Domain (i) Contextual **Stage(s) of Recovery:** Return to Participation RTP **RTS decision-making guidelines:** 1. Asymptomatic completion of 6 stage rehabilitation programme: Standardised physiotherapy programme + Sport-specific functional field testing 2. Isokinetic evaluation 3. Clinical examination + MRI 4. Consideration of sport risk modifiers and decision modifiers also guided final RTP decision of treating physician **Decision-making approach:** Isolated Stakeholder: Sports Physician	**Criteria Informing Rehabilitation Progression:** *Clinical Examination / Evaluation* **Pain** Pain free single leg squat Pain free bike @ 150W for 5mins Pain free sport specific functional field testing (e g , direction change drills, jumping drills, pass/run, passing/crossing progressions) Pain free high-speed changes of direction (+) *Assessment Method/Tools/Tests Used* VAS (0-10) **Range of Motion** Full knee extension (supine) Hamstrings ≥75% uninvolved side SLR ≥75% uninvolved side *Assessment Method/Tools/Tests Used* Not stated *Functional/Performance Based Criteria* **High Speed Running / Sprinting** Run ≥70% running speed (30m) (Progressed from 25% - 70% max speed) Achieve 100% running speed (30m) (Progressed from 70% to 100% max speed) *Assessment Method/Tools/Tests Used* Patient rated/determined running speeds **Agility** High speed changes of direction (Progress from 70% - 100% max speed) *Assessment Method/Tools/Tests Used* Modified T-test Patient rated/determined running speeds **Completion of a Specific Programme** Progressive Running Programme

									3-Stage Standardised Physiotherapy Programme (e g , ROM, progressive strengthening, core stability and agility exercises) **Criteria Informing RTP:** *Clinical Examination / Evaluation* **Pain** Pain free completion of sport specific rehab (e.g., shooting, 1v1 and scoring scenarios) *Assessment Method/Tools/Tests Used* VAS (0-10) **Satisfactory Clinical Exam** *Strength Tests* **Isokinetic** (Performed on injured + uninjured leg) Concentric Quadriceps & Hamstring Strength 5 reps - 60 /s concentric knee flexion / extension 10 reps - 300 /s concentric knee flexion / extension Eccentric / Concentric Hamstring Strength 5 reps - 60 /s eccentric knee extension and 180 /s concentric knee flexion *Assessment Method/Tools/Tests Used* IKD *Functional/Performance Based Criteria* **Completion of a Specific Programme** Sport Specific Functional Field Testing (Without limitation and/or symptoms) **Post RTP follow up:** *Follow Up Period*

									Monitored monthly via Telephone Interview – player subjective feedback regarding any suspicion of re-injury – 2months

De Vos et al ,	2014	Holland	Prospective study of a cohort of participants in a larger RCT	III	To investigate the association between clinical and imaging findings at baseline (including MRI findings of the initial injury) and standardised clinical tests just after RTP with the occurrence of hamstring re-injuries.	**Sport:** Multi-Sport Including Football and American Football **Level:** Mixed: Professional (*n*=49) Recreational (*n*=15) **Total Sample:** *n*=64 Injuries: *n*=64 Injuries recorded Injuries involving Footballers *n*=45 American football *n*=1 **Sex:** Male (*n*=61) Female (*n*=3) **Age: Median** 28 (Range 23-33)	**Muscle Group:** Hamstring **Specific Muscle(s) Involved:** Biceps Femoris (long head) (n=56) Semitendinosus / Semimembranosus (n=8) **Diagnosis Approach:** Clinical Symptoms and Assessment Tests: (i) Acute onset of posterior thigh pain (ii) Pain on hamstring stretching (iii) Pain on hamstring resisted contraction (iv) Presence and localised pain on palpation **Imaging Performed**: Yes Imaging Technique: MRI **Injury Grading:** **(Only G1/2 injuries considered)** 18 Grade 1 injuries 46 Grade 2 injuries **Time to RTP (Median) (IQR):** 40 (Range 31-55) **Injury Recurrences:** 17	**Treatment Approach**: Non-Surgical + PRP Therapy Group 1: 2x 3 mL Platelet-rich plasma Group 2: 2x 3 mL normal saline **Domain(s) of Rehabilitation:** Physical Domain (i) Clinical (ii) Functional Non-Physical Domain (i) Psychological **Stage(s) of Recovery:** Return to Participation RTP **RTS decision-making guidelines:** 1. Asymptomatic completion of phased rehabilitation programme: Standardised physiotherapy programme + progressive agility and trunk stability programme 2. Symptom-free (e.g., pain and stiffness) full range of motion 3. Symptom-free full-speed sprinting 4. Symptom-free performance of sport-specific movements **Decision-making approach:** Isolated Stakeholder: Physiotherapist	**Criteria Informing Rehabilitation Progression:** *Clinical Examination / Evaluation* **Pain** Demonstrate normal walking stride/gait without pain Pain free high knee march Very low speed running without pain (+) Pain-free sub-maximal isometric contraction (+) Pain-free full strength isometric contraction (+) Pain-free forward / backward running (50% max speed) (+) *Assessment Method/Tools/Tests Used* Pain – Patient feedback *Strength Tests* **Isometric** Submaximal (50-70% resistance) manual strength test in prone knee flexion (90 knee flexion) *Assessment Method/Tools/Tests Used* Manual assessment of strength Full strength (5/5) during 1 rep maximal effort manual strength test in prone knee flexion (90 knee flexion) *Assessment Method/Tools/Tests Used* Manual assessment of strength *Functional/Performance Based Criteria* **Low / Moderate Speed Running (Activity)** Perform very low speed running Forward + backward running at 50% max speed *Assessment Method/Tools/Tests Used* Not stated **Completion of a Specific Programme** Progressive agility and trunk stability programme

									Criteria Informing RTP: *<u>Clinical Examination / Evaluation</u>* **Pain** Pain free full range of motion (+) Pain free max speed running (+) Pain free sport specific movements/actions Full strength without pain (+) *<u>Assessment Method/Tools/Tests Used</u>* Pain - Patient feedback **Range of Motion (ROM)** Full range of motion *<u>Assessment Method/Tools/Tests Used</u>* Not stated *<u>Strength Tests</u>* **Isometric** Manual strength testing - 4 consecutive max effort reps in prone knee flexion (90 and 15 flexion) *<u>Assessment Method/Tools/Tests Used</u>* Manual assessment of strength **Isokinetic** <5% bilateral deficit in H:Q ratio – (eccentric hamstrings 30 /s / concentric quadriceps 240 /s) *<u>Assessment Method/Tools/Tests Used</u>* IKD Bilateral symmetry in knee flexion angle of peak concentric knee flexion torque at 60 /s *<u>Assessment Method/Tools/Tests Used</u>* IKD

									Functional/Performance Based Criteria **High Speed Running / Sprinting** Achieve max speed sprinting *Assessment Method/Tools/Tests Used* Not stated **Non-Specific Performance-Based Criteria** Unhindered functional sports-specific testing *Assessment Method/Tools/Tests Used* Not stated **Post RTP follow up:** (Assessments performed within 7 days of RTP) Patient Report **Patient-Reported Outcome Measures** Hamstring Outcome Score (HaOS) (0-100% score) Patients perceived recovery (VAS 0-7) *Assessment Method/Tools/Tests Used* HaOS Perceived recovery (VAS) *Clinical Examination / Evaluation* **Pain** Localised pain on palpation (presence/absence) *Assessment Method/Tools/Tests Used* Pain - Patient feedback **Range of Motion (ROM)** (Performed on injured + uninjured leg) Active knee extension (90 hip flexion) – max knee angle measured in both limbs + flexibility deficit calculated between injured and uninjured leg

									Assessment Method/Tools/Tests Used Inclinometer Passive SLR – max angle measured in both legs + flexibility deficit calculated between injured and uninjured leg *Assessment Method/Tools/Tests Used* Inclinometer *Strength Tests* (Performed on injured + uninjured leg) **Isometric** Peak knee flexion force at 90 and 15 (knee flexion) – relative strength deficit calculated between injured and uninjured leg *Assessment Method/Tools/Tests Used* HHD *Follow Up Period* 12 months periodic follow up – whereby re-injury occurrences were registered

Reurink et al ,	2014	Holland / Qatar	Prospective study of a cohort of participants in a larger RCT	III	To describe MRI findings of hamstring muscles in athletes, who have clinically recovered from an acute non-contact hamstring injury, and were cleared to RTP	**Sport:** Multi-Sport including Football **Level:** Mixed, Professional: *n*=24 Competitive: *n*=19 Recreational: *n*=10 **Total Sample:** *n*=53 Injuries: *n*=53 Injuries involving Footballers (*n*=40) **Sex:** Male **Age: Median** 27 (Range 18-46)	**Muscle Group:** Hamstring **Specific Muscle(s) Involved:** Biceps Femoris (long head) (*n*=44) Semitendinosus (*n*=2) Semimembranosus (*n*=9) **Diagnosis Approach:** Clinical Symptoms and Assessment Tests: Not stated **Imaging Performed**: Yes Imaging Technique: MRI **Injury Grading:** **(Only G1/2 injuries considered)** 27 Grade 1 Injuries 26 Grade 2 Injuries **Time to RTP (Median):** 28 (Range 12-76) **Injury Recurrences:** 5	**Treatment Approach**: Non-surgical / PRP Dutch Cohort: Group 1: 2x 3 mL Platelet-rich plasma Group 2: 2x 3 mL normal saline Qatar Cohort: Group 1: 3 mL Platelet-rich plasma Group 2: 3 mL Platelet-poor plasma Group 3: No injection **Domain(s) of Rehabilitation:** Physical Domain (i) Clinical (ii) Functional **Stage(s) of Recovery:** RTP **RTS decision-making guidelines:** 1. Asymptomatic completion of 4-stage rehabilitation programme: Standardised physiotherapy programme + Sport-specific functional field testing 2. Isokinetic evaluation: <10% bilateral strength asymmetry 3. Players advised to complete 5 days if team training before participating in partial match-play (Recommendation only) **Decision-making approach:** Dutch Cohort: Isolated Stakeholder: Physiotherapist Qatar Cohort: Not stated	**Criteria Informing RTP:** *Strength Tests* **Isokinetic** <10% asymmetry between injured and uninjured limbs *Assessment Method/Tools/Tests Used* IKD *Imaging* MRI (Compared between MRI exam on initial injury (within 5 days of injury) and post-RTP MRI exam (within 3 days of RTP clearance) Measurements: Injury severity (Grading) Intramuscular increased signal intensity (present / absent) Longitudinal length (craniocaudal) Involved cross sectional area (%) (transverse plane) *Functional/Performance Based Criteria* **Completion of a Specific Programme** Sport specific functional field testing (Without limitation and/or symptoms) **Non-Specific Performance-Based Criteria** Complete 5 days of team training before participating in partial match-play (recommendation only) **Post RTP follow up:** *Follow Up Period* 2 months periodic follow up – whereby re-injury occurrences were registered

Hamilton et al ,	2015	Qatar	RCT	II	To evaluate the efficacy of a single platelet-rich plasma (PRP) injection in reducing return to sport (RTS) duration among male athletes, following an acute hamstring injury.	**Sport:** Multi-Sport including Football **Level:** Mixed: Professional (*n*=87) Competitive (*n*=3) **Total Sample:** *n*=90 Injuries: *n*=90 Injuries involving Footballers (*n*=66) **Sex:** Male **Age: Mean (SD)** Group 1: PRP Treatment 26.6(5.9) Group 2: Platelet-poor plasma Treatment 25.6(5.8) Group 3: No injection 25.5(5.7)	**Muscle Group:** Hamstring **Specific Muscle(s) Involved:** Not stated **Diagnosis Approach:** Clinical Symptoms and Assessment Tests: (i) Acute onset of posterior thigh pain **Imaging Performed**: Yes Imaging Technique: MRI **Injury Grading:** **(Only G1/2 injuries considered)** Group 1: PRP Treatment 17 Grade 1 Injuries 13 Grade 2 injuries Group 2: Platelet-poor plasma Treatment 16 Grade 1 Injuries 13 Grade 2 injuries Group 3: No injection 13 Grade 1 Injuries 17 Grade 2 injuries **Time to RTP (Median):** Group 1: PRP – 21 days Group 2: Platelet-poor plasma – 27 days Group 3: No injection – 25 days	**Treatment Approach**: Non-surgical / PRP Group 1: 3 mL Platelet-rich plasma Group 2: 3 mL Platelet-poor plasma Group 3: No injection **Domain(s) of Rehabilitation:** Physical Domain (i) Clinical (ii) Functional **Stage(s) of Recovery:** Return to Participation RTP **RTS decision-making guidelines:** 1. Asymptomatic completion of 6 stage rehabilitation programme: Standardised physiotherapy programme + Sport-specific functional field testing 2. Isokinetic evaluation 3. Clinical examination + MRI **Decision-making approach:** Isolated Stakeholder: Sports Physician	**Criteria Informing Rehabilitation Progression:** *Clinical Examination / Evaluation* **Pain** Pain free single leg squat Pain free bike @ 150W for 5mins Pain free sport specific functional field testing (e g , direction change drills, jumping drills, pass/run, passing/crossing progressions) Pain free high-speed changes of direction (+) *Assessment Method/Tools/Tests Used* VAS (0-10) **Range of Motion** Full knee extension (supine) Hamstrings ≥75% uninvolved side SLR ≥75% uninvolved side *Assessment Method/Tools/Tests Used* Not stated *Functional/Performance Based Criteria* **High Speed Running / Sprinting** Run ≥70% running speed (30m) (Progressed from 25% - 70% max speed) Achieve 100% running speed (30m) (Progressed from 70% to 100% max speed) *Assessment Method/Tools/Tests Used* Patient rated/determined running speeds **Agility** High speed changes of direction (Progress from 70% - 100% max speed) *Assessment Method/Tools/Tests Used* Modified T-test Patient rated/determined running speeds **Completion of a Specific Programme** Progressive Running Programme 3-Stage Standardised Physiotherapy Programme

							Injury Recurrences: 14 Group 1: PRP Treatment Within 2 months RTP (2) Within 6 months RTP (2) Group 2: Platelet-poor plasma Treatment Within 2 months RTP (2) Within 6 months RTP (3) Group 3: No injection Within 2 months RTP (2) Within 6 months RTP (3)		(e g , ROM, progressive strengthening, core stability and agility exercises) **Criteria Informing RTP:** *Clinical Examination / Evaluation* **Pain** Pain free completion of sport specific rehab (e.g., shooting, 1v1 and scoring scenarios) *Assessment Method/Tools/Tests Used* VAS (0-10) **Satisfactory Clinical Exam** *Strength Tests* **Isokinetic** (Performed on injured + uninjured leg) Concentric quadriceps and hamstring strength: 5 reps - 60 /s concentric knee flexion / extension 10 reps - 300 /s concentric knee flexion / extension Eccentric / Concentric Hamstring Strength 5 reps - 60 /s eccentric knee extension and 180 /s concentric knee flexion *Assessment Method/Tools/Tests Used* IKD *Functional/Performance Based Criteria* **Completion of a Specific Programme** Sport Specific Functional Field Testing (Without limitation and/or symptoms) *Imaging* MRI **Post RTP follow up:** *Follow Up Period*

									Monitored for 6 months via Telephone Interview – player subjective feedback

Pedret et al.,	2015	Spain	Case series	IV	To assess whether the location of the soleus muscle injury determines the time to RTP	**Sport:** Multi-Sport Including Football **Level:** Professional **Total Sample:** *n*=61 Injuries: *n*=44 Injuries involving Footballers (*n*=27) **Sex:** Male **Age: Mean (SD)** 31.85(7.45)	**Muscle Group:** Calf **Specific Muscle(s) Involved:** Soleus **Diagnosis Approach:** Clinical Symptoms and Assessment Tests: (i) Acute onset of posterior calf pain (ii) Presence and localised pain on palpation (iii) Strength testing (iv) Pain with passive ROM of ankle and stretching **Imaging Performed**: Yes Imaging Technique: MRI **Injury Grading:** Not stated **Time to RTP (SD):** Soleus Injuries Overall 29.1(18.8) (Range 6-81) Location Specific Overview: Myotendinous junction (Overall) 27 (17.7) (Range 6-79) - Myotendinous medial 25 (10.7) (Range 13-54) - Myotendinous central 44.3 (23) (Range 21-79) - Myotendinous lateral	**Treatment Approach**: Non-surgical **Domain(s) of Rehabilitation:** Physical Domain (i) Clinical (ii) Functional **Stage(s) of Recovery:** RTP **RTS decision-making guidelines:** 1. Asymptomatic completion of rehabilitation programme **Decision-making approach:** Not stated	**Criteria Informing RTP:** *Clinical Examination / Evaluation* **Pain** Pain free completion of rehabilitation programme (to pass between phases, players had to remain asymptomatic) *Assessment Method/Tools/Tests Used* Pain – Patient feedback **Post RTP follow up:** 12 months follow up – whereby re-injury occurrences were registered

							19.2 (13.5) (Range 6-54) Myofascial Injuries (Overall) 34.6 (21.8) (Range 9-81) - Myofascial anterior 33.1 (19) (Range 9-62) - Myofascial posterior 37.5 (29.4) (Range 17-81) **Injury Recurrences:** 3		

Botha et al.,	2015	South Africa	Case series	IV	The primary aim of this case report is to describe the effect on the recovery time of hamstring injuries when coming hyperbaric oxygen therapy and PRP injection therapy with exercise rehabilitation.	**Sport:** Rugby **Level:** Professional **Total Sample:** *n*=42 Injuries: *n*=42 **Sex:** Male **Age: Mean (SD)** 27.87 (3.86)	**Muscle Group:** Hamstring **Specific Muscle(s) Involved:** Not stated **Diagnosis Approach:** Clinical Symptoms and Assessment Tests: Not stated **Imaging Performed**: Yes Imaging Technique: MRI / Ultrasound **Injury Grading:** 37 Grade 1 Injuries 5 Grade 2 Injuries **Time to RTP (SD):** Grade 1 Injuries 13.1 (6.4) Grade 2 Injuries 22.8 (8.7) **Injury Recurrences:** 8 All re-injuries occurred in players with grade 1 injuries	**Treatment Approach**: Non-surgical, hyperbaric oxygen therapy and PRP therapy Hyperbaric oxygen therapy protocol (11 sessions): Breathing 100% oxygen while being subjected to a pressure of 2 4 ATA for 60mins 2mL PRP injections were repeated at 7-day intervals until patient attained pain free fill range of motion **Domain(s) of Rehabilitation:** Physical Domain (i) Clinical (ii) Functional **Stage(s) of Recovery:** Return to Participation RTP **RTS decision-making guidelines:** 1. Asymptomatic completion of a 4-phase rehabilitation programme Pain required to be <2 (VAS 0-10) in all exercises to progress between phases 2. Pass a RTP fitness protocol **Decision-making approach:** Not stated	**Criteria Informing Rehabilitation Progression:** *Clinical Examination / Evaluation* **Pain** Pain during all activities (VAS <2) to progress rehab phases (+) *Assessment Method/Tools/Tests Used* VAS (0-10) **Satisfactory Clinical Exam** *Strength Tests* **Method of Strength Test not clearly stated** Address bilateral discrepancies *Functional/Performance Based Criteria* **High Speed Running / Sprinting** Sub-maximal running (80% max speed) Perform speed drills at full pace (100 % max speed) *Assessment Method/Tools/Tests Used* Not stated **Agility** Perform agility drills at full pace (100% max speed) *Assessment Method/Tools/Tests Used* Not stated **Completion of a Specific Programme** Rehabilitation programme **Criteria Informing RTP:** *Clinical Examination / Evaluation* **Pain** Pain free completion of sport specific drills (+)

									Assessment Method/Tools/Tests Used VAS (0-10) *Strength Tests* **Isokinetic** Hamstring concentric and eccentric strength - 100% of pre-injury baseline - Equal to contralateral uninjured limb - Appropriate to bodyweight - Adequate Hamstring:Quadriceps ratio *Assessment Method/Tools/Tests Used* IKD *Functional/Performance Based Criteria* **High Speed Running / Sprinting** 10m linear sprinting – performed in pre-injury time 40m linear sprinting – performed in pre-injury time 100m linear sprinting – performed in pre-injury time *Assessment Method/Tools/Tests Used* Not stated **Agility** T-Test – completed at pre-injury speeds Illinois Test – completed at pre-injury speeds *Assessment Method/Tools/Tests Used* T-test Illinois Test **Completion of a Specific Programme** Successfully complete a specific RTP clearance test protocol **Non-Specific Performance-Based Criteria** Sport-specific drills performed at full speed (Without any hesitation/guarding) *Assessment Method/Tools/Tests Used* Not stated

									Post RTP follow up: Not stated

Reurink et al ,	2015	Holland/ Qatar	Prospective study of a cohort of participants in a larger RCT	III	To examine the association between the presence of fibrosis on MRI at return to play after an acute hamstring injury and the risk of reinjury.	**Sport:** Multi-Sport Including Football **Level:** Mixed, Professional (n=44) Competitive (n=48) Recreational (n=16) **Total Sample:** *n*=108 Injuries: *n*=108 Injuries involving Footballers (*n*=76) **Sex:** Male (*n*=105) Female (*n*=3) **Age: Mean (SD)** 28(7)	**Muscle Group:** Hamstring **Specific Muscle(s) Involved:** Biceps Femoris (Long head) (*n*=88) Semimembranosus (*n*=16) Semitendinosus (*n*=4) **Diagnosis Approach:** Clinical Symptoms and Assessment Tests: Not stated **Imaging Performed**: Yes Imaging Technique: MRI **Injury Grading:** Not stated **Time to RTP (Median):** 30 (IQR 22-42) **Injury Recurrences:** 10 Biceps Femoris (Long head) (n=10)	**Treatment Approach**: Non-surgical + PRP Therapy Dutch Cohort: Group 1: 2x 3 mL Platelet-rich plasma Group 2: 2x 3 mL normal saline Qatar Cohort: Group 1: 3 mL Platelet-rich plasma Group 2: 3 mL Platelet-poor plasma Group 3: No injection **Domain(s) of Rehabilitation:** Physical Domain (i) Clinical (ii) Functional **Stage(s) of Recovery:** RTP **RTS decision-making guidelines:** 1. Asymptomatic completion of 6-stage rehabilitation programme: Standardised physiotherapy programme + Sport-specific functional field testing 2. Isokinetic evaluation 3. Clinical examination + MRI 4. Players advised to complete 5 days if team training before participating in partial match-play (Recommendation only) **Decision-making approach:** Not stated	**Criteria Informing Rehabilitation Progression:** *Clinical Examination / Evaluation* **Pain** Pain free single leg squat Pain free bike @ 150W for 5mins Pain free sport specific functional field testing (e g , direction change drills, jumping drills, pass/run, passing/crossing progressions) Pain free high-speed changes of direction (+) *Assessment Method/Tools/Tests Used* VAS (0-10) **Range of Motion** Full knee extension (supine) Hamstring ROM ≥75% uninvolved side SLR ≥75% uninvolved side *Assessment Method/Tools/Tests Used* Not stated *Functional/Performance Based Criteria* **High Speed Running / Sprinting** Run ≥70% running speed (30m) (Progressed from 25% - 70% max speed) Achieve 100% running speed (30m) (Progressed from 70% to 100% max speed) *Assessment Method/Tools/Tests Used* Patient rated/determined running speeds **Agility** High speed changes of direction (Progress from 70% - 100% max speed) *Assessment Method/Tools/Tests Used* Modified T-Test Patient rated/determined running speeds **Completion of a Specific Programme**

									Progressive Running Programme 3-Stage Standardised Physiotherapy Programme (e g , ROM, progressive strengthening, core stability and agility exercises) **Criteria Informing RTP:** *Clinical Examination / Evaluation* **Pain** Pain free completion of sport specific rehab (e.g., shooting, 1v1 and scoring scenarios, pass and run) *Assessment Method/Tools/Tests Used* VAS (0-10) **Satisfactory Clinical Exam** *Imaging* MRI (performed within 1 week of RTP) Measurements: Longitudinal length (craniocaudal) Cross sectional area (%) of total muscle CSA Intramuscular fibrosis (Absent / Present) Fibrosis longitudinal length Length of fibrosis (axial view) Width of fibrosis (axial view) Volume (fibrosis) *Strength Tests* **Isokinetic testing** (Performed on injured + uninjured leg) (No strict isokinetic criteria were specified to be met) Concentric Quadriceps & Hamstring Strength 5 reps - 60 /s concentric knee flexion / extension 10 reps - 300 /s concentric knee flexion / extension Eccentric / Concentric Hamstring Strength

									5 reps - 60 /s eccentric knee extension and 180 /s concentric knee flexion *Assessment Method/Tools/Tests Used* Isokinetic Dynamometer (IKD) *Functional/Performance Based Criteria* **Completion of a Specific Programme** Sport Specific Functional Field Testing (Without limitation and/or symptoms) **Non-Specific Performance-Based Criteria** Complete 5 days if team training before participating in partial match-play (Recommendation only) **Post RTP follow up:** *Follow Up Period* 1 year follow up wherein reinjuries were registered

Francavilla et al.,	2015	Italy	Case study	IV	The study objectives were to: 1) describe how localized BIA is performed on the muscle groups of the lower limbs; 2) measure and record changes in BIA parameters postinjury and during the healing process; 3) identify the order of magnitude of the relative differences in the BIA values and compare them with baseline (non-injury) values; 4) monitor the changes in BIA values as indicators for return to play in a soccer player who had sustained a leg muscle injury.	**Sport:** Football **Level:** Professional **Total Sample:** *n*=1 Injuries: *n*=1 **Sex:** Male **Age:** 24	**Muscle Group:** Hamstrings **Specific Muscle(s) Involved:** Biceps Femoris **Diagnosis Approach:** Clinical Symptoms and Assessment Tests: Not stated **Imaging Performed**: Yes Imaging Technique: MRI Other Diagnostic tests: L-BIA **Injury Grading:** Grade 2 Injury **Time to RTP:** 39 days **Injury Recurrences:** 0	**Treatment Approach**: Non-surgical **Domain(s) of Rehabilitation:** Physical Domain (i) Clinical (ii) Functional **Stage(s) of Recovery:** RTP **RTS decision-making guidelines:** 1. Completion of rehabilitation programme **Decision-making approach:** Not stated	**Criteria Informing RTP:** *Bioelectrical Impedance Vector Analysis* Localised Bioelectrical Impedance (L-BIA) Measurements: Resistance (describes changes in tissue fluid volume) Reactance (describes changes in soft-tissue structure) Phase angle (together with reactance describes general status of cell membranes) % Change in each parameter relative to baseline values Injury leg compared to baseline values of the leg recorded pre-injury. Values required to have returned (or be in line) with baseline values for RTP (recovery value) L-BIA measurements were recorded at: 1 day post injury 4 days post injury 12 days post injury 18 days post injury 22 days post injury Day of return to play *Imaging* MRI Measurements: Sagittal, axial and coronal scans taken at 21- and 40-days post injury **Post RTP follow up:** Not stated

Wangensteen et al.,	2015	Qatar	Prospective study of a cohort of participants in a larger RCT	III	To investigate the predictive value of patient history taking and clinical examination at baseline alone, and again with the addition of MRI findings for time to RTS after acute hamstring injuries in male athletes using multivariate analyses and controlling for potential confounders.	**Sport:** Multi-Sport Including Football **Level:** Mixed, Professional (*n*=177) Competitive (*n*=3) **Total Sample:** *n*=180 Injuries: *n*=180 Injuries involving Footballers (n=139) **Sex:** Male **Age: Mean (SD)** 26 (5)	**Muscle Group:** Hamstring **Specific Muscle(s) Involved:** Biceps Femoris (Long head) (*n*=112) Biceps Femoris (Short head) (*n*=1) Semitendinosus (*n*=4) Semimembranosus (*n*=24) In 27 cases, two or more muscles involved **Diagnosis Approach:** Clinical Symptoms and Assessment Tests: (i) Acute onset of posterior thigh pain (ii) Pain experienced with injury (VAS scale, 0-10) (iii) Pain with ROM testing - Trunk flexion - Passive straight leg raise - Active knee extension (at 90° hip flexion) (iv) Manual muscle testing - Pain on resisted isometric knee flexion with 90° hip and knee flexion - Pain on resisted isometric hip extension with 30° hip and knee flexion (v) Slump test (vi) Presence and localised pain on palpation **Imaging Performed**: Yes Imaging Technique: MRI **Injury Grading:**	**Treatment Approach**: Non-surgical + PRP Therapy Group 1: 3 mL Platelet-rich plasma Group 2: 3 mL Platelet-poor plasma Group 3: No injection **Domain(s) of Rehabilitation:** Physical Domain (i) Clinical (ii) Functional Non-Physical Domain (i) Contextual **Stage(s) of Recovery:** Return to Participation RTP **RTS decision-making guidelines:** 1. Asymptomatic completion of 6-stage rehabilitation programme: Standardised physiotherapy programme + Sport-specific functional field testing 2. Isokinetic evaluation 3. Clinical examination 4. Consideration of sports risk modifiers and decision modifiers **Decision-making approach:** Isolated Stakeholder: Sports Physician	**Criteria Informing Rehabilitation Progression:** *Clinical Examination / Evaluation* **Pain** Pain free single leg squat Pain free bike @ 150W for 5mins Pain free sport specific functional field testing (e g , direction change drills, jumping drills, pass/run, passing/crossing progressions) Pain free high-speed changes of direction (+) *Assessment Method/Tools/Tests Used* VAS (0-10) **Range of Motion** Full knee extension (supine) Hamstrings ≥75% uninvolved side SLR ≥75% uninvolved side *Assessment Method/Tools/Tests Used* Not stated *Functional/Performance Based Criteria* **High Speed Running / Sprinting** Run ≥70% running speed (30m) (Progressed from 25% - 70% max speed) Achieve 100% running speed (30m) (Progressed from 70% to 100% max speed) *Assessment Method/Tools/Tests Used* Patient rated/determined running speeds **Agility** High speed changes of direction (Progress from 70% - 100% max speed) *Assessment Method/Tools/Tests Used* Modified T-test Patient rated/determined running speeds **Completion of a Specific Programme** Progressive Running Programme

							39 Grade 0 Injuries 82 Grade 1 Injuries 59 Grade 2 Injuries **Time to RTP (SD):** **(Only G1/2 injuries considered)** -All Injuries 21(12) (Range 1-72) -MRI Positive Injury Cases 24(12) *Grade 1 Injuries* *21(11) (Range 1-66)* *Grade 2 Injuries* *28(12) (Range 9-72)* -Presence of central tendon disruption Yes: 28 (11) No: 21 (11) -MRI Negative Injury Cases *Grade 0 Injuries* *13(8) (Range 4-36)* **Injury Recurrences:** Not stated		3-Stage Standardised Physiotherapy Programme (e g , ROM, progressive strengthening, core stability and agility exercises) **Criteria Informing RTP:** *Clinical Examination / Evaluation* **Pain** Pain free completion of sport specific rehab (e.g., shooting, 1v1 and scoring scenarios) *Assessment Method/Tools/Tests Used* VAS (0-10) **Satisfactory Clinical Exam** *Strength Tests* **Isokinetic** (Performed on injured + uninjured leg) Concentric Quadriceps & Hamstring Strength 5 reps - 60 /s concentric knee flexion / extension 10 reps - 300 /s concentric knee flexion / extension Eccentric / Concentric Hamstring Strength 5 reps - 60 /s eccentric knee extension and 180 /s concentric knee flexion *Assessment Method/Tools/Tests Used* IKD *Functional/Performance Based Criteria* **Completion of a Specific Programme** Sport Specific Functional Field Testing (Without limitation and/or symptoms) Custom made Rehabilitation programme (Applicable to athletes included in prospective case series who did not undertake the outlined protocol – no specific information given i e club/federation specific) **Post RTP follow up:** Not stated

Jacobsen et al ,	2016	Qatar	Prospective study of a cohort of participants in a larger RCT	III	To examine the ability of (1) subjective and objective information obtained at the time of initial physiotherapy examination, (2) results of physiotherapy examination 7 days after the initial examination and (3) the MRI examination at initial examination to predict time to return to play after hamstring injury.	**Sport:** Multi-sport including football **Level:** Professional **Total Sample:** *n*=90 Injuries: *n*=90 Injuries involving footballers: *n*=66 **Sex:** Male **Age: Mean (SD)** 25.8 (5.8)	**Muscle Group:** Hamstring **Specific Muscle(s) Involved:** Not stated **Diagnosis Approach:** Clinical Symptoms & Assessment Tests: Initial exam was subsequently performed daily, except for IKD assessment Pain reported using VAS (0-10) pain scale (i) Subjective pain level reported Maximum pain at time of injury Average pain day of assessment (ii) Pain on standing trunk flexion (iii) Functional Testing Pain limited walking Pain limited jogging Pain on 2-leg half squat Pain on 1-leg quarter squat Single/Double leg bridge testing (iv) Presence and localised pain on palpation (v) Strength assessments (injured/uninjured legs tested) (Isometric strength assessed using HHD) Strength/pain on inner range Strength/pain on mid-range	**Treatment Approach**: Non-surgical + PRP Therapy Group 1: 3 mL Platelet-rich plasma Group 2: 3 mL Platelet-poor plasma Group 3: No injection (All groups performed standardised rehabilitation programme) **Domain(s) of Rehabilitation:** Physical Domain (i) Clinical (ii) Functional **Stage(s) of Recovery:** Return to Participation RTP **RTS decision-making guidelines:** 1. Asymptomatic completion of 6-stage rehabilitation programme: Standardised physiotherapy programme + Sport-specific functional field testing 2. Isokinetic evaluation 3. Clinical examination + MRI **Decision-making approach:** Isolated Decision Stakeholder: Sports Physician	**Criteria Informing Rehabilitation Progression:** *Clinical Examination / Evaluation* **Pain** Pain free single leg squat Pain free bike @ 150W for 5mins Pain free sport specific functional field testing (e g , direction change drills, jumping drills, pass/run, passing/crossing progressions) Pain free high-speed changes of direction (+) *Assessment Method/Tools/Tests Used* VAS (0-10) **Range of Motion** Full knee extension (supine) Hamstring ROM ≥75% uninvolved side SLR ≥75% uninvolved side *Assessment Method/Tools/Tests Used* Not stated *Functional/Performance Based Criteria* **High Speed Running / Sprinting** Run ≥70% running speed (30m) (Progressed from 25% - 70% max speed) Achieve 100% running speed (30m) (Progressed from 70% to 100% max speed) *Assessment Method/Tools/Tests Used* Patient rated/determined running speeds **Agility** High speed changes of direction (Progress from 70% - 100% max speed) *Assessment Method/Tools/Tests Used* Modified T-Test Patient rated/determined running speeds

							Strength/pain outer-range (vi) ROM assessments (ROM measured with inclinometer) Range/pain on SLR Range/pain on PKET (90 hip flexion) Range/pain on MHFAKE (vii) IKD evaluation (Uninjured leg only) Peak torque and angle of peak torque for knee flexion and extension at: Concentric Quadriceps & Hamstring Strength 5 reps - 60 /s concentric knee flexion / extension 10 reps - 300 /s concentric knee flexion / extension Eccentric / Concentric Hamstring Strength 5 reps - 60 /s eccentric knee extension and 180 /s concentric knee flexion **Imaging Performed**: Yes Imaging Technique: MRI **Injury Grading:** **(Only G1/2 injuries considered)** 46 Grade 1 Injuries 44 Grade 2 Injuries **Time to RTP (SD):** 25.1 (10.1) **Injury Recurrences:** Not stated		**Completion of a Specific Programme** Progressive Running Programme 3-Stage Standardised Physiotherapy Programme (e g , ROM, progressive strengthening, core stability and agility exercises) **Criteria Informing RTP:** *Clinical Examination / Evaluation* **Pain** Pain free completion of sport specific rehab (e.g., shooting, 1v1 and scoring scenarios, pass and run) *Assessment Method/Tools/Tests Used* VAS (0-10) **Satisfactory Clinical Exam** *Imaging* MRI examination Measurements: - Distance from ischial tuberosity - Longitudinal length (craniocaudal) of lesion - Volume of the lesion - Involved cross-sectional area as a % of the total muscle cross-sectional area (in transversal plane) *Strength Tests* **Isokinetic testing** (Performed on injured + uninjured leg) (No strict isokinetic criteria were specified to be met) Concentric Quadriceps & Hamstring Strength 5 reps - 60 /s concentric knee flexion / extension 10 reps - 300 /s concentric knee flexion / extension Eccentric / Concentric Hamstring Strength 5 reps - 60 /s eccentric knee extension and 180 /s concentric knee flexion

									Assessment Method/Tools/Tests Used Isokinetic Dynamometer (IKD) *Functional/Performance Based Criteria* **Completion of a Specific Programme** Sport Specific Functional Field Testing (Without limitation and/or symptoms) **Post RTP follow up:** Not stated

Kellis et al.,	2016	Greece	Case study	IV	To examine the use of ultrasound to monitor changes in the long head of the biceps femoris architecture of a professional footballers with acute hamstring injury.	**Sport:** Football **Level:** Professional **Total Sample:** *n*=1 Injuries: *n*=1 **Sex:** Male **Age**: 23	**Muscle Group:** Hamstring **Specific Muscle(s) Involved:** Biceps Femoris (Long head) **Diagnosis Approach:** Clinical Symptoms and Assessment Tests: (i) Presence and localised pain on palpation (ii) Pain on SLR (>45%) **Imaging Performed**: Yes Imaging Technique: MRI / Ultrasound Muscle injury Classification System used: Munich muscle classification system **Injury Grading:** Not stated **Time to RTP:** Not stated **Injury Recurrences:** 0	**Treatment Approach**: Non-surgical **Domain(s) of Rehabilitation:** Physical Domain (i) Clinical (ii) Functional **Stage(s) of Recovery:** Return to Participation RTP **RTS decision-making guidelines:** 1. Asymptomatic completion of 3-phase rehabilitation programme 2. Perform advanced sport-specific exercises without pain 2. Strength imbalances between injured and uninjured leg <5% **Decision-making approach:** Not stated	**Criteria Informing Rehabilitation Progression:** *Clinical Examination / Evaluation* **Pain** Pain free full range of motion Pain free submaximal isometric contraction (+) Pain free maximal voluntary isometric contraction (+) *Assessment Method/Tools/Tests Used* Pain – Patient feedback **Range of Motion (ROM)** Full range of motion *Assessment Method/Tools/Tests Used* Not stated *Strength Tests* **Isometric** Demonstrate submaximal isometric strength *Assessment Method/Tools/Tests Used* Not stated Perform maximal voluntary contraction at 0 (full extension), 45 , 90 (knee flexion) *Assessment Method/Tools/Tests Used* IKD *Imaging* Ultrasound (To quantify changes in pentation angle and scar dimensions) **Criteria Informing RTP:** *Clinical Examination / Evaluation* **Pain**

									Perform sport specific exercises without pain (+) *Assessment Method/Tools/Tests Used* Pain – Patient feedback *Strength Tests* **Isometric** Perform maximal voluntary contraction at 0 (full extension), 45 , 90 (knee flexion) <5% strength asymmetry between legs *Assessment Method/Tools/Tests Used* IKD *Imaging* Ultrasound (To quantify changes in pennation angle and scar dimensions) *Functional/Performance Based Criteria* **Non-Specific Performance-Based Criteria** Able to perform advanced sport specific exercises *Assessment Method/Tools/Tests Used* Not stated **Post RTP follow up:** *Follow Up Period* 12 months follow up period *Strength Tests* **Isometric** Perform maximal voluntary contraction at 0 (full extension), 45 , 90 (knee flexion) *Assessment Method/Tools/Tests Used* IKD *Imaging* Ultrasound (To quantify changes in pentation angle and scar dimensions)

Mendiguchia et al.,	2016	Spain	Case study	IV	To describe changes in power-force-velocity properties in two injury cases related to hamstring strain management.	**Sport:** Multi-Sport Including Football and Rugby **Level:** Professional **Total Sample:** *n*=2 Injuries: *n*=2 Injuries involving Footballers (*n*=1) Rugby players (*n*=1) **Sex:** Male **Age:** Footballer: 25 Rugby Player: 23	**Muscle Group:** Hamstring **Specific Muscle(s) Involved:** Biceps Femoris **Diagnosis Approach:** Clinical Symptoms and Assessment Tests: (Rugby case only) (i) Presence and localised pain on palpation (ii) Weakness in hamstring during contraction **Imaging Performed**: Yes (Football case only) Imaging Technique: MRI **Injury Grading:** 1 Grade 1 Injury 1 Grade 2 Injury **Time to RTP:** Footballer (33 days) Rugby player (not stated) **Injury Recurrences:** 0 Rugby player elected to have arthroscopic surgery on his shoulder and his rehabilitation was directed at this	**Treatment Approach**: Non-surgical **Domain(s) of Rehabilitation:** Physical Domain (i) Clinical (ii) Functional **Stage(s) of Recovery:** Return to Participation RTP **RTS decision-making guidelines:** 1. Asymptomatic completion of rehabilitation programme 2. Progressive re-introduction to full team training 3. Evaluation of pre- and post-injury power-force-velocity properties in sprint performance test **Decision-making approach:** Not stated	**Criteria Informing Rehabilitation Progression:** Rehabilitation protocol only outlined for football case as rugby case elected to undergo arthroscopic surgery on shoulder and as such his rehabilitation programme was directed toward this. *Clinical Examination / Evaluation* **Pain** Demonstrate normal walking stride/gait without pain Very low speed running without pain (+) Pain free sub-maximal isometric contraction (+) Pain free full strength isometric contraction (+) Pain free forward / backward running (50% max speed) (+) *Assessment Method/Tools/Tests Used* Pain – Patient feedback *Strength Tests* **Isometric** Submaximal (50-70% resistance) manual strength test in prone knee flexion (90 knee flexion) *Assessment Method/Tools/Tests Used* Manual assessment of strength Full strength (5/5) during 1 rep maximal effort manual strength test in prone knee flexion (90 knee flexion) *Assessment Method/Tools/Tests Used* Manual assessment of strength *Functional/Performance Based Criteria* **Low / Moderate Speed Running (Activity)** Perform very low speed running Forward + backward running at 50% max speed *Assessment Method/Tools/Tests Used* Not stated

									Completion of a Specific Programme Eccentric strength programme (completed prior to returning to run) **Criteria Informing RTP:** *Clinical Examination / Evaluation* **Pain** Pain free full range of motion (+) Pain free full-speed running (2x 50m max sprint test) (+) Pain free sport specific movements/actions (+) Full strength without pain (+) *Assessment Method/Tools/Tests Used* Pain - Patient feedback **Range of Motion (ROM)** Full range of motion *Assessment Method/Tools/Tests Used* Not stated *Strength Tests* **Isometric** Manual strength testing - 4 consecutive max effort reps in prone knee flexion (90 and 15 flexion) *Assessment Method/Tools/Tests Used* Manual assessment of strength **Isokinetic** <5% bilateral deficit in H:Q ratio – (eccentric hamstrings 30 /s / concentric quadriceps 240 /s) *Assessment Method/Tools/Tests Used* IKD Bilateral symmetry in knee flexion angle of peak concentric knee flexion torque at 60 /s

									<u>*Assessment Method/Tools/Tests Used*</u> IKD <u>*Functional/Performance Based Criteria*</u> **High Speed Running / Sprinting** Perform 2x 50m sprint test (Spit times recorded at 2m / 5m / 10m / 20m / 30m) Top speed recorded was compared to pre-injury sprint test scores Sprint horizontal external antero-posterior GRF computed from speed-time data measured during sprint tests: Sprint horizonal mechanical properties evaluated: Theoretical Max velocity Theoretical Max force Peak power production Force velocity profile <u>*Assessment Method/Tools/Tests Used*</u> Radar Gun **Non-Specific Performance-Based Criteria** Unhindered functional sports-specific testing Progressive resumption of full team training <u>*Assessment Method/Tools/Tests Used*</u> Not stated **Post RTP follow up:** Not stated

Wangensteen et al.,	2016	Qatar	Prospective case series	IV	To investigate the location, radiological severity, and timing of reinjuries on magnetic resonance imaging (MRI) com- pared with the index injury	**Sport:** Multi-Sport Including Football **Level:** Mixed, Professional (*n*=177) Competitive (*n*=3) **Total Sample:** *n*=180 Injuries: *n*=180 Reinjuries: *n*=19 Injuries involving Footballers (n=139) Re-injuries involving Footballers (n=18) **Sex:** Male **Age: Mean (SD)** 26 (5)	**Muscle Group:** Hamstring **Specific Muscle(s) Involved:** **Index injuries** <u>Primary Lesions:</u> Biceps Femoris (Long head) (*n*=15) Semimembranosus (*n*=1) <u>Injuries involving 2 or more muscles:</u> Biceps Femoris (Long head) + Semitendinosus (*n*=1) Biceps Femoris (Long head) + Biceps Femoris (Short head) (*n*=1) Biceps Femoris (Long head) + Semimembranosus (*n*=1) **Re-injuries** <u>Primary Lesions:</u> Biceps Femoris (Long head) (*n*=10) Semitendinosus (*n*=1) Semimembranosus (*n*=3) <u>Injuries involving 2 or more muscles:</u> Biceps Femoris (Long head) + Semitendinosus (*n*=4) Biceps Femoris (Long head) + Biceps Femoris (Short head) (*n*=1) **Diagnosis Approach:** Clinical Symptoms and Assessment Tests:	**Treatment Approach**: Non-surgical + PRP Therapy Group 1: 3 mL Platelet-rich plasma Group 2: 3 mL Platelet-poor plasma Group 3: No injection **Domain(s) of Rehabilitation:** Physical Domain (i) Clinical (ii) Functional **Stage(s) of Recovery:** Return to Participation RTP **RTS decision-making guidelines:** 1. Asymptomatic completion of 6-stage rehabilitation programme: Standardised physiotherapy programme + Sport-specific functional field testing 2. Isokinetic evaluation 3. Clinical examination **Decision-making approach:** Isolated Stakeholder: Sports Physician or Physiotherapist	**Criteria Informing Rehabilitation Progression:** *<u>Clinical Examination / Evaluation</u>* **Pain** Pain free single leg squat Pain free bike @ 150W for 5mins Pain free sport specific functional field testing (e g , direction change drills, jumping drills, pass/run, passing/crossing progressions) Pain free high-speed changes of direction (+) *<u>Assessment Method/Tools/Tests Used</u>* VAS (0-10) **Range of Motion** Full knee extension (supine) Hamstrings ≥75% uninvolved side SLR ≥75% uninvolved side *<u>Assessment Method/Tools/Tests Used</u>* Not stated *<u>Functional/Performance Based Criteria</u>* **High Speed Running / Sprinting** Run ≥70% running speed (30m) (Progressed from 25% - 70% max speed) Achieve 100% running speed (30m) (Progressed from 70% to 100% max speed) *<u>Assessment Method/Tools/Tests Used</u>* Patient rated/determined running speed **Agility** High speed changes of direction (Progress from 70% - 100% max speed) *<u>Assessment Method/Tools/Tests Used</u>* Modified T-test Patient rated/determined running speeds **Completion of a Specific Programme**

							(i) Pain experienced with injury (VAS scale, 0-10) (ii) Pain with ROM testing - Trunk flexion - Passive straight leg raise - Active knee extension (at 90° hip flexion) (iii) Manual muscle testing - Pain on resisted isometric knee flexion with 90° hip and knee flexion - Pain on resisted isometric hip extension with 30° hip and knee flexion (iv) Slump test (v) Presence and localised pain on palpation **Imaging Performed**: Yes Imaging Technique: MRI **Injury Grading:** **(Only G1/2 injuries considered)** **Index Injuries** 11 Grade 1 Injuries 8 Grade 2 Injuries **Re-injuries** 10 Grade 1 Injuries 7 Grade 2 Injuries 2 Grade 3 Injuries **Time to RTP (Median):** Index Injury 19 (Range 5-37; IQR, 15) Time from RTS to Re-injury		Progressive Running Programme 3-Stage Standardised Physiotherapy Programme (e g , ROM, progressive strengthening, core stability and agility exercises) **Criteria Informing RTP:** *Clinical Examination / Evaluation* **Pain** Pain free completion of sport specific rehab (e.g., shooting, 1v1 and scoring scenarios) *Assessment Method/Tools/Tests Used* VAS (0-10) **Satisfactory Clinical Exam** *Strength Tests* **Isokinetic** (Performed on injured + uninjured leg) Concentric Quadriceps & Hamstring Strength 5 reps - 60 /s concentric knee flexion / extension 10 reps - 300 /s concentric knee flexion / extension Eccentric / Concentric Hamstring Strength 5 reps - 60 /s eccentric knee extension and 180 /s concentric knee flexion *Assessment Method/Tools/Tests Used* IKD *Functional/Performance Based Criteria* **Completion of a Specific Programme** Sport Specific Functional Field Testing (Without limitation and/or symptoms) Custom made Rehabilitation programme (Applicable to athletes included in prospective case series who did not undertake the outlined protocol – no specific information given i e club/federation specific)

							24 (Range 4-311; IQR, 140) **Injury Recurrences:** 19		**Post RTP follow up:** *<u>Follow Up Period</u>* 12 month follow up - whereby re-injury occurrences were registered If re-injury was confirmed by clinical assessment, MRI examination was performed.

Zanon et al.,	2016	Italy	Case series	IV	To describe the use of PRP in the treatment of hamstring injuries by the medical club of a top-league professional club.	**Sport:** Football **Level:** Professional **Total Sample:** *n*=57 Injuries: *n*=25 (Involving 18 players) **Sex:** Male **Age: Mean** 24.2 (Range 18-34)	**Muscle Group:** Hamstring **Specific Muscle(s) Involved:** Biceps Femoris (*n*=21) Semitendinosus (*n*=1) Semimembranosus (*n*=3) **Diagnosis Approach:** Clinical Symptoms and Assessment Tests: (36) Presence and localised pain on palpation (ii) Active mobility of hip and knee evaluated Imaging Performed: Yes Imaging Technique: MRI, Ultrasound **Injury Grading:** **(Only G2 injuries considered)** Total 18 Grade 2a injuries 3 Grade 2b injuries 4 Grade 2c injuries Biceps femoris 15 Grade 2a injuries 3 Grade 2b injuries 3 Grade 2c injuries Semimembranosus 2 Grade 2a injuries 1 Grade 2c injuries Semitendinosus 1 Grade 2a injuries **Time to RTP (SD):**	**Treatment Approach**: Non-surgical + PRP Therapy 1st PRP injury performed 48-72hrs post injury For Grade 2a Lesions: A 2nd injection was administered after 7 days. For Grade 2b/c Lesions: Three injections were administered at 7-day intervals. **Domain(s) of Rehabilitation:** Physical Domain (36) Clinical (ii) Functional **Stage(s) of Recovery:** Return to participation RTP **RTS decision-making guidelines:** 36. Completion of rehabilitation programme 2. Clinical evaluation 3. Radiological examination MRI + Ultrasound **Decision-making approach:** Shared	**Criteria Informing Rehabilitation Progression:** *Clinical Examination / Evaluation* **Satisfactory Clinical Exam** Progression through rehabilitation program was decided step by step on the basis of clinical and radiological evidence of healing *Imaging* MRI Ultrasound Progression through rehabilitation program was decided step by step on the basis of clinical and radiological evidence of healing Measurements: (Evaluation of tissue healing process) Reduction in vascularity Progressive reduction of T2 signal intensity Tissue repair resulting in stable scar formation Reduction in surrounding edema or hematoma **Criteria Informing RTP:** *Clinical Examination / Evaluation* **Satisfactory Clinical Exam** Progression through rehabilitation program was decided step by step on the basis of clinical and radiological evidence of healing *Imaging* MRI Ultrasound Progression through rehabilitation program was decided step by step on the basis of clinical and radiological evidence of healing Measurements: (Evaluation of tissue healing process)

							Total: 35.1(18.9) Grade 2a injuries: 26.4(12.9) Grade 2b injuries: 61.3(8.5) Grade 2c injuries: 54.2(14.5) Biceps femoris Total: 36.6(17.3) Grade 2a injuries: 28.9(12.9) Grade 2b injuries: 61.3(8.5) Grade 2c injuries: 49.3(13) Semimembranosus Total: 33.3(3.2) Grade 2a injuries: 15.5(6.4) Grade 2c injuries: 69 Semitendinosus Total: 11 Grade 2a injuries: 11 **Injury Recurrences:** 3 Biceps femoris (*n*=3)			Reduction in vascularity Progressive reduction of T2 signal intensity Tissue repair resulting in stable scar formation Reduction in surrounding edema or hematoma *Functional/Performance Based Criteria* **Non-Specific Performance-Based Criteria** Regain competency in sport-specific skills Regain complete fitness *Assessment Method/Tools/Tests Used* Not stated **Post RTP follow up:** *Imaging* MRI Ultrasound Measurements: (Evaluation of tissue healing process) Reduction in vascularity Progressive reduction of T2 signal intensity Tissue repair resulting in stable scar formation Reduction in surrounding edema or hematoma *Follow Up Period* 36.6 months (Range 22-42)

Tyler et al.,	2017	USA	Prospective case series	IV	To examine if a progressive eccentric strengthening program during hamstring-strain rehabilitation restored isometric knee flexion strength relative to the contralateral side and restored the angle–torque relationship relative to the contralateral side or shifted it to a longer functional muscle length (rightward shift in the length–tension relationship) and to document the reinjury rate after return to sport.	**Sport:** Multi-Sport Including American Football and Football **Level:** Mixed, Professional: *n*=2 Competitive: *n*=16 Recreational: *n*=32 Injuries involving American Football players (n=8) Footballers (n=2) **Total Sample:** *n*=50 Injuries: *n*=50 **Sex:** Male (30) Female (20) **Age: Mean (SD)** 36 (16)	**Muscle Group:** Hamstring **Specific Muscle(s) Involved:** Not stated **Diagnosis Approach:** Clinical Symptoms and Assessment Tests: (i) Presence and localised pain on palpation over 1 of the hamstring muscles (ii) Pain with resisted prone knee flexion (iii) Pain with passive tension testing using passive straight leg raise test (iv) Any loss of function in sport activity **Imaging Performed**: No **Injury Grading:** 3 Grade 1 Injuries 43 Grade 2 Injuries 4 Grade 3 Injuries **Time to RTP (SD):** 11 weeks (10) **Injury Recurrences:** 4	**Treatment Approach**: Non-surgical **Domain(s) of Rehabilitation:** Physical Domain (i) Clinical (ii) Functional **Stage(s) of Recovery:** Return to Participation RTP **RTS decision-making guidelines:** 1. Asymptomatic completion of 3 stage rehabilitation programme: Standardised physiotherapy programme + Sport-specific functional field testing 2. Isokinetic evaluation – Pain-free maximal eccentric strength in lengthened state 3. Pain-free when sprinting 4. Pain-free when performing sport specific functional tasks **Decision-making approach:** Not stated	**Criteria Informing Rehabilitation Progression:** *Clinical Examination / Evaluation* **Pain** Demonstrate normal walking /gait without pain Pain free sub-maximal isometric manual strength test (+) Pain free, full strength (5/5) isometric strength test (+) Pain free forward / backward running Pain free max eccentric contraction in non-lengthened state (+) *Assessment Method/Tools/Tests Used* Pain - Patient feedback *Strength Tests* **Isometric** Manual strength test - Sub-max isometric contraction (50-70% resistance) prone knee flexion (90 flexion) Full strength (5/5) manual strength test in prone knee flexion (90 flexion) *Assessment Method/Tools/Tests Used* Manual assessment of strength **Isokinetic** Eccentric Hamstring Strength (non-lengthened state) 20 /s Eccentric knee extension (Progressing from sub-max to maximum contraction) *Assessment Method/Tools/Tests Used* IKD **Criteria Informing RTP:** *Clinical Examination / Evaluation* **Pain** Pain free during all activities

									Pain-free sprinting Pain-free completion of sport specific testing (+) Pain-free maximal eccentric contraction in lengthened state (+) *Assessment Method/Tools/Tests Used* Pain - Patient feedback *Strength Tests* **Isokinetic** Eccentric Hamstring Strength (lengthened state) 20 /s Eccentric knee extension (max contraction) (Eccentric contractions were performed from 90° to 20° knee flexion) IKD position: hip flexed 40° above the horizontal and seat back at 90° to the horizontal *Assessment Method/Tools/Tests Used* IKD *Functional/Performance Based Criteria* **Completion of a Specific Programme** Progressive Treadmill Running Programme Sport Specific Functional Field Testing **Post RTP follow up:** *Follow Up Period* 24 month periodic follow up – whereby re-injury occurrences were registered. Athletes contacted at 3, 6 (and every 6 months thereafter)

Ritchie et al ,	2017	Australia	Prospective cohort study	III	To quantify the effect of injury on training load before and after return to play in professional Australian Rules Football	**Sport:** Australian Football League **Level:** Professional **Total Sample:** *n*=44 Injuries: *n*=38 **Sex:** Male **Age: Mean (SD)** 24.1 (3.8)	**Muscle Group:** Lower limb muscles **Specific Muscle(s) Involved:** Not stated **Diagnosis Approach:** Clinical Symptoms and Assessment Tests: Not stated **Imaging Performed**: Not stated **Injury Grading:** Not stated **Time to RTP (SD):** 29 days (24) Absence by weeks 24 Injuries: < 3 weeks 8 Injuries: >3 weeks 5 Injuries: > 6 weeks 1 Injury: > 9 weeks **Injury Recurrences:** 0	**Treatment Approach**: Non-surgical **Domain(s) of Rehabilitation:** Physical Domain (i) Functional **Stage(s) of Recovery:** RTP Return to Performance **RTS decision-making guidelines:** Not stated **Decision-making approach:** Not stated	**Criteria Informing RTP:** *Training Load* Compared against training load outputs of training group (Players returning to training/match play were required to be in line with training load outputs of the uninjured group) **Internal Load Monitoring** Perceived training load (RPE x session duration) - Gym based sessions (upper and lower body) - Skill based field sessions - Running based sessions - Other (general conditioning sessions) *Assessment Method/Tools/Tests Used* RPE **Metrics** Arbitrary units (RPE x session duration) 7:21days Acute:chronic ratio **External Load Monitoring** GPS monitoring (rehab training data) - Skill based field sessions - Running based sessions **Metrics** Total distance High speed running (>14.4km/h) Average speed (m.min) PlayerLoad (accelerometer based metric accounting for all movements in the 3 vectors (X, Y, Z)) 7:21days Acute:chronic ratio *Assessment Method/Tools/Tests Used* GPS **Post RTP follow up:** Compared against training load outputs of the training group *Follow Up Period* 3 week monitoring period

									Training Load **Internal Load Monitoring** Perceived training load (RPE x session duration) - Gym based sessions (upper and lower body) - Skill based field sessions - Running based sessions - Other (general conditioning sessions) - Competitive match play *Assessment Method/Tools/Tests Used* RPE **Metrics** Arbitrary units (RPE x session duration) 7:21days Acute:chronic ratio **External Load Monitoring** GPS monitoring (training data) - Skill based field sessions - Running based sessions - Competitive match play **Metrics** Total distance High speed running (>14.4km/h) Average speed (m.min) PlayerLoad (accelerometer based metric accounting for all movements in the 3 vectors (X, Y, Z)) 7:21days Acute:chronic ratio *Assessment Method/Tools/Tests Used* GPS

Lempainen et al.,	2018	Finland	Case series	IV	To describe the operative treatment and outcomes of central tendon injuries of the hamstring after acute or recurrent injuries.	**Sport:** Multi-Sport including football **Level:** Mixed, Professional (*n*=6) Recreational (*n*=2) **Total Sample:** *n*=8 Injuries: *n*=8 Injuries involving footballers: *n* = 5 **Sex:** Male (n=7) Female (*n*=1) **Age: Mean (SD)** 25.5 (11.5)	**Muscle Group:** Hamstring **Specific Muscle(s) Involved:** Biceps Femoris (long head) (n=6) Semimembranosus (n=2) Semitendinosus (n=1) **Diagnosis Approach:** Clinical Symptoms and Assessment Tests: Not stated Indications for surgery in acute cases was the existence of a clear gap between central hamstring tendon ends **Imaging Performed**: Yes Imaging Technique: MRI **Injury Grading:** Not stated **Time to RTP:** All athletes achieved RTP by 2.5 to 4.5 months Footballers specifically achieved RTP by 4 to 4.5 months **Injury Recurrences:** 0	**Treatment Approach**: Surgical **Domain(s) of Rehabilitation:** Physical Domain (i) Clinical (ii) Functional **Stage(s) of Recovery:** Return to Participation RTP **RTS decision-making guidelines:** 1. Pain-free completion of 4 stage rehabilitation programme: Sport-specific functional field testing **Decision-making approach:** Not stated	**Criteria Informing Rehabilitation Progression:** *Time* Postoperative healing/injury management (2-3 weeks) *Clinical Examination / Evaluation* **Range of Motion (ROM)** Achieve normal range of motion *Assessment Method/Tools/Tests Used* Not stated **Criteria Informing RTP:** *Clinical Examination / Evaluation* **Pain** Pain free completion of sport specific rehabilitation *Assessment Method/Tools/Tests Used* Pain - Patient feedback *Functional/Performance Based Criteria* **High Speed Running / Sprinting** Incline / decline running – focus on reducing peak forces to hamstring during running (GFR data analysed) *Assessment Method/Tools/Tests Used* Treadmill (GFR analysis) **Motor Control / Proprioception** Sufficient proprioception achieved *Assessment Method/Tools/Tests Used* Circuit training on dry sand **Completion of a Specific Programme** Sport specific functional field testing (without restriction) **Post RTP follow up:**

									Follow Up Period Average follow up 14.5 months (Range 8-24). Re-injury occurrences were registered

Crema et al.,	2018	Brazil	Retrospective cohort study	IV	To assess the association of the extent of MRI-detected edema-like changes with the time needed to RTP in a sample of male professional soccer players sustaining MRI-defined grade 1 hamstring injuries	**Sport:** Football **Level:** Professional **Total Sample:** *n*=22 Injuries: *n*=22 **Sex:** Male **Age: Mean (SD)** 25.6 (5.1) (Range 19-34)	**Muscle Group:** Hamstring **Specific Muscle(s) Involved:** Biceps Femoris (Long head) (n=18) Not reported (n=4) **Diagnosis Approach:** Clinical Symptoms and Assessment Tests: Not stated **Imaging Performed**: Yes Imaging Technique: MRI **Injury Grading:** **(Only G1 injuries considered)** 22 Grade 1 Injuries **Time to RTP (SD):** 13.6 (8.9) (Range 3-32) **Injury Recurrences:** Not stated	**Treatment Approach**: Non-surgical **Domain(s) of Rehabilitation:** Physical Domain (i) Clinical (ii) Functional **Stage(s) of Recovery:** RTP **RTS decision-making guidelines:** 1. Pain free completion of phased rehabilitation programme 2. Supervising physician gave the definitive clearance for RTP **Decision-making approach:** Isolated Stakeholder: Sports Physician	**Criteria Informing RTP:** *Clinical Examination / Evaluation* **Pain** Perform rehabilitation exercises within pain free limits *Assessment Method/Tools/Tests Used* Pain – Patient feedback *Strength Tests* **Method of Strength Test not clearly stated** Address bilateral asymmetries Address muscle strength balance (Hamstring:Quadricep ratio) *Assessment Method/Tools/Tests Used* Not stated *Functional/Performance Based Criteria* **Non-Specific Performance-Based Criteria** Performance of sport-specific drills **Post RTP follow up:** Not stated

Stares et al.,	2018	Australia	Prospective cohort study	III	The primary aims of this study were to determine the relationship between: (i) rehabilitation training loads and RTP time and (ii) rehabilitation training loads and subsequent injury rate. The secondary aim was to inform practitioner best practice by providing useful rehabilitation guidelines for lower limb muscle injuries in elite Australian footballers.	**Sport:** Australian Football League **Level:** Professional **Total Sample:** *n*=85 Injuries: *n*=70 (rehabilitated to RTP) **Sex:** Male **Age:** Not stated	**Muscle Group:** Hamstring (*n*=37) Quadriceps (*n*=13) Calf (*n*=21) Adductor (*n*=9) Gluteal (*n*=3) Other (*n*=2) **Specific Muscle(s) Involved:** Not stated **Diagnosis Approach:** Clinical Symptoms and Assessment Tests: Not Stated **Imaging Performed**: Not stated **Injury Grading:** Not stated **Time to RTP: Median (IQR)** Overall (including all injuries) 21 (14-24) Hamstring 22 (21-27) Quadriceps 15 (11.5-18.5) Calf 19.5 (14-23) Adductor 14 (13-15) Gluteal 21 (15-24) Other 36 (36-36) **Injury Recurrences:** 8 Hamstring (*n*=7) Calf (*n*=1)	**Treatment Approach**: Non-surgical **Domain(s) of Rehabilitation:** Physical Domain (i) Functional **Stage(s) of Recovery:** Return to Participation RTP **RTS decision-making guidelines:** 1. Completion of 3-stage rehabilitation programme: Initial injury management phase (i e , off-legs) followed by a Running conditioning programme and the resumption of group football training phases **Decision-making approach:** Not stated	**Criteria Informing Rehabilitation Progression:** <u>*Functional/Performance Based Criteria*</u> **Completion of a Specific Programme** Progressive running programme <u>*Training Load*</u> **Internal Load Monitoring (10-point Borg Scale) (+)** Perceived training load (RPE x session duration) - Running based sessions **Metrics** Arbitrary units (RPE x session duration) Total accumulated load (across rehab phases) Chronic load (4-week average training load) Acute load (7-day average training load) <u>*Assessment Method/Tools/Tests Used*</u> RPE **External Load Monitoring (+)** GPS monitoring (rehab training data) -Running based sessions **Metrics** Total distance Sprint distance (distance >75% relative max speed) Total accumulated load (across rehab phases) Chronic load (4-week average training load) Acute load (7-day average training load) <u>*Assessment Method/Tools/Tests Used*</u> GPS **Criteria Informing RTP:** <u>*Functional/Performance Based Criteria*</u> **Non-Specific Performance-Based Criteria** Resume full team training sessions

									<u>Training Load</u> **Internal Load Monitoring (10-point Borg Scale) (+)** Perceived training load (RPE x session duration) Group based training sessions **Metrics** Arbitrary units (RPE x session duration) Total accumulated load (across rehab phases) Chronic load (4-week average training load) Acute load (7-day average training load) *<u>Assessment Method/Tools/Tests Used</u>* RPE **External Load Monitoring (+)** GPS monitoring (training data) - Group based training sessions **Metrics** Total distance Sprint distance (distance >75% relative max speed) Total accumulated load (across rehab phases) Chronic load (4-week average training load) Acute load (7-day average training load) *<u>Assessment Method/Tools/Tests Used</u>* GPS **Post RTP follow up:** Not stated

Murphy and Rennie	2018	United Kingdom	Case study	IV	To discuss the rehabilitation of a surgically repaired biceps femoris intramuscular tendon hamstring injury in an English Premier League soccer player	**Sport:** Football **Level:** Professional **Total Sample:** *n*=1 Injuries: *n*=1 **Sex:** Male **Age:** 23	**Muscle Group:** Hamstring **Specific Muscle(s) Involved:** Biceps Femoris **Diagnosis Approach:** Clinical Symptoms and Assessment Tests: (i) Limited ROM with passive SLR (ii) Limited ROM with hip and knee 90 passive knee extension test (iii) Loss of contractile power **Imaging Performed**: Yes Imaging Technique: MRI **Injury Grading:** Grade 3c injury **Time to RTP:** RTT: ~ 63 days RTP: ~ 70 days **Injury Recurrences:** 0	**Treatment Approach**: Surgical **Domain(s) of Rehabilitation:** Physical Domain (i) Clinical (ii) Functional **Stage(s) of Recovery:** Return to Participation RTP Return to Performance **RTS decision-making guidelines:** 1. Completion of a treadmill running programme 2. Completion of an eccentric strength programme 3. Completion of a pitch-based running programme: >90% of pre-injury peak speed deemed acceptable benchmark for RTP **Decision-making approach:** Not stated	**Criteria Informing Rehabilitation Progression:** *Time* Postoperative management and consideration to tendon healing timeframes (2 weeks) *Clinical Examination / Evaluation* **Pain** Pain free isometric contraction (+) Pain free/mild pain treadmill running (VAS 0 to 4) (+) *Assessment Method/Tools/Tests Used* VAS (0-10) **Range of Motion (ROM)** (compared to uninjured limb) Full ROM demonstrated in passive SLR Full ROM demonstrated in a hip and knee 90 passive knee extension test *Assessment Method/Tools/Tests Used* Not stated *Strength Tests* **Isometric** Full strength (5/5) during isometric strength test *Assessment Method/Tools/Tests Used* Manual assessment of strength **Eccentric Hamstring Strength** Asymptomatic eccentric knee flexor strength test (Nordic curl) at full bodyweight Eccentric knee flexor strength (Nordic curl) - <10% LSI eccentric strength *Assessment Method/Tools/Tests Used* Nordbord *Functional/Performance Based Criteria*

									High Speed Running / Sprinting Treadmill (pain free or with minor discomfort VAS rating 0 to 4 / treadmill speeds correlated to GPS thresholds) Sustain 2x2km high speed run - 14.4kph Sustain 1km high speed run - 16.5kph High speed Interval runs 30s on:30s off – 16.2, 18 & 19.4kph Complete treadmill criteria to progress to outdoor rehabilitation *Assessment Method/Tools/Tests Used* Treadmill Internal load monitoring – Heart rate *Training Load* **Internal Load Monitoring (+)** Heart rate monitoring data **Completion of a Specific Programme** Progressive treadmill running programme Progressive eccentric strengthening programme **Criteria Informing RTP:** *Clinical Examination / Evaluation* **Pain** Pain free completion of progressive running programme (+) *Assessment Method/Tools/Tests Used* VAS (0-10) *Functional/Performance Based Criteria* **High Speed Running / Sprinting** Achieve >90% max speed in high-speed running drill to permit clearance to RTP Running drill: Achieve >90% max speed 20m acceleration phase 20m speed maintenance phase 20m deceleration phase Progression 2: Achieve >90% max speed

									15m acceleration phase 20m speed maintenance phase 15m deceleration phase Progression 3: Achieve >90% max speed 10m acceleration phase 20m speed maintenance phase 10m deceleration phase Progression 4: Achieve >90% max speed 5m acceleration phase 20m speed maintenance phase 5m deceleration phase *Assessment Method/Tools/Tests Used* GPS **Completion of a Specific Programme** Progressive running programme (asymptomatic) *Training Load* **External Load Monitoring (+)** GPS monitoring (rehab training data / training data) **Metrics** Running volumes Peak speed *Assessment Method/Tools/Tests Used* GPS **Non-Specific Performance-Based Criteria** Complete full team training sessions **Post RTP follow up:** *Follow Up Period* Not stated *Functional/Performance Based Criteria* **High Speed Running / Sprinting** High-speed exposure maintained (>90% max speed) after RTP using high-speed running drill within the training week if required *Assessment Method/Tools/Tests Used* GPS

									<u>*Training Load*</u> **External Load Monitoring (+)** GPS monitoring (rehab training data / training data) **Metrics** Running volumes Peak speed <u>*Assessment Method/Tools/Tests Used*</u> GPS

Hamilton et al ,	2018	Qatar	Prospective case series	IV	To prospectively investigate the predictive value of the MRI scoring system of Cohen for return to sport	**Sport:** Football **Level:** Professional **Total Sample:** *n*=139 Injuries: *n*=110 **Sex:** Male **Age: Mean** 26 (Range 18 – 39)	**Muscle Group:** Hamstring **Specific Muscle(s) Involved:** Biceps Femoris (Long head) (*n*=89) Biceps Femoris (Short head) (*n*=1) Semimembranosus (*n*=17) Semitendinosus (*n*=3) **Diagnosis Approach:** Clinical Symptoms and Assessment Tests: (i) Acute onset of posterior thigh pain **Imaging Performed**: Yes Imaging Technique: MRI **Injury Grading:** **(Only G1/2 injuries considered)** Grade 1 Injuries Grade 2 Injuries (n, not stated) **Time to RTP (SD):** 22.7 (11.03) (Range 1-66) **Injury Recurrences:** not stated	**Treatment Approach**: Non-surgical + PRP Therapy Group 1: Platelet-rich plasma Group 2: Platelet-poor plasma Group 3: No injection **Domain(s) of Rehabilitation:** Physical Domain (i) Clinical (ii) Functional **Stage(s) of Recovery:** Return to Participation RTP **RTS decision-making guidelines:** 1. Asymptomatic completion of 6 stage rehabilitation programme: Standardised physiotherapy programme + Sport-specific functional field testing 2. Isokinetic evaluation 3. Clinical examination **Decision-making approach:** Not stated	**Criteria Informing Rehabilitation Progression:** *Clinical Examination / Evaluation* **Pain** Pain free single leg squat Pain free bike @ 150W for 5mins Pain free sport specific functional field testing (e g , direction change drills, jumping drills, pass/run, passing/crossing progressions) Pain free high-speed changes of direction (+) *Assessment Method/Tools/Tests Used* VAS (0-10) **Range of Motion** Full knee extension (supine) Hamstrings ≥75% uninvolved side SLR ≥75% uninvolved side *Assessment Method/Tools/Tests Used* Not stated *Functional/Performance Based Criteria* **High Speed Running / Sprinting** Run ≥70% running speed (30m) (Progressed from 25% - 70% max speed) Achieve 100% running speed (30m) (Progressed from 70% to 100% max speed) *Assessment Method/Tools/Tests Used* Patient rated/determined running speeds **Agility** High speed changes of direction (Progress from 70% - 100% max speed) *Assessment Method/Tools/Tests Used* Modified T-test Patient rated/determined running speeds

									Completion of a Specific Programme Progressive Running Programme 3-Stage Standardised Physiotherapy Programme (e g , ROM, progressive strengthening, core stability and agility exercises) **Criteria Informing RTP:** *Clinical Examination / Evaluation* **Pain** Pain free completion of sport specific rehab (e.g., shooting, 1v1 and scoring scenarios) *Assessment Method/Tools/Tests Used* VAS (0-10) **Satisfactory Clinical Exam** *Strength Tests* **Isokinetic** (Performed on injured + uninjured leg) Concentric Quadriceps & Hamstring Strength 5 reps - 60 /s concentric knee flexion / extension 10 reps - 300 /s concentric knee flexion / extension Eccentric / Concentric Hamstring Strength 5 reps - 60 /s eccentric knee extension and 180 /s concentric knee flexion *Assessment Method/Tools/Tests Used* IKD *Functional/Performance Based Criteria* **Completion of a Specific Programme** Sport Specific Functional Field Testing (Without limitation and/or symptoms) **Post RTP follow up:** Not stated

Taberner and Cohen	2018	United Kingdom	Case Study	IV	Physical preparation of the football player with an intramuscular hamstring tendon tear	**Sport:** Football **Level:** Professional **Total Sample:** *n*=1 Injuries: *n*=1 **Sex:** Male **Age:** Not stated	**Muscle Group:** Hamstring **Specific Muscle(s) Involved:** Not stated **Diagnosis Approach:** Clinical Symptoms and Assessment Tests: Not stated **Imaging Performed**: Yes Imaging Technique: MRI **Injury Grading:** Not stated **Time to RTP:** 120 days **Injury Recurrences:** No	**Treatment Approach**: Non-surgical **Domain(s) of Rehabilitation:** Physical Domain (i) Clinical (ii) Functional **Stage(s) of Recovery:** RTP **RTS decision-making guidelines:** 1. Completion of rehabilitation programme: Strength based programme and Sport-specific functional field testing 2. Asymmetry in lower limb strength parameters within accepted limits 3. Player has received adequate high and max speed running exposure **Decision-making approach:** Not stated	**Criteria Informing RTP:** *Strength Tests* **Isometric** (compared to uninjured leg) Isometric posterior chain test <10% asymmetry in peak force between limbs - allowing progression to exercise emphasising hip extension and eccentric knee flexion Isometric posterior chain test < 10% asymmetry in peak force between limbs – to allow initiation of jump landing activities and progression to plyometric activities Isometric posterior chain test < 10% asymmetry in peak force between limbs – to allow initiation of graded high-speed running programme High-speed running exposure progressed to higher cumulative weekly loads when < 10% asymmetry in isometric posterior chain test force generated at 100ms between limbs (Used as an indicator of rate of force development) *Assessment Method/Tools/Tests Used* Force plate **Eccentric Hamstring Strength** Eccentric knee flexor strength test (Nordic curl) - <10% asymmetry - Strength comparison with pre-injury scores *Assessment Method/Tools/Tests Used* Norbord **Predetermined Benchmark** Eccentric knee flexor strength > 350N (Nordic curl) *Assessment Method/Tools/Tests Used* Norbord *Functional/Performance Based Criteria* **High Speed Running / Sprinting**

									External load parameters were progressively increased to ensure exposure to running loads reflective of: High-speed running relative to match play Max speed Position specific demands Pre-injury acute and chronic weekly high-speed running distance Adequate exposure to sprints >90% max speed *Assessment Method/Tools/Tests Used* GPS **Completion of a Specific Programme** Strength programme Progressive running programme Jump landing and plyometric programme *Training Load* **External Load Monitoring (+)** GPS monitoring (rehab training data) (Load progressed relative to typical game load outputs for specific metrics) **Metrics** Acute: Chronic load (7:21) Total distance High-speed running distance Sprint distance Explosive distance High metabolic load distance Max speed Accelerations Decelerations *Assessment Method/Tools/Tests Used* GPS **Post RTP follow up:** *Follow Up Period* 13 month follow up wherein any reinjuries or other injuries were registered

Whiteley et al ,	2018	Qatar	Prospective study of a cohort of participants in a larger RCT	III	To investigate the association (and variance) of a series of clinical measures with both the progress of rehabilitation to return to participation and running effort to better inform clinical practice.	**Sport:** Multi-Sport Including Football **Level:** Mixed Professional (*n*=127) Competitive (*n*=4) **Total Sample:** *n*=131 Injuries: *n*=131 Injuries involving Footballers (*n*=93) **Sex:** Male **Age: Mean (SD)** 25.9 (5.5)	**Muscle Group:** Hamstring **Specific Muscle(s) Involved:** Not stated **Diagnosis Approach:** Clinical Symptoms and Assessment Tests: Pain reported using VAS (0-10) pain scale (i) Subjective pain level reported (ii) Pain on standing trunk flexion (iii) Functional Testing Pain limited walking Pain limited jogging Pain on 2-leg half squat Pain on 1-leg quarter squat Single/Double leg bridge testing (iv) Presence and localised pain on palpation (v) Strength assessments (injured/uninjured legs tested) (Isometric strength assessed using HHD) Strength/pain on inner range Strength/pain on mid-range Strength/pain outer-range (vi) ROM assessments (ROM measured with inclinometer) Range/pain on SLR Range/pain on PKET (90 hip flexion)	**Treatment Approach**: Non-surgical 1.Growth factor study rehabilitation protocol 2. Aspetar hamstring rehabilitation study protocol **Domain(s) of Rehabilitation:** Physical Domain (i) Clinical (ii) Functional **Stage(s) of Recovery:** Return to Participation RTP **RTS decision-making guidelines:** 1. Asymptomatic completion of 6 stage rehabilitation programme: Standardised physiotherapy programme + Sport-specific functional field testing 2. Clinical examination 3. Isokinetic evaluation 4. Askling H-test (Aspetar rehab protocol only) 5. Nordic hamstring exercise (Aspetar rehab protocol only) **Decision-making approach:** Not stated	**Growth Factor Study Protocol** **Criteria Informing Rehabilitation Progression:** *Clinical Examination / Evaluation* **Pain** Pain free single leg squat Pain free bike @ 150W for 5mins Pain free sport specific functional field testing (e g , direction change drills, jumping drills, pass/run, passing/crossing progressions) Pain free high-speed changes of direction (+) *Assessment Method/Tools/Tests Used* VAS (0-10) **Range of Motion** Full knee extension (supine) Hamstrings ≥75% uninvolved side SLR ≥75% uninvolved side *Assessment Method/Tools/Tests Used* Not stated *Functional/Performance Based Criteria* **High Speed Running / Sprinting** Run ≥70% running speed (30m) (Progressed from 25% - 70% max speed) Achieve 100% running speed (30m) (Progressed from 70% to 100% max speed) *Assessment Method/Tools/Tests Used* Patient rated/determined running speeds **Agility** High speed changes of direction (Progress from 70% - 100% max speed) *Assessment Method/Tools/Tests Used* Modified T-test Patient rated/determined running speeds

							Range/pain on MHFAKE (vii) IKD evaluation (Uninjured leg only) Concentric Quadriceps & Hamstring Strength 5 reps - 60 /s concentric knee flexion / extension 10 reps - 300 /s concentric knee flexion / extension Eccentric Hamstring Strength 5 reps - 60 /s eccentric knee flexion / extension 5 reps - 180 /s eccentric knee flexion / extension **Imaging Performed**: Yes Imaging Technique: MRI **Injury Grading:** **(Only G1/2 injuries considered)** No specific injury information given **Time to RTP (SD):** Return to training: 23.9(10.8) **Injury Recurrences:** Not stated		**Completion of a Specific Programme** Progressive Running Programme 3-Stage Standardised Physiotherapy Programme (e g , ROM, progressive strengthening, core stability and agility exercises) **Criteria Informing RTP:** *Clinical Examination / Evaluation* **Pain** Pain free completion of sport specific rehab (e.g., shooting, 1v1 and scoring scenarios) *Assessment Method/Tools/Tests Used* VAS (0-10) **Satisfactory Clinical Exam** *Strength Tests* **Isokinetic** (Performed on injured + uninjured leg) Concentric Quadriceps & Hamstring Strength 5 reps - 60 /s concentric knee flexion / extension 10 reps - 300 /s concentric knee flexion / extension Eccentric / Concentric Hamstring Strength 5 reps - 60 /s eccentric knee extension and 180 /s concentric knee flexion *Assessment Method/Tools/Tests Used* IKD *Functional/Performance Based Criteria* **Completion of a Specific Programme** Sport Specific Functional Field Testing (Without limitation and/or symptoms) **Post RTP follow up:**

									Not stated **<u>Aspetar Hamstring Rehabilitation Study Protocol</u>** **Criteria Informing Rehabilitation Progression:** *<u>Clinical Examination / Evaluation</u>* **Pain** Pain free single leg squat Pain free bike @ (Watt: 2x bodyweight) for 5mins Pain free sport specific functional field testing (e g , direction change drills, jumping drills, pass/run, passing/crossing progressions) Pain free high-speed changes of direction (+) Pain free acceleration & deceleration during high-speed running Pain isometric eccentric mid-range strength test (VAS $\leq$ 2) (+) *<u>Assessment Method/Tools/Tests Used</u>* VAS (0-10) **Range of Motion** Full knee extension (supine) SLR > 75% uninvolved side *<u>Assessment Method/Tools/Tests Used</u>* Inclinometer *<u>Strength Tests</u>* **Isometric** (compared to uninjured leg) >75% eccentric strength – mid-range strength test *<u>Assessment Method/Tools/Tests Used</u>* HHD *<u>Functional/Performance Based Criteria</u>* **High Speed Running / Sprinting** Run >70% running speed (30m) (Progressed from 25% - 70% max speed)

									Achieve 100% running speed (30m) (Progressed from 70% to 100% max speed) *<u>Assessment Method/Tools/Tests Used</u>* Patient rated/determined running speeds **Agility** High speed changes of direction (Progress from 70% - 100% max speed) *<u>Assessment Method/Tools/Tests Used</u>* Modified T-test Patient rated/determined running speeds **Completion of a Specific Programme** Progressive Running Programme 3-Stage Standardised Physiotherapy Programme (e g ROM, progressive strengthening, core stability and agility exercises) **Criteria Informing RTP:** *<u>Clinical Examination / Evaluation</u>* **Satisfactory Clinical Exam** **Range of Motion** Dynamic flexibility H-Test (without insecurity or pain) *<u>Assessment Method/Tools/Tests Used</u>* H-test *<u>Strength Tests</u>* **Eccentric Hamstring Strength** Asymptomatic Eccentric knee flexor strength test (Nordic curl) Average and peak force measured (1x 3 rep) *<u>Assessment Method/Tools/Tests Used</u>* Nordbord **Isokinetic** (Performed on injured + uninjured leg)

									Concentric Quadriceps & Hamstring Strength 5 reps - 60 /s concentric knee flexion / extension 10 reps - 300 /s concentric knee flexion / extension Eccentric / Concentric Hamstring Strength 5 reps - 60 /s eccentric knee extension and 180 /s concentric knee flexion *Assessment Method/Tools/Tests Used* IKD *Functional/Performance Based Criteria* **Completion of a Specific Programme** Sport Specific Functional Field Testing (Without limitation and/or symptoms) **Post RTP follow up:** Not stated

Wangensteen et al.,	2018	Qatar	Prospective study of a cohort of participants in a larger RCT	III	To determine agreement between modified Peetrons, Chan acute muscle strain injury classification and British Athletics Muscle Injury Classification and to investigate their associations and ability to predict time to return to sport in athletes with acute hamstring injury	**Sport:** Multi-Sport Including Football **Level:** Mixed, Professional (*n*=173) Competitive (*n*=3) **Total Sample:** *n*=176 Injuries: *n*=176 Injuries involving Footballers (n=135) **Sex:** Males **Age: Mean (SD)** 26 (5.2)	**Muscle Group:** Hamstring **Specific Muscle(s) Involved:** <u>Single muscle injuries:</u> Biceps Femoris (Long head) (*n*=112) Biceps Femoris (Short head) (*n*=1) Semitendinosus (*n*=5) Semimembranosus (*n*=22) <u>Injuries involving 2 or more muscles:</u> Biceps Femoris (Long head) (*n*=3) Biceps Femoris (Short head) (*n*=3) Semitendinosus (*n*=30) **Diagnosis Approach:** Clinical Symptoms and Assessment Tests: Not stated **Imaging Performed**: Yes Imaging Technique: MRI **Injury Grading:** **(Only G1/2 injuries considered)** Negative MRI Cases: 36 Modified Peetrons Grade 0: 36 Grade 1: 70 Grade 2: 68 Grade 3: 2 Chan Classification No injury: 36 Grade 1: 106 Grade 2: 32 Grade 3: 2	**Treatment Approach**: Non-surgical + PRP Therapy Group 1: 3 mL Platelet-rich plasma Group 2: 3 mL Platelet-poor plasma Group 3: No injection **Domain(s) of Rehabilitation:** Physical Domain (i) Clinical (ii) Functional **Stage(s) of Recovery:** Return to Participation RTP **RTS decision-making guidelines:** 1. Asymptomatic completion of 6 stage rehabilitation programme: Standardised physiotherapy programme + Sport-specific functional field testing 2. Isokinetic evaluation 3. Clinical examination **Decision-making approach:** Isolated Stakeholder: Sports Physician or Physiotherapist	**Criteria Informing Rehabilitation Progression:** <u>*Clinical Examination / Evaluation*</u> **Pain** Pain free single leg squat Pain free bike @ 150W for 5mins Pain free sport specific functional field testing (e g , direction change drills, jumping drills, pass/run, passing/crossing progressions) Pain free high-speed changes of direction (+) <u>*Assessment Method/Tools/Tests Used*</u> VAS (0-10) **Range of Motion** Full knee extension (supine) Hamstrings ≥75% uninvolved side SLR ≥75% uninvolved side <u>*Assessment Method/Tools/Tests Used*</u> Not stated <u>*Functional/Performance Based Criteria*</u> **High Speed Running / Sprinting** Run ≥70% running speed (30m) (Progressed from 25% - 70% max speed) Achieve 100% running speed (30m) (Progressed from 70% to 100% max speed) <u>*Assessment Method/Tools/Tests Used*</u> Patient rated/determined running speeds **Agility** High speed changes of direction (Progress from 70% - 100% max speed) <u>*Assessment Method/Tools/Tests Used*</u> Modified T-test Patient rated/determined running speeds **Completion of a Specific Programme** Progressive Running Programme

							BAMIC 0 a/b: 36 Grade 1: 25 Grade 2: 76 Grade 3: 37 Grade 4: 2 **Time to RTP (SD):** 21.6 (11.8) **Injury Recurrences:** Not stated		3-Stage Standardised Physiotherapy Programme (e g , ROM, progressive strengthening, core stability and agility exercises) **Criteria Informing RTP:** *Clinical Examination / Evaluation* **Pain** Pain free completion of sport specific rehab (e.g., shooting, 1v1 and scoring scenarios) *Assessment Method/Tools/Tests Used* VAS (0-10) **Satisfactory Clinical Exam** *Strength Tests* **Isokinetic** (Performed on injured + uninjured leg) Concentric Quadriceps & Hamstring Strength 5 reps - 60 /s concentric knee flexion / extension 10 reps - 300 /s concentric knee flexion / extension Eccentric / Concentric Hamstring Strength 5 reps - 60 /s eccentric knee extension and 180 /s concentric knee flexion *Assessment Method/Tools/Tests Used* IKD *Functional/Performance Based Criteria* **Completion of a Specific Programme** Sport Specific Functional Field Testing (Without limitation and/or symptoms) Custom made Rehabilitation programme (Applicable to athletes included in prospective case series who did not undertake the outlined protocol – no specific information given i e club/federation specific)

									Post RTP follow up: *Follow Up Period* 12 months follow up wherein athletes were encouraged to report any reinjuries. However patients were not actively monitored monthly by phone. Thus, long term RTP successfulness not reported

van der Made et al.,	2018	Holland / Qatar	Prospective study of a cohort of participants in a larger RCT	III	To determine whether intramuscular tendon injury is associated with higher re-injury rates in acute hamstring injury.	**Sport:** Multi Sport including Football **Level:** Mixed Professional (*n*=87) Competitive (*n*=58) Recreational (*n*=20) **Total Sample:** *n*=165 Injuries: *n*=165 Injuries involving Footballers (*n*=119) **Sex:** Male **Age: Median** 26 (IQR 22-31)	**Muscle Group:** Hamstring **Specific Muscle(s) Involved:** Biceps Femoris (*n*=135) Semitendinosus (*n*=7) Semimembranosus (*n*=23) **Diagnosis Approach:** Clinical Symptoms and Assessment Tests: Not stated **Imaging Performed**: Yes Imaging Technique: MRI **Injury Grading:** **(Only G1/2 injuries considered)** 68 Grade 1 Injuries 97 Grade 2 Injuries Injuries involving intramuscular tendon disruption (*n*=64) - <50% of tendon CSA (*n*=12) - 50-99% of tendon CSA (*n*=28) - 100% of tendon CSA (*n*=24) Specific Muscles involved - Biceps femoris (*n*=48) - Semimembranosus (*n*=8) - Involving biceps femoris and semitendinosus (*n*=8) Injuries without intramuscular tendon disruption (*n*=101) - No tendon disruption (*n*=96) - Free tendon disruption (*n*=5) **Time to RTP:**	**Treatment Approach**: Non-surgical + PRP therapy Dutch Cohort: Group 1: 2x 3 mL Platelet-rich plasma Group 2: 2x 3 mL normal saline Qatar Cohort: Group 1: 3 mL Platelet-rich plasma Group 2: 3 mL Platelet-poor plasma Group 3: No injection **Domain(s) of Rehabilitation:** Physical Domain (i) Clinical (ii) Functional Non-Physical Domain (i) Contextual **Stage(s) of Recovery:** Return to Participation RTP **RTS decision-making guidelines:** **Dutch Cohort** 1. Asymptomatic completion of rehabilitation programme: Standardised physiotherapy programme + progressive agility and trunk stability programme **Qatar Cohort** 1. Asymptomatic completion of 6-stage rehabilitation programme: Standardised physiotherapy programme + Sport-specific functional field testing	**<u>Dutch Cohort</u>** **Criteria Informing Rehabilitation Progression:** *<u>Clinical Examination / Evaluation</u>* **Pain** Demonstrate normal walking stride/gait without pain Pain free high knee march Very low speed running without pain (+) Pain free sub-maximal isometric contraction (+) Pain free full strength isometric contraction (+) Pain free forward / backward running (50% max speed) (+) *<u>Assessment Method/Tools/Tests Used</u>* Pain – Patient feedback *<u>Strength Tests</u>* **Isometric** Submaximal (50-70% resistance) manual strength test in prone knee flexion (90 knee flexion) *<u>Assessment Method/Tools/Tests Used</u>* Manual assessment of strength Full strength (5/5) during 1 rep maximal effort manual strength test in prone knee flexion (90 knee flexion) *<u>Assessment Method/Tools/Tests Used</u>* Manual assessment of strength *<u>Functional/Performance Based Criteria</u>* **Low / Moderate Speed Running (Activity)** Perform very low speed running Forward + backward running at 50% max speed *<u>Assessment Method/Tools/Tests Used</u>* Not stated **Completion of a Specific Programme**

							Not stated **Injury Recurrences:** 32	2. Isokinetic evaluation 3. Clinical evaluation 4. Consideration of sport risk modifiers and decision modifiers **Decision-making approach:** Dutch Cohort: Shared Qatar Cohort: Isolated Stakeholder: Sports Physician	Progressive agility and trunk stability programme **Criteria Informing RTP:** *Clinical Examination / Evaluation* **Pain** Pain free full range of motion (+) Pain free full-speed running (+) Pain free sport specific movements/actions Full strength without pain (+) *Assessment Method/Tools/Tests Used* Pain – Patient feedback **Range of Motion (ROM)** Full range of motion *Assessment Method/Tools/Tests Used* Not stated *Strength Tests* **Isometric** Manual strength testing - 4 consecutive max effort reps in prone knee flexion (90 and 15 flexion) *Assessment Method/Tools/Tests Used* Manual assessment of strength **Isokinetic** <5% bilateral deficit in H:Q ratio – (eccentric hamstrings 30 /s / concentric quadriceps 240 /s) *Assessment Method/Tools/Tests Used* IKD Bilateral symmetry in knee flexion angle of peak concentric knee flexion torque at 60 /s

									Assessment Method/Tools/Tests Used IKD *Functional/Performance Based Criteria* **High Speed Running / Sprinting** Achieve full speed sprinting *Assessment Method/Tools/Tests Used* Not stated **Non-Specific Performance-Based Criteria** Unhindered functional sports-specific testing *Assessment Method/Tools/Tests Used* Not stated **Post RTP follow up:** *Follow Up Period* 12 month periodic follow up - whereby re-injury occurrences were registered **Qatar Cohort** **Criteria Informing Rehabilitation Progression:** *Clinical Examination / Evaluation* **Pain** Pain free single leg squat Pain free bike @ 150W for 5mins Pain free sport specific functional field testing (e g , direction change drills, jumping drills, pass/run, passing/crossing progressions) Pain free high-speed changes of direction (+) *Assessment Method/Tools/Tests Used* VAS (0-10) **Range of Motion** Full knee extension (supine) Hamstrings ≥75% uninvolved side SLR ≥75% uninvolved side

									<u>*Assessment Method/Tools/Tests Used*</u> Not stated <u>*Functional/Performance Based Criteria*</u> **High Speed Running / Sprinting** Run ≥70% running speed (30m) (Progressed from 25% - 70% max speed) Achieve 100% running speed (30m) (Progressed from 70% to 100% max speed) <u>*Assessment Method/Tools/Tests Used*</u> Patient rated/determined running speeds **Agility** High speed changes of direction (Progress from 70% - 100% max speed) <u>*Assessment Method/Tools/Tests Used*</u> Modified T-test Patient rated/determined running speeds **Completion of a Specific Programme** Progressive Running Programme 3-Stage Standardised Physiotherapy Programme (e g , ROM, progressive strengthening, core stability and agility exercises) **Criteria Informing RTP:** <u>*Clinical Examination / Evaluation*</u> **Pain** Pain free completion of sport specific rehab (e.g., shooting, 1v1 and scoring scenarios) <u>*Assessment Method/Tools/Tests Used*</u> VAS (0-10) **Satisfactory Clinical Exam**

									<u>*Strength Tests*</u> **Isokinetic** (Performed on injured + uninjured leg) Concentric Quadriceps & Hamstring Strength 5 reps - 60 /s concentric knee flexion / extension 10 reps - 300 /s concentric knee flexion / extension Eccentric / Concentric Hamstring Strength 5 reps - 60 /s eccentric knee extension and 180 /s concentric knee flexion <u>*Assessment Method/Tools/Tests Used*</u> IKD <u>*Functional/Performance Based Criteria*</u> **Completion of a Specific Programme** Sport Specific Functional Field Testing (Without limitation and/or symptoms) **Post RTP follow up:** <u>*Follow Up Period*</u> 12 month periodic follow up - whereby re-injury occurrences were registered

Gomez-Piqueras et al ,	2018	Spain	Prospective cohort study	III	To evaluate if the Safe Multidimensional Algorithm for Return to Training (SMART) scores differ between football players who suffer a subsequent re-injury and those who do not.	**Sport:** Football **Level:** Professional **Total Sample:** *n*=71 Injuries: *n*=55 (Involving 29 players) **Sex:** Male **Age: Mean (SD)** 23.9(4.5)	**Muscle Group:** Lower limb muscle injuries (*n*=31) **Specific Muscle(s) Involved:** Not stated **Diagnosis Approach:** Clinical Symptoms and Assessment Tests: Not stated **Imaging Performed**: No **Injury Grading:** No stated Only injuries resulting in >10 days' time loss were considered **Time to RTP (SD):** 29.1(16.9) **Injury Recurrences:** 12	**Treatment Approach**: Non-surgical **Domain(s) of Rehabilitation:** Physical Domain (i) Clinical (ii) Functional Non-Physical Domain (i) Psychological (ii) Contextual **Stage(s) of Recovery:** Return to Participation RTP **RTS decision-making guidelines:** 1. Asymptomatic completion of 3-stage rehabilitation programme: Pain must be <2 on VAS on all activities to progress between rehabilitation stages **Decision-making approach:** Not stated	**Criteria Informing Rehabilitation Progression:** *Clinical Examination / Evaluation* **Pain** Pain during all activities (VAS <2) (To progress athletes must complete stages in rehab protocol without pain) *Assessment Method/Tools/Tests Used* VAS (0-10) **Effusion/Swelling** None *Assessment Method/Tools/Tests Used* Clinical exam **Body Composition** Fat percentage (4 skinfold measurements) A player <10% gets worse - <0.5% change permitted A player 10-11% gets worse - <0.3% change permitted A player >11% gets worse - 0.15% change permitted *Assessment Method/Tools/Tests Used* Anthropometry – Skinfold measurement Patient Report **Patient-Reported Outcome Measures** Mood state score (POMS) -Anger (score 0-2) -Depression (score 0-2) -Fatigue (score 0-4) -Tension (score 0-4) -Vitality (score 8-12) -Friendship (score 8-12) Anxiety - State Trait Anxiety Inventory Questionnaire (Score 0-16)

									Assessment Method/Tools/Tests Used POMS State trait anxiety inventory questionnaire **Predetermined Benchmark** Basic sport specific evaluation (score 65-80) Advance sport specific evaluation (score 65-80) *Assessment Method/Tools/Tests Used* Functional follow up tool *Functional/Performance Based Criteria* **Agility** Barrow test (<10% difference with pre-injury score) *Assessment Method/Tools/Tests Used* Barrow test **Hop test** Single leg hop test (>90% limb symmetry) *Assessment Method/Tools/Tests Used* Single leg hop test **Jump Test** CMJ height (<3cm difference with pre-injury score) *Assessment Method/Tools/Tests Used* Counter movement jump assessment **Motor Control / Proprioception** Y-Balance Test (side to side difference <2cm) *Assessment Method/Tools/Tests Used* Y-Balance test **Criteria Informing RTP:** Patient Report **Patient-Reported Outcome Measures**

									Adherence - Rehabilitation Adherence Scale (Score 15-18) Self-perception state – self-perception of return questionnaire (score >39) *Assessment Method/Tools/Tests Used* Rehabilitation Adherence Scale Self-Perception of Return Questionnaire **Predetermined Benchmark** Group sport specific evaluation (score 65-80) *Assessment Method/Tools/Tests Used* Functional follow up tool *Functional/Performance Based Criteria* **Agility** Shuttle test (<10% difference with pre-injury score) *Assessment Method/Tools/Tests Used* Shuttle test **Hop test** Single leg triple hop test (>90% limb symmetry) *Assessment Method/Tools/Tests Used* Single leg triple hop test **Post RTP follow up:** *Follow Up Period* 2 month follow up period wherein re-injuries were registered

Lempainen et al.,	2018	Spain	Case series	IV	To evaluate the outcomes from a retrospective series of 27 cases grade 4 midsubstance ruptures of the rectus femoris muscle treated operatively in athletes	**Sport:** Multi-sport including Football **Level:** Competitive including Professional athletes **Total Sample:** 27 (Football 11) **Sex:** Male (23) Female (4) **Age: Mean (Range)** 29 (<15 - >50)	**Muscle Group:** Quadriceps **Specific Muscle(s) Involved:** Rectus Femoris **Diagnosis Approach:** Clinical Symptoms and Assessment Tests: (i) Pain and discomfort of anterior thigh in hip flexion and knee extension (ii) Weakness of anterior thigh in hip flexion and knee extension (iii) Inability to run and presentation of abnormal gait due to pain **Imaging Performed**: Yes Imaging Technique: MRI **Injury Grading:** 27 Grade 4 Injuries **Time to RTP:** 5 months **Injury Recurrences:** 1	**Treatment Approach**: Surgical **Domain(s) of Rehabilitation:** Physical Domain (i) Clinical (ii) Functional **Stage(s) of Recovery:** RTP **RTS decision-making guidelines:** Not stated **Decision-making approach:** Not stated	**Criteria Informing RTP:** *Time* Postoperative healing/injury management Progression of rehabilitation based on time **Post RTP follow up:** Periodic follow up over 12 months. Additional visits were scheduled until the athlete had returned to play. The mean length of follow up was 30 months

van der Made et al.,	2018	Holland / Qatar	Prospective study of a cohort of participants in a larger RCT	III	To determine whether intramuscular tendon involvement is associated with delayed RTP or elevated rates of reinjury.	**Sport:** Multi Sport including Football **Level:** Mixed Professional (*n*=69) Competitive (*n*=1) **Total Sample:** *n*=70 Injuries: *n*=70 Injuries involving Footballers (*n*=55) **Sex:** Male **Age: Median** 24 (IQR 21-30)	**Muscle Group:** Hamstring **Specific Muscle(s) Involved:** Biceps Femoris (long head) (*n*=56) Semitendinosus (*n*=2) Semimembranosus (*n*=12) **Diagnosis Approach:** Clinical Symptoms and Assessment Tests: Not stated **Imaging Performed**: Yes Imaging Technique: MRI **Injury Grading:** **(Only G1/2 injuries considered)** 34 Grade 1 Injuries 36 Grade 2 Injuries Injuries involving intramuscular tendon disruption (*n*=29) - <50% of tendon CSA (*n*=5) - 50-99% of tendon CSA (*n*=12) - 100% of tendon CSA (*n*=12) Specific Muscles involved - Biceps femoris (long head) (*n*=17) - Semimembranosus (*n*=5) - Involving biceps femoris and semitendinosus (*n*=7) Injuries without intramuscular tendon disruption (*n*=41) Intramuscular tendon disruption (*n*=29) **Time to RTP (SD):**	**Treatment Approach**: Non-surgical + PRP therapy Group 1: 3 mL Platelet-rich plasma Group 2: 3 mL Platelet-poor plasma Group 3: No injection **Domain(s) of Rehabilitation:** Physical Domain (i) Clinical (ii) Functional **Stage(s) of Recovery:** Return to Participation RTP **RTS decision-making guidelines:** 1. Asymptomatic completion of 6-stage rehabilitation programme: Standardised physiotherapy programme + Sport-specific functional field testing 2. Isokinetic evaluation 3. Clinical evaluation **Decision-making approach:** Isolated Stakeholder: Sports Physician	**Criteria Informing Rehabilitation Progression:** *Clinical Examination / Evaluation* **Pain** Pain free single leg squat Pain free bike @ 150W for 5mins Pain free sport specific functional field testing (e g , direction change drills, jumping drills, pass/run, passing/crossing progressions) Pain free high-speed changes of direction (+) *Assessment Method/Tools/Tests Used* VAS (0-10) **Range of Motion** Full knee extension (supine) Hamstrings ≥75% uninvolved side SLR ≥75% uninvolved side *Assessment Method/Tools/Tests Used* Not stated *Functional/Performance Based Criteria* **High Speed Running / Sprinting** Run ≥70% running speed (30m) (Progressed from 25% - 70% max speed) Achieve 100% running speed (30m) (Progressed from 70% to 100% max speed) *Assessment Method/Tools/Tests Used* Patient rated/determined running speeds **Agility** High speed changes of direction (Progress from 70% - 100% max speed) *Assessment Method/Tools/Tests Used* Modified T-test Patient rated/determined running speeds **Completion of a Specific Programme** Progressive Running Programme

							Overall 24.5(8.9) No intramuscular tendon disruption 22.2(7.4) Intramuscular tendon disruption 27.7(10) - <50% of tendon CSA: 24(9.7) - 50-99% of tendon CSA: 25.3(8.6) - 100% of tendon CSA: 31.6(10.9) No waviness present 22.6(7.5) Waviness present 30.2(10.8) **Injury Recurrences:** 25 Occurring ≤ 2 months (*n*=6) Occurring ≤ 6 months (*n*=8) Occurring ≤ 12 months (*n*=12)		3-Stage Standardised Physiotherapy Programme (e g , ROM, progressive strengthening, core stability and agility exercises) **Criteria Informing RTP:** *Clinical Examination / Evaluation* **Pain** Pain free completion of sport specific rehab (e.g., shooting, 1v1 and scoring scenarios) *Assessment Method/Tools/Tests Used* VAS (0-10) **Satisfactory Clinical Exam** *Strength Tests* **Isokinetic** (Performed on injured + uninjured leg) Concentric Quadriceps & Hamstring Strength 5 reps - 60 /s concentric knee flexion / extension 10 reps - 300 /s concentric knee flexion / extension Eccentric / Concentric Hamstring Strength 5 reps - 60 /s eccentric knee extension and 180 /s concentric knee flexion *Assessment Method/Tools/Tests Used* IKD *Functional/Performance Based Criteria* **Completion of a Specific Programme** Sport Specific Functional Field Testing (Without limitation and/or symptoms) **Post RTP follow up:** *Follow Up Period* 12 month periodic follow up - whereby re-injury occurrences were registered

Green et al.,	2019	Australia	Retrospective cohort study	III	The first aim of this study was to describe the epidemiology of calf muscle strain injury in elite Australian Football players. Second, to determine if recovery following injury is different according to: (a) injury type (index vs re-injury); (b) muscle injured (soleus vs gastrocnemius); and (c) mechanism of injury (running-related activity vs non-running-related activity).	**Sport:** Australian Football League **Level:** Professional **Total Sample:** *n*=184 Injuries: *n*=184 **Sex:** Male **Age: Median** 25 (Range 18-33)	**Muscle Group:** Calf **Specific Muscle(s) Involved:** Not including calf muscle re-injuries Soleus (n=126) Gastrocnemius (n=17) Tibialis posterior (n=3) Peroneus longus (n=1) Plantaris (n=1) **Diagnosis Approach:** Clinical Symptoms and Assessment Tests: Not stated **Imaging Performed**: Yes Imaging Technique: MRI **Injury Grading:** Not stated **Time to Achieve Pain-Free Walking** All calf muscle injuries 4.1 (3.3) (Range 0-16) Index Injury 4.3 (3.3) (Range 0-16) Re-Injury 4.6 (3.3) (Range 0-12) Soleus 3.9 (3.1) (Range 0-12) Gastrocnemius 4.3 (4.3) (Range 0-16) **Time to Run at >90% of Max Speed** All calf muscle injuries 19.4 (14.5) (Range 2-87) Index Injury	**Treatment Approach**: Non-surgical **Domain(s) of Rehabilitation:** Physical Domain (i) Clinical (ii) Functional **Stage(s) of Recovery:** Return to Participation RTP **RTS decision-making guidelines:** Not stated Authors evaluated the time (days) to achieve 4 recovery milestones 1. Time to walk pain free 2. Time to run at >90% max speed 3. Time to return to full training 4. Time to return to competition **Decision-making approach:** Not stated	**Criteria Informing Rehabilitation Progression:** *Clinical Examination / Evaluation* **Pain** Pain free walking (number of days taken to achieve) *Assessment Method/Tools/Tests Used* Pain - Patient feedback *Functional/Performance Based Criteria* **High Speed Running / Sprinting** Running at >90% max speed (number of days taken to achieve) *Assessment Method/Tools/Tests Used* Not stated **Criteria Informing RTP:** **Non-Specific Performance-Based Criteria** Resume full team training (number of days taken to achieve) **Post RTP follow up:** *Follow Up Period* Follow up was performed up to 2 seasons after the date of the index injury to register re-injuries

							17.31 (11.2) (Range 2-63) Re-Injury 33.7 (24.9) (Range 2-87) Soleus 18.1 (11.3) (Range 2-63) Gastrocnemius 14.5 (10.2) (Range 2-44) **Time to Training (SD):** All calf muscle injuries 20.6 (14.9) (Range 2-92) Index Injury 18.3 (11.7) (Range 2-63) Re-Injury 34.5 (25.4) (Range 2-92) Soleus 20.9 (14.1) (Range 2-63) Gastrocnemius 14.9 (12.7) (Range 2-53) **Time to RTP (SD):** All calf muscle injuries 26.5 (18.8) (Range 2-102) Index Injury 22.9 (13.6) (Range 2-74) Re-Injury 41.8 (28.6) (Range 2-102) Soleus 25.4 (16.2) (Range 4-74) Gastrocnemius 19.1 (14.1) (Range 2-58) **Injury Recurrences:** 35		

Bezuglov et al ,	2019	Russia	RCT	II	To evaluate the efficacy of a single injection of PRP in the management of hamstring injuries in professional soccer players	**Sport:** Football **Level:** Professional **Total Sample:** *n*=40 Injuries: *n*=40 **Sex:** Male **Age: Mean (SD)** 27(3.3) (Range 22-31)	**Muscle Group:** Hamstring **Specific Muscle(s) Involved:** Biceps Femoris (*n*=26) Semimembranosus (*n*=10) Semitendinosus (*n*=4) **Diagnosis Approach:** Clinical Symptoms and Assessment Tests: (i) Presence and localised pain on palpation **Imaging Performed**: Yes Imaging Technique: Ultrasound / MRI **Injury Grading:** **(Only G2a/b injuries considered)** Group 1: Non-PRP Treatment 10 Grade 2a Injuries 10 Grade 2b Injuries Group 2: PRP Treatment 10 Grade 2a Injuries 10 Grade 2b Injuries **Time to RTP (SD):** Group 1: Non-PRP Treatment 21.3 (2.7) Group 2: PRP Treatment 11.4 (1.2) **Injury Recurrences:** 0	**Treatment Approach**: Non-surgical + PRP Group 1: 8mL Saline solution Group 2: 8mL Platelet-rich plasma **Domain(s) of Rehabilitation:** Physical Domain (i) Clinical (ii) Functional **Stage(s) of Recovery:** Return to Participation RTP **RTS decision-making guidelines:** 1. No pain on performing exercises of any intensity **Decision-making approach:** Not stated	**Criteria Informing Rehabilitation Progression:** *Clinical Examination / Evaluation* **Pain** No pain at rest and during regular movements No pain on slow walking (5km/h) No pain on fast walking (7km/h) No pain on palpation No pain when running at medium intensity (12km/h) No pain when performing sport specific exercises No pain on changes of direction at medium intensity (15km/h) No pain when sprinting (10m) *Assessment Method/Tools/Tests Used* Pain – Patient feedback **Criteria Informing RTP:** *Clinical Examination / Evaluation* **Pain** No pain when performing exercises of any intensity was required to RTP *Assessment Method/Tools/Tests Used* Pain – Patient feedback **Post RTP follow up:** *Follow Up Period* 6 month follow up period wherein any re-injuries were reported

Van Dyk et al ,	2019	Qatar	Prospective study of a cohort of participants in a larger RCT	III	To determine whether professional soccer players who had suffered acute hamstring injuries confirmed by magnetic resonance imaging displayed the same level of strength as measured during pre-season baseline testing. We aimed to compare the isokinetic strength at RTP with pre-injury strength in the injury limb and to investigate the side-to-side differences at RTP	**Sport:** Football **Level:** Professional **Total Sample:** *n*=41 Injuries: *n*=41 **Sex:** Male **Age: Mean (SD)** 25(4)	**Muscle Group:** Hamstring **Specific Muscle(s) Involved:** Biceps Femoris (long head) (*n*=30) Semitendinosus (*n*=9) Semimembranosus (*n*=2) **Diagnosis Approach:** Clinical Symptoms and Assessment Tests: (i) Acute onset of posterior thigh pain (ii) Presence and localised pain on palpation (iii) Increasing pain during isometric contraction (iv)Localised pain when performing passive SLR (v) IKD evaluation (Uninjured leg only) Concentric Quadriceps & Hamstring Strength 5 reps - 60 /s concentric knee flexion / extension 10 reps - 300 /s concentric knee flexion / extension Eccentric Hamstring Strength 5 reps - 60 /s eccentric knee flexion / extension **Imaging Performed**: Yes Imaging Technique: MRI **Injury Grading:** **(Only G1/2 injuries considered)**	**Treatment Approach**: Non-surgical **Domain(s) of Rehabilitation:** Physical Domain (i) Clinical (ii) Functional **Stage(s) of Recovery:** Return to Participation RTP **RTS decision-making guidelines:** 1. Asymptomatic completion of 6 stage rehabilitation programme: Standardised physiotherapy programme + Sport-specific functional field testing 2. Clinical examination 3. Isokinetic evaluation 4. Askling H-test (Aspetar rehab protocol only) 5. Nordic hamstring exercise (Aspetar rehab protocol only) **Decision-making approach:** Shared	<u>**Growth Factor Study Protocol**</u> **Criteria Informing Rehabilitation Progression:** *<u>Clinical Examination / Evaluation</u>* **Pain** Pain free single leg squat Pain free bike @ 150W for 5mins Pain free sport specific functional field testing (e g , direction change drills, jumping drills, pass/run, passing/crossing progressions) Pain free high-speed changes of direction (+) *<u>Assessment Method/Tools/Tests Used</u>* VAS (0-10) **Range of Motion** Full knee extension (supine) Hamstrings ≥75% uninvolved side SLR ≥75% uninvolved side *<u>Assessment Method/Tools/Tests Used</u>* Not stated *<u>Functional/Performance Based Criteria</u>* **High Speed Running / Sprinting** Run ≥70% running speed (30m) (Progressed from 25% - 70% max speed) Achieve 100% running speed (30m) (Progressed from 70% to 100% max speed) *<u>Assessment Method/Tools/Tests Used</u>* Patient rated/determined running speeds **Agility** High speed changes of direction (Progress from 70% - 100% max speed) *<u>Assessment Method/Tools/Tests Used</u>* Modified T-test Patient rated/determined running speeds

							21 Grade 1 Injuries 20 Grade 2 Injuries **Time to RTP (SD):** 25.3 (8.9) **Injury Recurrences:** 1		**Completion of a Specific Programme** Progressive Running Programme 3-Stage Standardised Physiotherapy Programme (e g , ROM, progressive strengthening, core stability and agility exercises) **Criteria Informing RTP:** *Clinical Examination / Evaluation* **Pain** Pain free completion of sport specific rehab (+) (e.g., shooting, 1v1 and scoring scenarios) *Assessment Method/Tools/Tests Used* VAS (0-10) **Satisfactory Clinical Exam** *Strength Tests* **Isokinetic** (Performed on injured + uninjured leg) Concentric Quadriceps & Hamstring Strength 5 reps - 60 /s concentric knee flexion / extension 10 reps - 300 /s concentric knee flexion / extension Eccentric Hamstring Strength 5 reps - 60 /s eccentric knee extension *Assessment Method/Tools/Tests Used* IKD *Functional/Performance Based Criteria* **Completion of a Specific Programme** Sport Specific Functional Field Testing (Without limitation and/or symptoms) **Post RTP follow up:**

									Follow Up Period 2 month follow up wherein reinjuries were registered **Aspetar Hamstring Rehabilitation Study Protocol** **Criteria Informing Rehabilitation Progression:** *Clinical Examination / Evaluation* **Pain** Pain free single leg squat Pain free bike @ (Watt: 2x bodyweight) for 5mins Pain free sport specific functional field testing (e g , direction change drills, jumping drills, pass/run, passing/crossing progressions) Pain free high-speed changes of direction (+) Pain free acceleration & deceleration during high-speed running Pain isometric eccentric mid-range strength test (VAS ≤ 2) (+) *Assessment Method/Tools/Tests Used* VAS (0-10) **Range of Motion** Full knee extension (supine) SLR > 75% uninvolved side *Assessment Method/Tools/Tests Used* Inclinometer *Strength Tests* **Isometric** (compared to uninjured leg) >75% eccentric strength – mid-range strength test *Assessment Method/Tools/Tests Used* HHD *Functional/Performance Based Criteria* **High Speed Running / Sprinting** Run >70% running speed (30m)

									(Progressed from 25% - 70% max speed) Achieve 100% running speed (30m) (Progressed from 70% to 100% max speed) *Assessment Method/Tools/Tests Used* Patient rated/determined running speeds **Agility** High speed changes of direction (Progress from 70% - 100% max speed) *Assessment Method/Tools/Tests Used* Modified T-test Patient rated/determined running speeds **Completion of a Specific Programme** Progressive Running Programme 3-Stage Standardised Physiotherapy Programme (e g , ROM, progressive strengthening, core stability and agility exercises) **Criteria Informing RTP:** *Clinical Examination / Evaluation* **Satisfactory Clinical Exam** **Range of Motion** Dynamic flexibility H-Test (without insecurity or pain) *Assessment Method/Tools/Tests Used* H-test *Strength Tests* **Eccentric Hamstring Strength** Asymptomatic Eccentric knee flexor strength test (Nordic curl) Average and peak force measured *Assessment Method/Tools/Tests Used* Nordbord

									Isokinetic (Performed on injured + uninjured leg) Concentric Quadriceps & Hamstring Strength 5 reps - 60 /s concentric knee flexion / extension 10 reps - 300 /s concentric knee flexion / extension Eccentric Hamstring Strength 5 reps - 60 /s eccentric knee extension *Assessment Method/Tools/Tests Used* IKD *Functional/Performance Based Criteria* **Completion of a Specific Programme** Sport Specific Functional Field Testing (Without limitation and/or symptoms) **Post RTP follow up:** *Follow Up Period* 2 month follow up wherein reinjuries were registered

Jimenez-Rubio et al.,	2019	Spain	Prospective cohort study	III	To develop and validate a new, functional on-field program for the rehabilitation and readaptation after hamstring strain injury (via an expert panel) and determine its usefulness through the application of this program in professional football players	**Sport:** Football **Level:** Professional **Total Sample:** *n*=19 Injuries: *n*=19 **Sex:** Male **Age: Mean (SD)** 24.23 (5.36)	**Muscle Group:** Hamstring **Specific Muscle(s) Involved:** Biceps Femoris **Diagnosis Approach:** Clinical Symptoms and Assessment Tests: Not stated **Imaging Performed**: Yes Imaging Technique: MRI/Ultrasound **Injury Grading:** **(Grade 2 only)** 19 Grade 2 Injuries **Time to RTP (SD):** 22.4 (2.3) **Injury Recurrences:** 0	**Treatment Approach**: Non-surgical + Ultrasound guided percutaneous needle electrolysis **Domain(s) of Rehabilitation:** Physical Domain (i) Clinical (ii) Functional **Stage(s) of Recovery:** Return to Participation RTP **RTS decision-making guidelines:** 1. Completion of gym-based rehabilitation programme 2. Completion of on-field sport specific rehabilitation programme: All programme items must be completed simultaneously on same day before clearance to team training 3. Complete 1 week of full training **Decision-making approach:** Not stated	**Criteria Informing Rehabilitation Progression:** *<u>Clinical Examination / Evaluation</u>* **Pain** Pain free execution of gym-based rehabilitation programme exercises (+) *<u>Assessment Method/Tools/Tests Used</u>* Pain – Patient feedback **Range of Motion** Achieve full hip range of motion Achieve full knee range of motion *<u>Assessment Method/Tools/Tests Used</u>* Not stated *<u>Functional/Performance Based Criteria</u>* **Completion of a Specific Programme** Gym based rehabilitation programme Progressive running programme + Sport Specific Functional Field Testing: (13 drills of progressive complexity to be successfully completed simultaneously to be declared fit to return to team training) *<u>Assessment Method/Tools/Tests Used</u>* GPS **Criteria Informing RTP:** *<u>Functional/Performance Based Criteria</u>* **Non-Specific Performance-Based Criteria** Complete 1 week of full team training sessions *<u>Assessment Method/Tools/Tests Used</u>* GPS *<u>Training Load</u>* **External Load Monitoring (+)**

									GPS monitoring (training data) **Metrics** No specific metrics were reported *Assessment Method/Tools/Tests Used* GPS **Post RTP follow up:** *Follow Up Period* 6 month follow up period wherein re-injuries were recorded

Jimenez-Rubio et al.,	2019	Spain	Prospective cohort study	III	To determine the changes in match-based physical performance parameters in professional soccer players before and after sustaining a hamstring strain injury and undergoing a soccer-specific rehabilitation program. To observe the progress of these performance parameters 6 to 10 weeks after the player returned from injury.	**Sport:** Football **Level:** Professional **Total Sample:** *n*=19 Injuries: *n*=19 **Sex:** Male **Age: Mean (SD)** 24.23 (5.36)	**Muscle Group:** Hamstring **Specific Muscle(s) Involved:** Not stated **Diagnosis Approach:** Clinical Symptoms and Assessment Tests: Not stated **Imaging Performed**: Yes Imaging Technique: MRI / Ultrasound **Injury Grading:** **(Only G2b injuries considered)** 19 Grade 2b Injuries **Time to RTP (SD):** 22.42 (2.31) **Injury Recurrences:** 0	**Treatment Approach**: Non-surgical + Ultrasound guided percutaneous needle electrolysis **Domain(s) of Rehabilitation:** Physical Domain (i) Clinical (ii) Functional **Stage(s) of Recovery:** Return to Participation RTP Return to Performance **RTS decision-making guidelines:** 1. Asymptomatic completion of gym-based rehabilitation programme 2. Completion of on-field sport specific rehabilitation programme All programme items must be completed simultaneously on same day (and consecutively on two days) before clearance to team training 3. Complete 1 week of full training **Decision-making approach:** Shared	**Criteria Informing Rehabilitation Progression:** *Clinical Examination / Evaluation* **Pain** Pain free execution of gym-based rehabilitation programme exercises (+) *Assessment Method/Tools/Tests Used* Pain – Patient feedback **Range of Motion** Achieve full hip range of motion Achieve full knee range of motion *Assessment Method/Tools/Tests Used* Not stated *Functional/Performance Based Criteria* **Completion of a Specific Programme** Gym based rehabilitation programme Progressive running programme + Sport Specific Functional Field Testing (13 drills of progressive complexity to be successfully completed simultaneously to be declared fit to return to team training – The player was declared fit to train with the group after all the drills had successfully been repeated for 2 days) *Assessment Method/Tools/Tests Used* GPS **Criteria Informing RTP:** *Functional/Performance Based Criteria* **Non-Specific Performance-Based Criteria** Complete 1 week of full team training sessions *Assessment Method/Tools/Tests Used* GPS *Training Load* **External Load Monitoring**

									GPS monitoring (Training data) **Metrics:** Not stated *Assessment Method/Tools/Tests Used* GPS **Post RTP follow up:** *Follow Up Period* 8 months follow up period wherein any re-injuries were reported *Training Load* **External Load Monitoring** GPS monitoring (Match data) - 1st competitive match post RTP - Match 6-10 weeks post RTP (minimum duration of 45 mins played) **Metrics** Distance per minute at high intensities (14.4-19.7 km/h) Distance per minute at very high intensities (19.8-25.1 km/h) Distance per minute at sprint velocities (>25.1km/h) Average speed Peak speed Work:Rest ratio (distance covered >7km/h vs <7km/h) *Assessment Method/Tools/Tests Used* GPS

Renoux et al ,	2019	France	Retrospective cohort study	IV	To demonstrate the prognostic value of ultrasound in assessing acute muscle injuries, the relationships between ultrasound features of muscles injuries and the time needed to RTP in a sample of elite athletes was assessed.	**Sport:** Multi-sport including rugby and football **Level:** Professional **Total Sample:** *n*=70 Injuries: *n*=70 Injuries involving Rugby Players (*n*=18) and Footballers (*n*=5) **Sex:** Male (n=45) Female (n=25) **Age: Mean (SD)** 27.8(6.1) Range (22-55)	**Muscle Group:** Hamstring (*n*=31) Quadriceps (*n*=10) Adductor (*n*=6) Calf (*n*=11) **Specific Muscle(s) Involved:** Not stated **Diagnosis Approach:** Clinical Symptoms and Assessment Tests: Not stated Imaging Performed: Yes Imaging Technique: US **Injury Grading:** 24 Grade 1 Injuries 34 Grade 2 Injuries 12 Grade 3 Injuries **Time to RTP (SD):** **Overall** Grade 1 Injuries: 2.2 weeks (1.1) (Range 0-4) Grade 2 Injuries: 4.6 weeks (1.9) (Range 2-9) Grade 3 Injuries: 11.1 weeks (3.6) (Range 6-17) **Injuries without connective tissue disruption (*n*=52)** Grade 1 Injuries: 2.2 weeks (1.1) (Range 0-4) Grade 2 Injuries: 4.1 weeks (1.6)	**Treatment Approach**: Non-surgical **Domain(s) of Rehabilitation:** Physical Domain (i) Clinical (ii) Functional **Stage(s) of Recovery:** RTP **RTS decision-making guidelines:** 1. Asymptomatic completion of a rehabilitation programme 2. Perform sport-specific activities without any restriction or pain **Decision-making approach:** Isolated Decision Stakeholder: Sports Physician	**Criteria Informing RTP:** *Clinical Examination / Evaluation* **Pain** Pain free sport specific functional field testing (+) *Assessment Method/Tools/Tests Used* Not stated *Functional/Performance Based Criteria* **Completion of a Specific Programme** Sport Specific Functional Field Testing (Without limitation and/or symptoms) **Post RTP follow up:** Not stated

							(Range 2-8) Grade 3 Injuries: 10.2 weeks (3.8) (Range 6-17) **Injuries with connective tissue disruption (*n*=18)** Grade 2 Injuries: 5.4 weeks (2.3) (Range 3-9) Grade 3 Injuries: 11.8 weeks (3.6) (Range 6-16) **Injury Recurrences:** Not Stated		

Bradley et al ,	2020	USA	Retrospective cohort study	III	To evaluate return to play in professional American football players with acute hamstring injuries after leukocyte-poor PRP injections.	**Sport:** American Football **Level:** Professional **Total Sample:** n=108 Injuries: *n*=108 (Injuries categorised as grade 2: *n*=69) **Sex:** Male **Age: Mean** Group 1: PRP 28.8 Group 2: No PRP 25.7	**Muscle Group:** Hamstring **Specific Muscle(s) Involved:** Biceps Femoris (*n*=46) Semitendinosus (*n*=15) Semimembranosus (*n*=8) **Diagnosis Approach:** Clinical Symptoms and Assessment Tests: (i) Presence and localised pain on palpation (ii) Positive plank and modified plank test (iii) Pain with prone-resisted knee flexion **Imaging Performed**: Yes Imaging Technique: MRI **Injury Grading:** **(Only G2 injuries considered)** 69 Grade 2 Injuries **Time to RTP:** Group 1: PRP 22.5(20.1) – Days missed 18.2(9.2) – Practices missed 1.3(0.47) – Games missed Group 2: No PRP 25.7(20.6) – Days missed 22.8(11.9) – Practices missed 1.3(1.1) – Games missed	**Treatment Approach**: Non-surgical + PRP therapy Group 1: 5 mL Platelet-rich plasma (leukocyte-poor) with conventional conservative treatment (PRP injections received varied from 1-3) Group 2: Conventional conservative treatment only **Domain(s) of Rehabilitation:** Physical Domain (i) Clinical (ii) Functional **Stage(s) of Recovery:** Return to Participation RTP **RTS decision-making guidelines:** 1. Completion of rehabilitation programme: Standardised physiotherapy programme 2. Completion of RTP testing protocol **Decision-making approach:** Not stated	**Criteria Informing Rehabilitation Progression:** *Clinical Examination / Evaluation* **Pain** Pain free range of motion (+) Pain free eccentric strength exercises (+) *Assessment Method/Tools/Tests Used* Pain - Patient feedback **Range of Motion (ROM)** Normal range of motion *Assessment Method/Tools/Tests Used* Not stated *Strength Tests* **Method of Strength Test not clearly stated** Restore eccentric hamstring strength *Assessment Method/Tools/Tests Used* Not stated **Criteria Informing RTP:** *Clinical Examination / Evaluation* **Pain** Successful plank test without pain (+) *Assessment Method/Tools/Tests Used* Pain - Patient feedback **Range of Motion (ROM)** Normal range of motion *Assessment Method/Tools/Tests Used* Not stated

							Injury Recurrences: 2 Group 1: PRP (*n*=1) Group 2: No PRP (*n*=1)		*Strength Tests* **Method of Strength Test not clearly stated** Normal strength Plank testing *Assessment Method/Tools/Tests Used* Not stated *Functional/Performance Based Criteria* **Completion of a Specific Programme** RTP test protocol **Non-Specific Performance-Based Criteria** Normal position-specific functional testing *Assessment Method/Tools/Tests Used* Not stated **Post RTP follow up:** Not stated

Eggleston et al ,	2020	Australia	Prospective cohort study	III	Investigate whether an increase in hamstring injury severity involving high-grade IT disruption and proximal injury location is associated with longer RTP times in elite Australian Rules Football players.	**Sport:** Australian Football League **Level:** Professional **Total Sample:** *n*=50 Injuries: *n*=41 (Involving 24 players) **Sex:** Male **Age: Mean** 23.5 (Range 18-33)	**Muscle Group:** Hamstring **Specific Muscle(s) Involved:** Primary lesions: Biceps Femoris (*n*=27) Semitendinosus (*n*=3) Semimembranosus (*n*=3) Injuries involving 2 or more muscles: Biceps Femoris + Semitendinosus (*n*=5) **Diagnosis Approach:** Clinical Symptoms and Assessment Tests: Not stated **Imaging Performed**: Yes Imaging Technique: MRI **Injury Grading:** Modified Peetrons Classification 3 Grade 0 Injuries 24 Grade 1 Injuries 13 Grade 2 Injuries 1 Grade 3 Injury BAMIC 3 Grade 0 Injuries 1 Grade 1a Injury 1 Grade 1b Injury 4 Grade 2a Injuries 7 Grade 2b Injuries 5 Grade 2c Injuries 1 Grade 3a Injuries 8 Grade 3b Injuries	**Treatment Approach**: Non-surgical **Domain(s) of Rehabilitation:** Physical Domain (i) Clinical (ii) Functional **Stage(s) of Recovery:** RTP **RTS decision-making guidelines:** 1. Completion of rehabilitation programme: Standardised programme comprised of rehabilitation milestones **Decision-making approach:** Not stated	**Criteria Informing RTP:** *Clinical Examination / Evaluation* **Pain** Perform functional testing pain free *Assessment Method/Tools/Tests Used* Pain – Patient feedback *Strength Tests* **Method of Strength Test not clearly stated** Achieve accepted standard in Isometric strength testing *Assessment Method/Tools/Tests Used* IKD / HHD **Method of Strength Test not clearly stated** Achieve accepted standard in Eccentric strength testing *Assessment Method/Tools/Tests Used* Not stated *Functional/Performance Based Criteria* **High Speed Running / Sprinting** High speed running *Assessment Method/Tools/Tests Used* Not stated **Completion of a Specific Programme** Sport Specific Functional Field Testing Sport Specific Functional Field Testing - (kicking prog) **Non-Specific Performance-Based Criteria** Complete full team training sessions *Training Load* **External Load Monitoring** GPS monitoring (rehab training data) (+)

							10 Grade 3c Injuries 1 Grade 4 Injury **Time to RTP:** Biceps Femoris: 24.9(8.1) Semitendinosus: 23.3(8.1) Semimembranosus: 25 7(10 7) Biceps Femoris + Semitendinosus: 71.6(32.7) Modified Peetrons Classification Grade 0 Injuries: 12.3(2.9) Grade 1 Injuries: 23.3(8.5) Grade 2 Injuries: 44.8(29.3) *Grade 2 with intramuscular tendon involvement: 59 days* *Grade 2 without intramuscular tendon involvement: 28 days* Grade 3 Injuries: 35 BAMIC Grade 0 Injuries: 12.3(2.9) Grade 1a Injury: 20 Grade 1b Injury: 28 Grade 2a Injuries: 24.5(9) Grade 2b Injuries: 24.3(4.9) Grade 2c Injuries: 21.4(5) Grade 3a Injury: 35 Grade 3b Injuries: 19.5(6.3) Grade 3c Injuries: 52.8(30.1) Grade 4 Injury: 35 *Grade 3c with intermuscular tendon involvement: 33(8.9)*		**Metrics** High-speed running markers of frequency and volume *Assessment Method/Tools/Tests Used* GPS **Post RTP follow up:** *Follow Up Period* Periodic follow up over 12 months wherein any re-injuries were reported

							Grade 3c with intramuscular involvement and Biceps Femoris + Semitendinosus injury: 82.5(25.1) Grade 4 Injury: 35 **Injury Recurrences:** 8 With intramuscular tendon disruption (*n*=5) Without intramuscular tendon disruption (*n*=3)		

Serner et al.,	2020	Qatar	Prospective cohort study	III	To evaluate return to sport outcomes and re-injuries after criteria-based rehabilitation for athletes with acute adductor injuries.	**Sport:** Multi-sport Including Football **Level:** Professional **Total Sample:** *n*=81 Injuries: *n*=81 Injuries involving footballers (*n*=47) **Sex:** Male **Age: Mean (SD)** 25.7 (4.3) (Range 18-37)	**Muscle Group:** Adductors **Specific Muscle(s) Involved:** Adductor Longus (*n*=58) Adductor Brevis (*n*=3) Adductor Magnus (*n*=1) Pectineus (*n*=2) Obturator Externus (*n*=3) **Diagnosis Approach:** Clinical Symptoms and Assessment Tests: (i) Complete modified Copenhagen Hip and Groin Outcome Score Questionnaire (ii) Presence and localised pain on palpation (iii) Clinical pain provocation resistance tests: Squeeze 45 hip flexion Squeeze 0 hip flexion Outer-range adduction (iv) Clinical pain provocation stretch tests: Passive adductor stretch FABER test (v) Range of motion tests Bent knee fall out test Side-lying hip abduction (vi) Strength tests Eccentric hip abduction	**Treatment Approach**: Non-surgical **Domain(s) of Rehabilitation:** Physical Domain (i) Clinical (ii) Functional Non-Physical (i) Contextual **Stage(s) of Recovery:** Return to Participation RTP **RTS decision-making guidelines:** 1. Pain controlled completion of 4-stage groin rehabilitation programme 2 Pain controlled completion of 4-stage running rehabilitation programme 3. Pain free on clinical examination 4. Completion of on-pitch controlled sport training 5. Resumption of full team training **Decision-making approach:** Shared	**Criteria Informing Rehabilitation Progression:** *Clinical Examination / Evaluation* **Pain** Minimal pain during rest (VAS $\leq$ 2/10) Minimal pain during waking (VAS $\leq$ 2/10) Minimal pain during standing maximal abduction activation without resistance (VAS $\leq$ 2/10) No resting pain following early resistance exercise (DOMS accepted) (+) Resisted hip adduction within (VAS $\leq$ 2/10) (+) Full range of motion within (VAS $\leq$ 2/10) (+) Pain free running movements (+) (30% self-reported intensity) Pain free continuous running 15mins (+) (60% self-reported intensity) Pain free side stepping (+) (60% self-reported intensity) Pain free zig zag running (+) (60% self-reported intensity) Pain free 30m (10x) sprinting (+) (80% self-reported intensity) Pain free T-Test (+) (80% self-reported intensity) *Assessment Method/Tools/Tests Used* VAS (0-10) **Range of Motion (ROM)** Full range of motion high velocity active dynamic stretching / ballistic stretching *Assessment Method/Tools/Tests Used* Not stated *Strength Tests* **Predetermined Benchmark** Resisted hip adduction (1x 20reps) (elastic band)

							(Side-lying) Eccentric hip adduction (Side-lying) Eccentric hip adduction – outer range (supine) **Imaging Performed**: Yes Imaging Technique: MRI **Injury Grading:** 14 Grade 0 Injuries 20 Grade 1 Injuries *Adductor Longus 14* *Adductor Brevis 3* *Adductor Magnus 1* *Pectineus 1* *Obturator Externus 1* 30 Grade 2 Injuries *Adductor Longus 27* *Pectineus 1* *Obturator Externus 2* 17 Grade 3 Injuries *Adductor Longus 17* **Time to RTP (Median):** Clinically Pain-Free All Injuries: 15 (IQR, 12-29) (Range 6-166) Grade 0 Injuries: 13 (IQR, 11-14) Grade 1 Injuries: 13 (IQR, 11-17) Grade 2 Injuries: 17 (IQR, 11-24) Grade 3 Injuries: 55 (IQR, 31-75)		Resisted hip adduction (1x 15reps) (elastic band) *Assessment Method/Tools/Tests Used* Elastic resistance bands *Functional/Performance Based Criteria* **Low / Moderate Speed Running (Activity)** Pain free running movements (30% self-reported intensity) Continuous running (60% self-reported intensity) *Assessment Method/Tools/Tests Used* Patient determined running speeds **High Speed Running / Sprinting** 30m (10x) Sprinting (80% self-reported intensity) *Assessment Method/Tools/Tests Used* Patient determined running speeds **Agility** Zigzag / side-step run variations (60% self-reported intensity) T-Test (80% self-reported intensity) *Assessment Method/Tools/Tests Used* Zigzag / side-step drill T-Test Patient determined running speeds **Completion of a Specific Programme** Groin exercise Rehabilitation programme Progressive running programme **Criteria Informing RTP:** *Clinical Examination / Evaluation* **Pain** Pain free palpation Pain free maximal isometric adduction in outer range (+) Pain free maximal passive adductor stretch (+) Pain free resisted hip adduction (elastic band, 10reps) (+) Pain free Copenhagen adduction exercise (10reps) (+)

							Completion of controlled sports training All Injuries: 24 (IQR, 16-34) (Range 9-212) Grade 0 Injuries: 16 (IQR, 15-17) Grade 1 Injuries: 17 (IQR, 16-21) Grade 2 Injuries: 25 (IQR, 15-30) Grade 3 Injuries: 68 (IQR, 51-84) Return to training All Injuries: 22 (IQR, 15-33) (Range 5-224) Grade 0 Injuries: 17 (IQR, 13-18) Grade 1 Injuries: 21 (IQR, 16-26) Grade 2 Injuries: 21 (IQR, 14-28) Grade 3 Injuries: 78 (IQR, 68-98) **Injury Recurrences:** 6		Pain free sport specific drills (+) (e g , pre-planned & reactive COD drills with/without ball, jumps (multi-planar & bi/unilateral), passing (progressing distance), crossing and shooting, one vs one scenarios) Pain free T-Test (+) (100% self-reported intensity) Pain free 30m (x10) sprinting (+) (100% self-reported intensity) Pain free Illinois agility test (+) (100% self-reported intensity) Pain free spider test (with / without ball) (+) (100% self-reported intensity) *Assessment Method/Tools/Tests Used* VAS (0-10) **Range of Motion (ROM)** Full passive ROM *Assessment Method/Tools/Tests Used* Passive adductor stretch (instructor led) **Satisfactory Clinical Exam** *Strength Tests* **Isometric** Maximal isometric adduction strength in outer range *Assessment Method/Tools/Tests Used* HHD **Predetermined Benchmark** Resisted hip adduction (1x 10reps) (elastic band) Copenhagen adduction exercise (10 reps) *Assessment Method/Tools/Tests Used* Elastic resistance bands Copenhagen adductor test

									<u>Functional/Performance Based Criteria</u> **High Speed Running / Sprinting** 30m (10x) Sprinting (100% self-reported intensity) *<u>Assessment Method/Tools/Tests Used</u>* Patient determined running speeds **Agility** T-Test (100% self-reported intensity) Illinois agility test (100% self-reported intensity) Spider test (100% self-reported intensity) (including ball) *<u>Assessment Method/Tools/Tests Used</u>* T-test Illinois agility test Spider test Patient determined running speeds **Completion of a Specific Programme** Sport specific functional testing/drills **Non-Specific Performance-Based Criteria** Resume full team training **Post RTP follow up:** *<u>Follow Up Period</u>* Periodic follow up via telephone calls at 2,6 and 12 months wherein players reported suspected re-injury

Serner et al.,	2020	Qatar	Prospective cohort study	III	To investigate the association between initial clinical and imaging examination findings and time to return to sport in male athletes with acute adductor injuries.	**Sport:** Multi-sport Including Football **Level:** Professional **Total Sample:** *n*=81 Injuries: *n*=81 Injuries involving footballers (*n*=47) **Sex:** Male **Age: Mean (SD)** 25.7 (4.3) (Range 18-37)	**Muscle Group:** Adductors **Specific Muscle(s) Involved:** Name specific muscle group(s) or report that they were not stated **Diagnosis Approach:** Clinical Symptoms and Assessment Tests: (i) Complete modified Copenhagen Hip and Groin Outcome Score Questionnaire (ii) Presence and localised pain on palpation (iii) Clinical pain provocation resistance tests: - Adduction squeeze (0 /45 hip flexion) - Resisted hip flexion 0 /90 hip flexion) - Straight/Oblique abdominal flexion (iv) Clinical pain provocation stretch tests: - Passive adductor stretch - FABER test - Modified Thomas test - Hip internal ROM restriction (90 hip flexion) - Anterior Hip impingement tests **Imaging Performed**: Yes Imaging Technique: MRI **Injury Grading:** Not stated	**Treatment Approach**: Non-surgical **Domain(s) of Rehabilitation:** Physical Domain (i) Clinical (ii) Functional **Stage(s) of Recovery:** Return to Participation RTP **RTS decision-making guidelines:** 1. Pain controlled completion of 4-stage groin rehabilitation programme: 2 Pain controlled completion of 4-stage running rehabilitation programme 3. Pain free on clinical examination 4. Completion of on-pitch controlled sport training 5. Resumption of full team training **Decision-making approach:** Shared	**Criteria Informing Rehabilitation Progression:** *Clinical Examination / Evaluation* **Pain** Minimal pain during rest (VAS $\leq$ 2/10) Minimal pain during waking (VAS $\leq$ 2/10) Minimal pain during standing maximal abduction activation without resistance (VAS $\leq$ 2/10) No resting pain following early resistance exercise (DOMS accepted) (+) Resisted hip adduction within (VAS $\leq$ 2/10) (+) Full range of motion within (VAS $\leq$ 2/10) (+) Pain free running movements (+) (30% self-reported intensity) Pain free continuous running 15mins (+) (60% self-reported intensity) Pain free side stepping (+) (60% self-reported intensity) Pain free zig zag running (+) (60% self-reported intensity) Pain free 30m (10x) sprinting (+) (80% self-reported intensity) Pain free T-Test (+) (80% self-reported intensity) *Assessment Method/Tools/Tests Used* VAS (0-10) **Range of Motion (ROM)** Full range of motion high velocity active dynamic stretching/ballistic stretching *Assessment Method/Tools/Tests Used* Not stated *Strength Tests* **Predetermined Benchmark** Resisted hip adduction (1x 20reps) (elastic band)

							Time to RTP (Median): Clinically Pain-Free 15 (IQR, 12-28) Completion of controlled sports training 24 (IQR, 16-32) Return to training 22 (IQR, 15-31) **Injury Recurrences:** Not stated		Resisted hip adduction (1x 15reps) (elastic band) *Assessment Method/Tools/Tests Used* Elastic resistance bands *Functional/Performance Based Criteria* **Low / Moderate Speed Running (Activity)** Pain free running movements (30% self-reported intensity) Continuous running (60% self-reported intensity) *Assessment Method/Tools/Tests Used* Patient determined running speeds **High Speed Running / Sprinting** 30m (10x) Sprinting (80% self-reported intensity) *Assessment Method/Tools/Tests Used* Patient determined running speeds **Agility** Zigzag / side-step run variations (60% self-reported intensity) T-Test (80% self-reported intensity) *Assessment Method/Tools/Tests Used* Zigzag / side-step drill T-Test Patient determined running speeds **Completion of a Specific Programme** Groin exercise Rehabilitation programme Progressive running programme **Criteria Informing RTP:** *Clinical Examination / Evaluation* **Pain** Pain free palpation Pain free maximal isometric adduction in outer range (+) Pain free maximal passive adductor stretch (+) Pain free resisted hip adduction (elastic band, 10reps) (+) Pain free Copenhagen adduction exercise (10reps) (+)

									Pain free sport specific drills (+) (e g , pre-planned & reactive COD drills with/without ball, jumps (multi-planar & bi/unilateral), passing (progressing distance), crossing (static and running), shooting scenarios, one vs one scenarios) Pain free T-Test (+) (100% self-reported intensity) Pain free 30m (x10) sprinting (+) (100% self-reported intensity) Pain free Illinois agility test (+) (100% self-reported intensity) Pain free spider test (with / without ball) (+) (100% self-reported intensity) *Assessment Method/Tools/Tests Used* VAS (0-10) **Range of Motion (ROM)** Full passive ROM *Assessment Method/Tools/Tests Used* Passive adductor stretch (instructor led) **Satisfactory Clinical Exam** *Strength Tests* **Isometric** Maximal isometric adduction strength in outer range *Assessment Method/Tools/Tests Used* HHD **Predetermined Benchmark** Resisted hip adduction (1x 10reps) (elastic band) Copenhagen adduction exercise (10 reps) *Assessment Method/Tools/Tests Used* Elastic resistance bands Copenhagen adductor squeeze test

									Functional/Performance Based Criteria **High Speed Running / Sprinting** 30m (10x) Sprinting (100% self-reported intensity) *Assessment Method/Tools/Tests Used* Patient determined running speeds **Agility** T-Test (100% self-reported intensity) Illinois agility test (100% self-reported intensity) Spider test (100% self-reported intensity) (including ball) *Assessment Method/Tools/Tests Used* T-Test Illinois agility test Spider test Patient determined running speeds **Completion of a Specific Programme** Sport specific functional testing/drills **Non-Specific Performance-Based Criteria** Resume full team training **Post RTP follow up:** Not stated

Ayuob et al.,	2020	United Kingdom	Prospective case series	IV	The primary objective of this study was to assess the effect of operative repair of acute musculotendinous junction injuries of the long head of the biceps femoris (MTJ-BFlh). Secondary objectives were to assess the effect of surgical intervention on return to sporting function, patient satisfaction, hamstring muscle strength, straight-leg raise, functional performance, and complications	**Sport:** Multi-sport, including Rugby and Football **Level:** Mixed, Professional (*n*=51) Recreational (*n*=13) **Total Sample:** *n*=64 Injuries: *n*=64 Injuries involving rugby players (*n*=29) and football players (*n*=14) **Sex:** Male (42) Female (22) **Age: Mean (SD)** 26.6 (3.9) Male: 25.7 (3.8) Female: 28.4 (3.4)	**Muscle Group:** Hamstring **Specific Muscle(s) Involved:** Biceps Femoris (long head) **Diagnosis Approach:** Clinical Symptoms and Assessment Tests: (i) Clinically assessed loss of strength and/or flexibility of the hamstring muscle group Imaging Performed: Yes Imaging Technique: MRI **Injury Grading:** **(Only G3 and G4 injuries considered)** 36 Grade 3 Injuries 28 Grade 4 Injuries **Time to RTP (SD):** 13.4 weeks (5.1) **Injury Recurrences:** 3	**Treatment Approach**: Surgical **Domain(s) of Rehabilitation:** Physical Domain (i) Clinical (ii) Functional **Stage(s) of Recovery:** RTP **RTS decision-making guidelines:** 1. Completion of a 4-stage rehabilitation programme: 2 Pain-free full range of motion during passive straight leg raise 3. Isometric strength is ≥ 90% of the uninjured limb 4. Asymptomatic completion of sport specific training with no concerns reported by athlete **Decision-making approach:** Not stated	**Criteria Informing RTP:** *Clinical Examination / Evaluation* **Pain** Pain-free full range of motion (+) Pain-free full weightbearing (to begin condition rehab phase) *Assessment Method/Tools/Tests Used* Pain – Patient feedback **Range of Motion (ROM)** Max range of motion – PSLR (compared against uninjured leg – flexibility deficit calculated) *Assessment Method/Tools/Tests Used* Goniometer *Strength Tests* **Isometric** (compared to uninjured leg) 3 Reps - Max resisted knee flexion force at 0 15 45 90 (mean force calculated) ≤10% strength asymmetry in mean knee flexion force between legs *Assessment Method/Tools/Tests Used* IKD Patient Report **Patient-Reported Outcome Measures** Lower Extremity Functional Scale Marx activity rating score *Assessment Method/Tools/Tests Used* Lower Extremity Functional Scale (LEFS) Marx activity rating score (MARS)

									Subjective Statements Patient satisfaction (1-5 scale) - recorded using the Musculoskeletal Outcomes Data Evaluation and Management System *Assessment Method/Tools/Tests Used* VAS (1-5) *Functional/Performance Based Criteria* **Completion of a Specific Programme** Sport Specific Functional Field Testing **Post RTP follow up:** *Follow Up Period* 29.2 months (Range 24 – 37.1) Outcome measures recorded 3months and 1 year were collected during clinical consultation and outcomes at 2 years follow up were collated by telephone interview. *Clinical Examination / Evaluation* **Range of Motion (ROM)** Max Range of motion – PSLR (compared to contralateral limb) *Assessment Method/Tools/Tests Used* Goniometer *Strength Tests* **Isometric** (compared to uninjured leg) Maximal resisted knee flexion force at 0 15 45 90 (Mean force calculated) *Assessment Method/Tools/Tests Used* IKD

									Patient Report (collected at 3 months, 1 and 2 years) **Patient-Reported Outcome Measures** Lower Extremity Functional Scale Marx activity rating score *Assessment Method/Tools/Tests Used* Lower Extremity Functional Scale (LEFS) Marx activity rating score (MARS) **Subjective Statements** Patient satisfaction (1-5 scale) - recorded using the Musculoskeletal Outcomes Data Evaluation and Management System *Assessment Method/Tools/Tests Used* VAS (1-5)

Biglands et al ,	2020	United Kingdom	Prospective cohort study	IV	To assess the ability of quantitative T2 and diffusion tensor imaging (DTI) parameters to detect muscle changes following acute muscle tear and to assess the correlation between these parameters and return to play times.	**Sport:** Football and Rugby **Level:** Professional **Total Sample:** *n*=13 Injuries: *n*=13 **Sex:** Male **Age: Mean** 25 (Range 19-34)	**Muscle Group:** Hamstring (*n*=10) Calf (*n*=3) **Specific Muscle(s) Involved:** Biceps Femoris (*n*=8) Semitendinosus (*n*=2) Soleus (*n*=2) Gastrocnemius (*n*=1) **Diagnosis Approach:** Clinical Symptoms and Assessment Tests: (i) History of pain in a muscle group commencing during sporting activity (ii) Pain on walking 24 h after injury (iii) Presence and localised pain on palpation (iv) Reduced muscle power and range of movement on specific muscle testing Imaging Performed: Yes Imaging Technique: MRI **Injury Grading:** BAMIC 11 Grade 1-3 Injuries 2 Grade 4 Injuries Modified Peetrons 11 Grade 1-2 Injuries 2 Grade 3 Injuries **Time to RTP (Range):** 31 (17-56) **Injury Recurrences:** 0	**Treatment Approach**: Non-surgical **Domain(s) of Rehabilitation:** Physical Domain (i) Clinical **Stage(s) of Recovery:** RTP **RTS decision-making guidelines:** 1. Asymptomatic completion of a rehabilitation programme 2. Subjective clinical assessment by sports medicine team **Decision-making approach:** Shared	**Criteria Informing RTP:** *Clinical Examination / Evaluation* **Pain** Pain free completion of rehabilitation programme *Assessment Method/Tools/Tests Used* Pain – Patient feedback **Satisfactory Clinical Exam** **Post RTP follow up:** *Follow Up Period* 1 year follow up period in which re-injuries were reported *Imaging* MRI (performed within 7 days of RTP) To assess tissue changes and the effect of shrinkage in muscle tear size. Regions of interest included tear site, haematoma and oedema Measurements Recorded: Quantitative T2 weighted images Diffusion tensor imaging parameters - Mean diffusivity - Fractional anisotropy - Eigenvalues ($\lambda1$, $\lambda2$, and $\lambda3$)

Kayani et al ,	2020	United Kingdom	Prospective case series	IV	The primary objective of this study was to assess the effect of surgical repair of acute injuries to the distal musculotendinous T junction of the biceps femoris on injury recurrence. The secondary objectives were to assess the effect of surgical repair of acute injuries to the distal musculotendinous T junction of the biceps femoris in terms of time to return to preinjury level of sporting function, patient satisfaction, hamstring muscle strength, straight leg raise, functional performance, and complications.	**Sport:** Multi-Sport, including Rugby and Football **Level:** Professional **Total Sample:** *n*=34 Injuries: *n*=34 Injuries involving rugby players (*n*=19) and football players (*n*=12) **Sex:** Male (31) Female (3) **Age: Mean (SD)** 26.4 (3.1) Male: 26.3 (3.1) Female 27.3 (4.0)	**Muscle Group:** Hamstring **Specific Muscle(s) Involved:** Biceps Femoris **Diagnosis Approach:** Clinical Symptoms and Assessment Tests: (i) Clinically assessed loss of strength and/or flexibility of the hamstring muscle group Imaging Performed: Yes Imaging Technique: MRI **Injury Grading:** **(Only G3 and G4 injuries considered)** 21 Grade 3b Injuries 13 Grade 3c Injuries **Time to RTP (SD):** 11.7 weeks (3.6) **Injury Recurrences:** 0	**Treatment Approach**: Surgical **Domain(s) of Rehabilitation:** Physical Domain (i) Clinical (ii) Functional **Stage(s) of Recovery:** RTP **RTS decision-making guidelines:** 1. Completion of a 4-stage rehabilitation programme: 2 Pain-free full range of motion during passive straight leg raise 3. Isometric strength is $\geq$ 90% of the uninjured limb 4. Asymptomatic completion of sport specific training with no concerns reported by athlete **Decision-making approach:** Not stated	**Criteria Informing RTP:** *Clinical Examination / Evaluation* **Pain** Pain-free full range of motion (+) Pain-free full weightbearing (to begin condition rehab phase) *Assessment Method/Tools/Tests Used* Pain – Patient feedback **Range of Motion (ROM)** Full range of motion – PSLR (Compared against uninjured leg – flexibility deficit calculated) *Assessment Method/Tools/Tests Used* Goniometer *Strength Tests* **Isometric** (compared to uninjured leg) 3 Reps - Max resisted knee flexion force at 0 15 45 90 (mean force calculated) $\leq$10% strength asymmetry in mean knee flexion force between legs *Assessment Method/Tools/Tests Used* IKD Patient Report **Patient-Reported Outcome Measures** Lower Extremity Functional Scale Marx activity rating score *Assessment Method/Tools/Tests Used* Lower Extremity Functional Scale (LEFS) Marx activity rating score (MARS)

									Subjective Statements Patient satisfaction (1-5 scale) - recorded using the Musculoskeletal Outcomes Data Evaluation and Management System *Assessment Method/Tools/Tests Used* VAS (1-5) *Functional/Performance Based Criteria* **Completion of a Specific Programme** Sport Specific Functional Field Testing **Post RTP follow up:** *Follow Up Period* 28.4 months (Range 24 – 36.3) Outcome measures recorded 3months and 1 year were collected during clinical consultation and outcomes at 2 years follow up were collated by telephone interview. *Clinical Examination / Evaluation* **Range of Motion (ROM)** Max Range of motion – PSLR (compared to contralateral leg) *Assessment Method/Tools/Tests Used* Goniometer *Strength Tests* **Isometric** (compared to uninjured leg) Maximal resisted knee flexion force at 0 15 45 90 (Mean force calculated) *Assessment Method/Tools/Tests Used* IKD Patient Report (collected at 3 months, 1 and 2 years)

									Patient-Reported Outcome Measures Lower Extremity Functional Scale Marx activity rating score *Assessment Method/Tools/Tests Used* Lower Extremity Functional Scale (LEFS) Marx activity rating score (MARS) **Subjective Statements** Patient satisfaction (1-5 scale) - recorded using the Musculoskeletal Outcomes Data Evaluation and Management System *Assessment Method/Tools/Tests Used* VAS (1-5)

Portillo et al ,	2020	Spain	Prospective cohort study	III	To determine the effects of muscular injury on the technical and physical performance of professional soccer players when they return to league competition	**Sport:** Football **Level:** Professional **Total Sample:** 76 **Sex:** Male **Age: Mean (SD)** 27.5 (6.0)	**Muscle Group:** Lower limb muscle injuries **Specific Muscle(s) Involved:** Not stated **Diagnosis Approach:** Clinical Symptoms and Assessment Tests: Not stated Imaging Performed: Not stated **Injury Grading:** Not stated **Time to RTP (SD):** 24.9 (10.7) **Injury Recurrences:** Not stated	**Treatment Approach**: Not stated **Domain(s) of Rehabilitation:** Physical Domain (i) Functional **Stage(s) of Recovery:** Return to Performance **RTS decision-making guidelines:** Not stated **Decision-making approach:** Not stated	**Post RTP follow up:** *Follow Up Period* 3 competitive matches post return to play clearance Technical and physical performance data from three matches prior to muscle injury and three matches subsequent to returning to play were recorded and an analysis of the mean of the three matches was performed for each variable recorded. *Functional/Performance Based Criteria* **Non-Specific Performance-Based Criteria** Technical performance indicators (Normalised by number of minutes played by the player) **Metrics (representative of full match)** - Total passes made by player during the match - Number of successfully completed passes - Number of possession gains (won possession for team) - Number of possession losses (lost possession for team) *Training Load* **External Load Monitoring** Multi-camera computerised tracking system - (match data) **Metrics (recorded for each half & collated for full match)** Relative total distance (m.min) Number of sprints (>21 km/h) Maximum running speed Relative sprint distance (m.min covered > 21 km/h) *Assessment Method/Tools/Tests Used* TRACAB

Vermeulen et al.,	2020	Holland / Qatar	Prospective case series	IV	To examine the intramuscular tendon's MRI appearance at RTP after an intramuscular tendon hamstring injury. The primary aim was to describe MRI characteristics at RTP of hamstring intramuscular tendon injuries in athletes. The secondary aims were to describe the healing of the intramuscular tendon from baseline to RTP and compare intramuscular tendon injury characteristics on MRI at RTP of participants with and without a reinjury.	**Sport:** Multi Sport including Football **Level:** Mixed Professional (*n*=17) Competitive (*n*=15) Recreational (*n*=9) **Total Sample:** *n*=41 Injuries: *n*=41 Injuries involving Footballers (*n*=31) **Sex:** Male **Age: Median** 27 (IQR 22-31)	**Muscle Group:** Hamstring **Specific Muscle(s) Involved:** <u>Single muscle injuries:</u> Biceps femoris (n=23) Semimembranosus (n=8) <u>Injuries involving 2 or more muscles:</u> Biceps femoris + Semitendinosus (n=10) **Diagnosis Approach:** Clinical Symptoms and Assessment Tests: Not stated Imaging Performed: Yes Imaging Technique: MRI **Injury Grading:** Not stated **Time to RTP (Median) (IQR):** 31 (IQR 22-42) **Injury Recurrences:** 8	**Treatment Approach**: Non-surgical / PRP Dutch Cohort: Group 1: 2x 3 mL Platelet-rich plasma Group 2: 2x 3 mL normal saline Qatar Cohort: Group 1: 3 mL Platelet-rich plasma Group 2: 3 mL Platelet-poor plasma Group 3: No injection **Domain(s) of Rehabilitation:** Physical Domain (i) Clinical (ii) Functional **Stage(s) of Recovery:** Return to Participation RTP **RTS decision-making guidelines:** **Dutch Cohort** 1. Asymptomatic completion of rehabilitation programme: Standardised physiotherapy programme + Sport-specific functional field testing **Qatar Cohort** 1. Asymptomatic completion of 4-stage rehabilitation programme: Standardised physiotherapy programme + Sport-specific functional field testing **Decision-making approach:**	<u>**Dutch Cohort**</u> **Criteria Informing Rehabilitation Progression:** <u>*Clinical Examination / Evaluation*</u> **Pain** Demonstrate normal walking stride/gait without pain Pain free high knee march Very low speed running without pain (+) Pain free sub-maximal isometric contraction (+) Pain free full strength isometric contraction (+) Pain free forward / backward running (50% max speed) (+) <u>*Assessment Method/Tools/Tests Used*</u> Pain – Patient feedback <u>*Strength Tests*</u> **Isometric** Submaximal (50-70% resistance) manual strength test in prone knee flexion (90 knee flexion) <u>*Assessment Method/Tools/Tests Used*</u> Manual assessment of strength Full strength (5/5) during 1 rep maximal effort manual strength test in prone knee flexion (90 knee flexion) <u>*Assessment Method/Tools/Tests Used*</u> Manual assessment of strength <u>*Functional/Performance Based Criteria*</u> **Low / Moderate Speed Running (Activity)** Perform very low speed running Forward + backward running at 50% max speed <u>*Assessment Method/Tools/Tests Used*</u> Not stated **Completion of a Specific Programme** Progressive agility and trunk stability programme

								Dutch Cohort: Not stated Qatar Cohort: Isolated Stakeholder: Sports Physician	**Criteria Informing RTP:** *Clinical Examination / Evaluation* **Pain** Pain free full range of motion (+) Pain free full-speed running (+) Pain free sport specific movements/actions Full strength without pain (+) *Assessment Method/Tools/Tests Used* Pain – Patient feedback **Range of Motion (ROM)** Full range of motion *Assessment Method/Tools/Tests Used* Not stated *Strength Tests* **Isometric** Manual strength testing - 4 consecutive max effort reps in prone knee flexion (90 and 15 flexion) *Assessment Method/Tools/Tests Used* Manual assessment of strength **Isokinetic** <5% bilateral deficit in H:Q ratio – (eccentric hamstrings 30 /s / concentric quadriceps 240 /s) *Assessment Method/Tools/Tests Used* IKD Bilateral symmetry in knee flexion angle of peak concentric knee flexion torque at 60 /s *Assessment Method/Tools/Tests Used* IKD

									Functional/Performance Based Criteria **High Speed Running / Sprinting** Achieve full speed sprinting *Assessment Method/Tools/Tests Used* Not stated **Non-Specific Performance-Based Criteria** Unhindered functional sports-specific testing *Assessment Method/Tools/Tests Used* Not stated **Post RTP follow up:** *Follow Up Period* 12 month periodic follow up - whereby re-injury occurrences were registered *Imaging* MRI (performed within 7 days of RTP) To assess intramuscular tendon healing and change in MRI characteristics from baseline Measurements: Most involved muscle (i.e., muscle with most oedema) Extent of discontinuity (if at all) (> 0 – 100 % of tendon CSA) Disruption length of partial tendon thickness discontinuity (mm) Retraction length of complete tendon thickness discontinuity Presence / absence of tendon waviness Presence / absence of tendon thickening **Qatar Cohort** **Criteria Informing Rehabilitation Progression:** *Clinical Examination / Evaluation* **Pain** Pain free single leg squat Pain free bike @ 150W for 5mins Pain free sport specific functional field testing

									(e g , direction change drills, jumping drills, pass/run, passing/crossing progressions) Pain free high-speed changes of direction (+) *Assessment Method/Tools/Tests Used* VAS (0-10) **Range of Motion** Full knee extension (supine) Hamstrings ≥75% uninvolved side SLR ≥75% uninvolved side *Assessment Method/Tools/Tests Used* Not stated *Functional/Performance Based Criteria* **High Speed Running / Sprinting** Run ≥70% running speed (30m) (Progressed from 25% - 70% max speed) Achieve 100% running speed (30m) (Progressed from 70% to 100% max speed) *Assessment Method/Tools/Tests Used* Patient rated/determined running speeds **Agility** High speed changes of direction (Progress from 70% - 100% max speed) *Assessment Method/Tools/Tests Used* Modified T-test Patient rated/determined running speeds **Completion of a Specific Programme** Progressive Running Programme 3-Stage Standardised Physiotherapy Programme (e g , ROM, progressive strengthening, core stability and agility exercises) **Criteria Informing RTP:** *Clinical Examination / Evaluation* **Pain** Pain free completion of sport specific rehab

									(e.g., shooting, 1v1 and scoring scenarios) *<u>Assessment Method/Tools/Tests Used</u>* VAS (0-10) **Satisfactory Clinical Exam** *<u>Strength Tests</u>* **Isokinetic** (Performed on injured + uninjured leg) Concentric Quadriceps & Hamstring Strength 5 reps - 60 /s concentric knee flexion / extension 10 reps - 300 /s concentric knee flexion / extension Eccentric / Concentric Hamstring Strength 5 reps - 60 /s eccentric knee extension and 180 /s concentric knee flexion *<u>Assessment Method/Tools/Tests Used</u>* IKD *<u>Functional/Performance Based Criteria</u>* **Completion of a Specific Programme** Sport Specific Functional Field Testing (Without limitation and/or symptoms) **Non-Specific Performance-Based Criteria** Complete at least 5 days of full training before being cleared to for partial match play (Advised only) **Post RTP follow up:** *<u>Follow Up Period</u>* 12 month periodic follow up - whereby re-injury occurrences were registered *<u>Imaging</u>* MRI (performed within 7 days of RTP) To assess intramuscular tendon healing and change in MRI characteristics from baseline Measurements: Most involved muscle (i.e., muscle with most oedema) Extent of discontinuity (if at all) (> 0 – 100 % of tendon CSA)

									Disruption length of partial tendon thickness discontinuity (mm) Retraction length of complete tendon thickness discontinuity Presence / absence of tendon waviness Presence / absence of tendon thickening

Serner et al.,	2020	Qatar	Prospective case series	IV	To investigate the association between specific clinical measures and the rehabilitation progress of athletes with acute adductor injuries who were completion a criteria-based rehabilitation protocol	**Sport:** Multi-sport Including Football **Level:** Professional **Total Sample:** *n*=61 Injuries: *n*=61 Injuries involving footballers (*n*=35) **Sex:** Male **Age: Mean (SD)** 25.7 (4.3) (Range 18-37)	**Muscle Group:** Adductors **Specific Muscle(s) Involved:** Not stated **Diagnosis Approach:** Clinical Symptoms and Assessment Tests: (i) Complete modified Copenhagen Hip and Groin Outcome Score Questionnaire (ii) Presence and localised pain on palpation (iii) Clinical pain provocation resistance tests: Squeeze 45 hip flexion Squeeze 0 hip flexion Outer-range adduction (iv) Clinical pain provocation stretch tests: Passive adductor stretch FABER test (v) Range of motion tests Bent knee fall out test Side-lying hip abduction (vi) Strength tests Eccentric hip abduction (Side-lying) Eccentric hip adduction (Side-lying)	**Treatment Approach**: Non-surgical **Domain(s) of Rehabilitation:** Physical Domain (i) Clinical (ii) Functional **Stage(s) of Recovery:** Return to Participation RTP **RTS decision-making guidelines:** 1. Pain controlled completion of 4-stage groin rehabilitation programme: 2 Pain controlled completion of 4-stage running rehabilitation programme 3. Pain free on clinical examination 4. Completion of on-pitch controlled sport training 5. Resumption of full team training **Decision-making approach:** Not stated	**Criteria Informing Rehabilitation Progression:** *Clinical Examination / Evaluation* **Pain** Minimal pain during rest (VAS ≤ 2/10) Minimal pain during waking (VAS ≤ 2/10) Minimal pain during standing maximal abduction activation without resistance (VAS ≤ 2/10) No resting pain following early resistance exercise (DOMS accepted) (+) Resisted hip adduction within (VAS ≤ 2/10) (+) Full range of motion within (VAS ≤ 2/10) (+) Pain free running movements (+) (30% self-reported intensity) Pain free continuous running 15mins (+) (60% self-reported intensity) Pain free side stepping (+) (60% self-reported intensity) Pain free zig zag running (+) (60% self-reported intensity) Pain free 30m (10x) sprinting (+) (80% self-reported intensity) Pain free T-Test (+) (80% self-reported intensity) *Assessment Method/Tools/Tests Used* VAS (0-10) **Range of Motion (ROM)** Full range of motion high velocity active dynamic stretching / ballistic stretching *Assessment Method/Tools/Tests Used* Not stated *Strength Tests* **Predetermined Benchmark** Resisted hip adduction (1x 20reps) (elastic band)

							Eccentric hip adduction – outer range (supine) **Imaging Performed**: Yes Imaging Technique: MRI **Injury Grading:** 48 Grade 0-2 Injuries (grouped) 13 Grade 3 Injuries **Time to RTP (Median):** Clinically Pain-Free All Injuries: 15 (IQR, 12-29) (Range 6-166) Grade 0-2 Injuries: 13 (IQR, 11-21) (Range 6-44) (grouped) Grade 3 Injuries: 55 (IQR, 31-75) (Range 27-166) Completion of controlled sports training All Injuries: 24 (IQR, 16-34) (Range 9-212) Grade 0-2 Injuries: 17 (IQR, 15-27) (Range 9-64) (grouped) Grade 3 Injuries: 68 (IQR, 32-84) (Range 32-212) **Injury Recurrences:** Not stated		Resisted hip adduction (1x 15reps) (elastic band) *Assessment Method/Tools/Tests Used* Elastic resistance bands *Functional/Performance Based Criteria* **Low / Moderate Speed Running (Activity)** Pain free running movements (30% self-reported intensity) Continuous running (60% self-reported intensity) *Assessment Method/Tools/Tests Used* Patient determined running speeds **High Speed Running / Sprinting** 30m (10x) Sprinting (80% self-reported intensity) *Assessment Method/Tools/Tests Used* Patient determined running speeds **Agility** Zigzag / side-step run variations (60% self-reported intensity) T-Test (80% self-reported intensity) *Assessment Method/Tools/Tests Used* Zigzag / side-step drill T-Test Patient determined running speeds **Completion of a Specific Programme** Groin exercise Rehabilitation programme Progressive running programme **Criteria Informing RTP:** *Clinical Examination / Evaluation* **Pain** Pain free palpation Pain free maximal isometric adduction in outer range (+) Pain free maximal passive adductor stretch (+) Pain free resisted hip adduction (elastic band, 10reps) (+) Pain free Copenhagen adduction exercise (10reps) (+)

									Pain free sport specific drills (+) (e g , pre-planned & reactive COD drills with/without ball, jumps (multi-planar & bi/unilateral), passing (progressing distance), crossing and shooting, one vs one scenarios) Pain free T-Test (+) (100% self-reported intensity) Pain free 30m (x10) sprinting (+) (100% self-reported intensity) Pain free Illinois agility test (+) (100% self-reported intensity) Pain free spider test (with / without ball) (+) (100% self-reported intensity) *Assessment Method/Tools/Tests Used* VAS (0-10) **Range of Motion (ROM)** Full passive ROM *Assessment Method/Tools/Tests Used* Passive adductor stretch (instructor led) **Satisfactory Clinical Exam** *Strength Tests* **Isometric** Maximal isometric adduction strength in outer range *Assessment Method/Tools/Tests Used* HHD **Predetermined Benchmark** Resisted hip adduction (1x 10reps) (elastic band) Copenhagen adduction exercise (10 reps) *Assessment Method/Tools/Tests Used* Elastic resistance bands Copenhagen adductor test

									Functional/Performance Based Criteria **High Speed Running / Sprinting** 30m (10x) Sprinting (100% self-reported intensity) *Assessment Method/Tools/Tests Used* Patient determined running speeds **Agility** T-Test (100% self-reported intensity) Illinois agility test (100% self-reported intensity) Spider test (100% self-reported intensity) (including ball) *Assessment Method/Tools/Tests Used* T-test Illinois agility test Spider test Patient determined running speeds **Completion of a Specific Programme** Sport specific functional testing/drills **Non-Specific Performance-Based Criteria** Resume full team training **Post RTP follow up:** *Follow Up Period* Periodic follow up via telephone calls at 2,6 and 12 months wherein players reported suspected re-injury

Green et al.,	2020	Australia	Case control study	IV	To (1) describe the MRI findings (including index vs recurrent injuries) and functional progression after calf muscle strain injuries occurring at various locations and (2) determine if clinical and MRI data concerning index calf muscle strain injuries are associated with time to RTP and recurrence	**Sport:** Australian Football League **Level:** Professional **Total Sample:** *n*=149 Injuries: *n*=149 (114 index / 35 recurrent) **Sex:** Male **Age: Median** 25 (Range 18-33)	**Muscle Group:** Calf **Specific Muscle(s) Involved:** Not including calf muscle re-injuries Single muscle Injuries: Soleus (n=126) Gastrocnemius (n=17) Tibialis posterior (n=3) Peroneus longus (n=1) Plantaris (n=1) Injuries involving 2 or more muscles: Soleus (n=7) Gastrocnemius (n=29) Tibialis posterior (n=4) Peroneus longus (n=9) Popliteus (n=1) **Diagnosis Approach:** Clinical Symptoms and Assessment Tests: Not stated **Imaging Performed**: Yes Imaging Technique: MRI **Injury Grading:** Not stated **Time to Achieve Pain-Free Walking** **Soleus Injuries (anatomical location)** Central intramuscular aponeurosis - Present 6(4.5) (Range 1-14) - Absent 4.2(2.5) (Range 1-10) Lateral intramuscular aponeurosis - Present 4.3(3.4) (Range 0-16) - Absent 3.1(2.9) (Range 0-9)	**Treatment Approach**: Non-surgical **Domain(s) of Rehabilitation:** Physical Domain (i) Clinical (ii) Functional **Stage(s) of Recovery:** Return to Participation RTP **RTS decision-making guidelines:** Not stated Authors evaluated the time (days) to achieve 4 recovery milestones 1. Time to walk pain free 2. Time to run at >90% max speed 3. Time to return to full training 4. Time to return to competition **Decision-making approach:** Not stated	**Criteria Informing Rehabilitation Progression:** *Clinical Examination / Evaluation* **Pain** Pain free walking (number of days taken to achieve) *Assessment Method/Tools/Tests Used* Pain - Patient feedback *Functional/Performance Based Criteria* **High Speed Running / Sprinting** Running at >90% max speed (number of days taken to achieve) *Assessment Method/Tools/Tests Used* Not stated **Criteria Informing RTP:** **Non-Specific Performance-Based Criteria** Resume full team training (number of days taken to achieve) **Post RTP follow up:** *Follow Up Period* Follow up was performed up to 2 seasons after the date of the index injury to register re-injuries

							Medial intramuscular aponeurosis - Present 4.2(1.9) (Range 1-7) - Absent 3.4(2.3) (Range 0-8) Posterior intermuscular aponeurosis - Present 3.6(2.9) (Range 0-9) - Absent 1.8(2.0) (Range 0-4) **Gastrocnemius Injuries** **(Anatomical location)** Anterior aponeurosis (medial-gastroc) - Present 6.2(6.8) (Range 0-16) - Absent 2.0(1.0) (Range 1-3) Anterior aponeurosis (lateral-gastroc) - Present 3.7(3.5) (Range 0-7) - Absent 4.5(4.0) (Range 1-10) **Time to Run at >90% of Max Speed** **Soleus Injuries (anatomical location)** Central intramuscular aponeurosis - Present 24.4(12.9) (Range 10-40) - Absent 16(8.9) (Range 6-38) Lateral intramuscular aponeurosis - Present 26.7(16.2) (Range 7-63) - Absent 11.3(5.1) (Range 2-25) Medial intramuscular aponeurosis - Present 19.6(7.7) (Range 5-28) - Absent 15.4(8.5) (Range 7-38) Posterior intermuscular aponeurosis - Present 18.9(10.3) (Range 6-38) - Absent 10.8(4.1) (Range 5-16) **Gastrocnemius Injuries**		

							(Anatomical location) Anterior aponeurosis (medial-gastroc) - Present 18.8(15.8) (Range 5-44) - Absent 7.7(7.4) (Range 2-16) Anterior aponeurosis (lateral-gastroc) - Present 17.3(11.0) (Range 14-28) - Absent 12.51(6.4) (Range 6-18) **Time to Training (SD):** **Soleus Injuries (anatomical location)** Central intramuscular aponeurosis - Present 26.3(11.9) (Range 12-45) - Absent 18.5(11.6) (Range 6-49) Lateral intramuscular aponeurosis - Present 28.8(13.0) (Range 10-56) - Absent 11.8(5.1) (Range 2-25) Medial intramuscular aponeurosis - Present 24.2(11.9) (Range 5-49) - Absent 15.3(7.8) (Range 7-35) Posterior intermuscular aponeurosis - Present 20.3(11.9) (Range 6-45) - Absent 11.0(4.5) (Range 7-18) **Gastrocnemius Injuries** **(Anatomical location)** Anterior aponeurosis (medial-gastroc) - Present 22.6(20.5) (Range 5-53) - Absent 9(8.2) (Range 2-18) Anterior aponeurosis (lateral-gastroc) - Present 18.7(8.1) (Range 10-30) - Absent 13.0(7.3) (Range 7-23)		

							Time to RTP (SD): **Soleus Injuries (anatomical location)** Central intramuscular aponeurosis - Present 32(13.9) (Range 15-50) - Absent 21.7(12.2) (Range 7-49) Lateral intramuscular aponeurosis - Present 35.1(16.9) (Range 13-74) - Absent 14.4(5.3) (Range 4-28) Medial intramuscular aponeurosis - Present 28.8(9.7) (Range 15-49) - Absent 19.9(9.7) (Range 10-44) Posterior intermuscular aponeurosis - Present 25(13.0) (Range 7-49) - Absent 16.6(5.6) (Range 9-23) **Gastrocnemius Injuries (Anatomical location)** Anterior aponeurosis (medial-gastroc) - Present 25.8(22.7) (Range 6-58) - Absent 11.3(10.1) (Range 2-22) Anterior aponeurosis (lateral-gastroc) - Present 19.7(9.8) (Range 14-31) - Absent 17(9.8) (Range 8-29) **Injury Recurrences:** 35		

Valera-Garrido et al ,	2020	Spain	Prospective cohort study	III	To assess the safety and feasibility of a combination of percutaneous needle electrolysis and a specific rehab and reconditioning program in professional soccer players with an acute muscle injury to the rectus femoris. A secondary aim of the study was to analyse possible reinjuries following RTP in the short, medium and long term.	**Sport:** Football **Level:** Professional **Total Sample:** *n*=13 Injuries: *n*=13 **Sex:** Male **Age: Mean (SD)** 27.9 (3.2)	**Muscle Group:** Quadriceps **Specific Muscle(s) Involved:** Rectus Femoris (*n*=13) **Diagnosis Approach:** Clinical Symptoms and Assessment Tests: Not stated Imaging Performed: Yes Imaging Technique: Ultrasound **Injury Grading:** **(Only G2 injuries considered)** 13 Grade 2 Injuries **Time to RTP (SD):** Time to Return to Training: 15.6(1.8) Time to Return to Play: 20.2(2.79) **Injury Recurrences:** 0	**Treatment Approach**: Non-surgical + Ultrasound guided percutaneous needle electrolysis **Domain(s) of Rehabilitation:** Physical Domain (i) Clinical (ii) Functional **Stage(s) of Recovery:** Return to Participation RTP Return to Performance **RTS decision-making guidelines:** 1. Asymptomatic completion of 2-stage rehabilitation programme: (Indoor and an on-field reconditioning programme) 2. Ultrasound imaging confirmed an optimal muscle repair 3. Resumption of full team training **Decision-making approach:** Not stated	**Criteria Informing Rehabilitation Progression:** *Clinical Examination / Evaluation* **Pain** No resting pain (DOMS accepted) Minor pain in ROM and Strength exercises (VAS ≤ 2/10) (+) Full pain free range of motion of lower velocity tasks (+) Pain free strength in mid/inner/outer range (VAS ≤ 2/10) Pain free absorption/landing forces (frontal/multiplanar) Perform pain-free running movements (45% max speed) Perform multidirectional movements pain-free (low/med speed) *Assessment Method/Tools/Tests Used* VAS (0-10) **Range of Motion (ROM)** Full ROM *Assessment Method/Tools/Tests Used* Not stated *Imaging* Ultrasound - Used to confirm a correct alignment of muscle fibres without evidence of oedema. *Functional/Performance Based Criteria* **Agility** Optimise rate of moment production in multiplane motion *Assessment Method/Tools/Tests Used* Not stated **Jump Test** Optimise absorption in multiplane motion (e g , multi-plane plyos) *Assessment Method/Tools/Tests Used* Not stated **Completion of a Specific Programme**

									Gym based rehabilitation programme (to optimise ROM + Strength & absorption and production of force in different planes) **Criteria Informing RTP:** *Clinical Examination / Evaluation* **Pain** Minor pain during sport specific functional field testing (VAS $\leq$ 2/10) (+) Perform kicking in the absence of pain *Imaging* Ultrasound - Used to confirm an optimal muscle repair. *Functional/Performance Based Criteria* **High Speed Running / Sprinting** Achieve 100% max speed Return to 100% acceleration and deceleration velocities *Assessment Method/Tools/Tests Used* GPS **Agility** Return to performing multidirectional and individual sport-specific drills (with/without ball) (e.g., COD drills) at speed *Assessment Method/Tools/Tests Used* Not stated **Completion of a Specific Programme** Progressive running programme + Sport Specific Functional Field Testing (with/without ball) (Optimal reconditioning to prepare player for competition demands through technical + coordination drills Drill increased in terms of complexity and demands of decision-making) **Non-Specific Performance-Based Criteria** Return to full team training *Training Load* **External Load Monitoring** GPS monitoring (Match data) - Players must achieve >70% game load

									GPS monitoring (Training data) - Players must achieve/accumulate running volume >90%, max speed, high-speed running distance and sprints number relative to full training demands **Metrics** Total distance Peak speed High-speed running distance (18.1 – 21 km/h) Very high-speed running distance (21.1 – 24 km/h) Sprint distance (>24 km/h) Explosive distance (m min) (distance covered when accel > 1 2 m sec) *Assessment Method/Tools/Tests Used* GPS **Post RTP follow up:** *Follow Up Period* Following clearance to RTP players were followed up in the short term (1 week), medium term (8 weeks) and long term (20 weeks) to assess any possibly re-injury concerns and adverse effects **External Load Monitoring** GPS monitoring – (Match data) - 1st competitive match post RTP - 2nd competitive match post RTP **Metrics** Total distance High-speed running distance (18.1 – 21 km/h) Very high-speed running distance (21.1 – 24 km/h) Sprint distance (>24 km/h) Peak speed registered Peak acceleration registered Explosive distance (m min) (distance covered when accel > 1 2 m sec) *Assessment Method/Tools/Tests Used* GPS

Whiteley et al ,	2020	Qatar	Non-randomised retrospective cohort study	IV	To document the high-speed running distance performed by individual players prior and subsequent to hamstring strain injury to assess the degree to which these players return to preinjury performance levels.	**Sport:** Football, Rugby and Australian Football **Level:** Professional **Total Sample:** *n*=15 Injuries: *n*=22 (15 index / 7 recurrent) **Sex:** Male **Age: Mean (SD)** 25.2 (4.7) (Range 18-34)	**Muscle Group:** Hamstring **Specific Muscle(s) Involved:** Not stated **Diagnosis Approach:** Clinical Symptoms and Assessment Tests: Not stated Imaging Performed: Yes Imaging Technique: MRI **Injury Grading:** Not stated **Time to RTP (SD):** Time to Return to Training: 15.6(1.8) Time to Return to Play: 20.2(2.79) **Injury Recurrences:** 7	**Treatment Approach**: Non-surgical **Domain(s) of Rehabilitation:** Physical Domain (i) Functional **Stage(s) of Recovery:** Return to Performance **RTS decision-making guidelines:** Not stated **Decision-making approach:** Shared	**Post RTP follow up:** *Follow Up Period* A minimum follow up period of 5 full competitive matches post return to play clearance was required for each player. **External Load Monitoring** GPS monitoring – (Match data) Multi-camera computerised tracking system - (match data) High-speed running distance during full match-play was evaluated pre and post injury for each player. **Metrics** High-speed running distance *Assessment Method/Tools/Tests Used* GPS / Prozone

Jimenez-Rubio et al.,	2020	Spain	Case series	IV	This case series follows the treatment protocol after a grade 2 injury to the semitendinosus muscle using US-guided Percutaneous Needle Electrolysis and a rehabilitation and reconditioning programme in two professional soccer players.	**Sport:** Football **Level:** Professional **Total Sample:** *n*=2 Injuries: *n*=2 **Sex:** Male **Age: Mean (SD)** 28 (2.8)	**Muscle Group:** Hamstring **Specific Muscle(s) Involved:** Semitendinosus **Diagnosis Approach:** Clinical Symptoms and Assessment Tests: Not stated Imaging Performed: Yes Imaging Technique: MRI / US **Injury Grading:** 2 Grade 2 Injuries **Time to RTP (SD):** Time to Return to Training: 11.5(3.5) Time to Return to Play: 15(1.4) **Injury Recurrences:** 0	**Treatment Approach**: Non-surgical + Ultrasound guided percutaneous needle electrolysis **Domain(s) of Rehabilitation:** Physical Domain (i) Clinical (ii) Functional **Stage(s) of Recovery:** Return to Participation RTP Return to Performance **RTS decision-making guidelines:** 1. Asymptomatic completion of 2-stage rehabilitation programme: (Indoor and an on-field reconditioning programme) 2. Ultrasound imaging confirmed an optimal muscle repair 3. Resumption of full team training **Decision-making approach:** Not stated	**Criteria Informing Rehabilitation Progression:** *Clinical Examination / Evaluation* **Pain** Pain free execution of gym-based rehabilitation programme exercises (+) Perform multidirectional movements pain-free (e.g., thrusts and different acceleration patterns without pain) *Assessment Method/Tools/Tests Used* Pain – Patient feedback **Range of Motion** Achieve full hip range of motion Achieve full knee range of motion *Assessment Method/Tools/Tests Used* Not stated *Imaging* Ultrasound - Used to confirm a correct alignment of muscle fibres without evidence of oedema. *Functional/Performance Based Criteria* **Completion of a Specific Programme** Gym based rehabilitation programme Progressive running programme Sport Specific Functional Field Testing: (players to pass drills of progressive complexity/intensity e g , change of direction, sprints and sport-specific drills with uncertainty and repetition of effort to be declared fit to return to team training) **Criteria Informing RTP:** *Imaging* Ultrasound - Used to confirm an optimal muscle repair. *Functional/Performance Based Criteria*

									Non-Specific Performance-Based Criteria Return to full team training **Post RTP follow up:** *Follow Up Period* 8 months follow up period wherein any re-injuries were reported *Training Load* **External Load Monitoring** GPS monitoring (Match data) - 5 competitive matches post RTP (90mins) (Compared to outputs in 2 matches pre-injury) **Metrics** Total distance Distance covered >21km/h Distance covered 14-21km/h Peak speed registered Peak acceleration registered Peak deceleration registered Explosive distance (m min) (distance covered when accel > 1 2 m sec) Work:Rest ratio (distance covered >7km/h vs <7km/h) *Assessment Method/Tools/Tests Used* GPS

Terms: RTP, Return to play; RTS, Return to sport; RTT, Return to full-team training; SD, Standard Deviation; MRI, Magnetic resonance imaging; HHD, Handheld dynamometer; MMT, manual muscle testing; VAS, visual analogue scale; IQR, Interquartile range; SLR, Straight leg raise; PRP, platelet-rich plasma; CI, Confidence Interval; ROM, Range of motion; BF, Biceps Femoris; ST, Semitendinosus; SM, Semimembranosus; L-BIA, localized bioimpedance; MHFAKE, Maximum hip flexion – active knee extension; AKE, Active knee extension; PKET, Passive knee extension; IKD, Isokinetic dynamometry; LSI, Limb symmetry index; GPS, Global Positioning System; CMJ, Counter movement jump; RPE, Rating of perceived exertion; GFR, ground force reaction; GRF, ground reaction force; DOMS, delayed onset of muscle soreness; CSA, Cross sectional area; BAMIC, British Athletics Muscle Injury Classification; MTJ, Musculotendinous junction; PSLR, Passive straight leg raise; (+), Indicates criteria is used in combination with another test/evaluation

Appendix A.6.

Study manual provided to professional football teams participating in psychological readiness to return to sport study

(Chapter Five)

Study Guide

In this file, you can find the different definitions used in the study and the detailed protocol of the study.

SECTION ONE: STUDY DEFINITIONS

Injury:

An injury is any physical damage that occurs during a training session or match and results in the player being unable to participate fully in training or match play.

Injuries that do not cause absence from football activities do not count.

Injuries that occur outside football activities do not count.

Return to full training:

The day when the player takes part to a full training session following his injury and is able to take part in all types of training.

Return to match-play:

The day when the player is selected in the players group for a game.

Re-injury:

Re-injury is defined as an injury of the same type and at the same site as an index injury that occurs after the player's return to full participation from previous injury.

Injuries such as contusions, lacerations and concussions should not be recorded as re-injuries.

SECTION TWO: PROTOCOL

Study period

The study period starts in January 2019. This month will be used as a familiarisation period to allow participating clubs/practitioners/players to become accustomed with the study protocol. Data collection for this study will commence from the 1st of February 2019 and will end on the season (May/June 2019). However, any injuries occurring in May/June 2019 which meet inclusion for this study should be followed until all data is collected for injured player(s).

In each club, a contact person should be selected to send all the data to the research group and to be in contact with the research group throughout the duration of the study.

Inclusion/exclusion criteria:

All players form the first-team squad (with a first-team contract) should be included in the study.
A player who joins the team during the season should be included from his date of joining the team.
A player who is injured at the beginning of the study period should be included in the study, but this particular injury will not be included in the injury statistics.
A player who leaves the club during the season or off-season is excluded from the date he leaves the club, but if the player goes on loan to another club and comes back before the end of the study period, he is included again as soon as he returns to the club.

All the players involved in the study should be informed about the study's aim and sign the declaration of consent (which has been sent to the contact person). Participation is voluntary; a player can withdraw from the study at any time.

Please, complete the information and declaration of consent form as following:
Name: Name of the player.

Study number of the player: A code given by the contact person to each player.

Birth date, height and weight: player's date of birth, height in centimetres and weight in kilograms.

Playing positions: Goalkeeper, Defender, Midfielder or Forward.

Signature and date: Signature of the player that means that he declares his consent to take part in the study and the date when he declares his consent.

How to complete the psychological questionnaire?

All the questionnaires should be given to the player who should be in a quiet room to complete it, without any influence from his teammates or any person of the club. Questionnaires are to be administered to a player when absence due to injury is equal to or greater than 3 weeks.

1) Confidence questionnaire

When?

This questionnaire should be given to the player on two separate occasions. It should firstly be administered the day before his return to training (last day of rehabilitation). It should then be again administered the day before his return to competition (selection in the players group for a game). This 6 items questionnaire should be given to the player only when the absence due to the injury is equal to or greater than 3 weeks

How?

This questionnaire is a 6 questions file. The player should answer to the 6 questions with the help of a 100-point scale, with intervals of 10. A score of 0 implies that the athlete has little to no confidence, a score of 50 implies moderate confidence and a score of 100 implies that the athlete has utmost confidence for that item. The file with

6 questions and the scale that should be given to the player has been sent to the contact person in each club taking part in the study.

After the athlete answers to the 6 questions, the 6 scores and the study number of the player should be reported in the file which will be sent to the research group in the week following the player's return to play.

Confidence Questionnaire

	Questions	Score
1	Overall confidence to play	Score 0-100
2	Confidence to play without pain	Score 0-100
3	Confidence to give 100% effort	Score 0-100
4	Confidence in injured body part to handle the demands of the situation	Score 0-100
5	Confidence in skill level/ability	Score 0-100
6	Confidence to not concentrate on the injury	Score 0-100

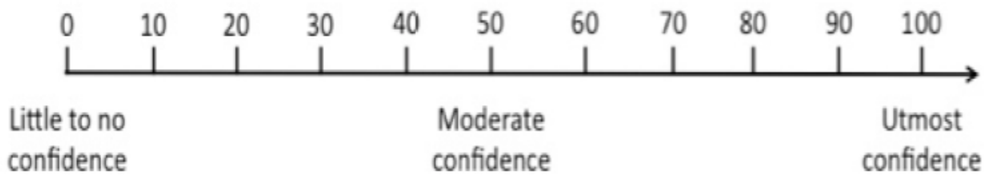


Figure 1: Confidence questionnaire

SECTION THREE: THE INJURY SHEET

Each injury where the absence due to the injury is equal to or greater than 3 weeks should be reported on an injury sheet. The injury information sheet should be filled out by the dedicated club contact and sent to the research group.

The injury sheet should be sent monthly with any associated psychological files concerning the injury of that month. If a player is injured during the month and does not return to training or match-play respectively within that month, the injury should be recorded on the file sent without the date(s) of return. Once the player returns and all or remaining psychological data associated with the injury is collected, a second injury report sheet can be added to the corresponding monthly file and sent with the date(s) of return entered.

Please note can all cases of re-injury to any player having previously met study inclusion be reported.

In instances where a re-injury does elicit a time loss of ≥ 3 weeks, simply follow the same procedure as documented above i.e. applying the questionnaires and completing the injury report sheet documenting the re-injury as directed.

In instances where a re-injury does not elicit a time loss of ≥ 3 weeks - You do not have to apply the confidence or perspective questionnaires, but could you please still complete the injury report sheet and send this to us to inform us of this occurrence.

Completing the Injury Sheet:

The first information requested are the name, the study number and the team of the injured player.

Date of injury: Enter the date the injury was sustained. If for some reason the date of injury is uncertain, enter the last date in which the player participated fully in a match or training.

Date of return to full-training: Enter the date when the player takes part to a full training with the group and without any restriction about the kind of training.

Date of return to match-play: Enter the date when the player is selected in a group to play a game (first team or reserve team).

Injured body part: Select the appropriate body part, among the following list:

- Head/face
- Neck/Cervical spine
- Shoulder/Clavicular
- Upper arm
- Elbow
- Forearm
- Wrist
- Hand/Finger/Thumb
- Sternum/ribs/Upper back
- Abdomen
- Lower back/pelvis/sacrum
- Hip/groin
- Thigh
- Knee
- Lower leg/Achilles tendon
- Ankle
- Foot/toe

Injury side: Select the injury side.

Type of injury: Choose the type of injury among the following list or specify if it is not in the list.

Here are the definitions of the different types of injury:

- Fracture and bone stress: Fracture / Other bone injuries
- Joint and ligament: Dislocation/subluxation / Sprain / Ligament injury / Lesion of meniscus or cartilage
- Muscle and tendon: Muscle rupture / Tear / Strain / Cramps / Tendon injury / Rupture / Tendinosis / Bursitis
- Contusions, lacerations and skin lesion: Haematoma / Contusion / Bruise / Abrasion / Laceration
- Central and peripheral nervous system: Concussion (With or without consciousness) / Nerve Injury
- Other: Dental injuries / Other injuries (to specify)

Training/match: indicate whether the injury was sustained during a training or a match. Select "N/A" (Not applicable) if it is not possible to assign the injury to either training or match.

Contact: indicate whether or not the injury was sustained as a result of contact with another player or object.

Re-Injury: indicate whether the injury is a re-injury or not (see definitions). Even if the index injury was sustained prior the player's inclusion in the study, the new injury should still be marked as re-injury.

SECTION FOUR: TRASFER OF COLLECTED DATA TO THE RESEARCH GROUP

The injury information sheet and consent forms should be filled out by the dedicated club contact and sent to Gordon Dunlop [redacted]. Once an injured player is back to training and competition (i.e. first selection in a group playing a game) respectively, all completed questionnaires by the player should be sent to Gordon Dunlop.

Gordon Dunlop will establish monthly correspondence with the nominated club contact to help manage the data collection/transfer process between club and research group in addition to addressing any questions/quires you may have.

<u>SECTION FIVE: WORKING EXAMPLE OF DATA COLLECTION PROCEDURE:</u>

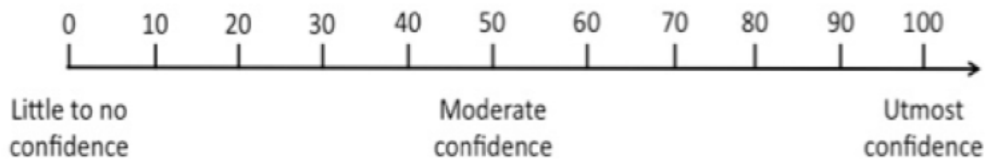
A player has suffered an injury which will result in a time loss/absence which is equal to or greater than 3 weeks and therefore meets the inclusion criteria for this study. The injury report sheet should now be filled out for the player (with proposed return dates entered if possible) and consent obtained from the player to participate in the study.

The protocol is that the day before the player returns to full training, he completes the confidence questionnaire. In this example the player is due to return to full training on the 10th of March 2018 – The confidence questionnaire should be administered on the 9th of March

Confidence Questionnaire Administered at Return to Training: The player should provide a score from 0-100 for each of following 6 Questions prior to returning to training.

Confidence Questionnaire

	Questions	Score
1	Overall confidence to play	Score 0-100
2	Confidence to play without pain	Score 0-100
3	Confidence to give 100% effort	Score 0-100
4	Confidence in injured body part to handle the demands of the situation	Score 0-100
5	Confidence in skill level/ability	Score 0-100
6	Confidence to not concentrate on the injury	Score 0-100

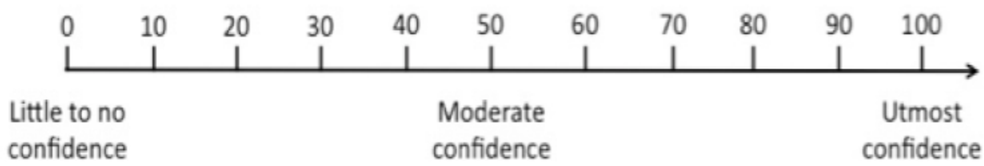


This process is then REPEATED when the player returns to his first full competitive match (i.e. selection in the match squad). In this example the player is set to return to competition on the 20th of March 2018 – The confidence questionnaire should therefore be administered on the 19th of March

Confidence Questionnaire Administered at Return to Competition: The player should provide a score from 0-100 for each of following 6 Questions prior to returning to competition.

Confidence Questionnaire

	Questions	Score
1	Overall confidence to play	Score 0-100
2	Confidence to play without pain	Score 0-100
3	Confidence to give 100% effort	Score 0-100
4	Confidence in injured body part to handle the demands of the situation	Score 0-100
5	Confidence in skill level/ability	Score 0-100
6	Confidence to not concentrate on the injury	Score 0-100



In total – For each injured player meeting study inclusion criteria (injury resulting in time loss greater or equal to 3 weeks) the information/data to be collected and forwarded to the research group is as follows:

- An injury report sheet
- A Player consent form
- A confidence questionnaire the day before returning to training.
- A confidence questionnaire the day before returning to competition.

Appendix A.7.

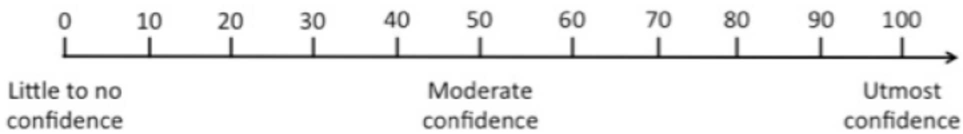
Cross-culturally adapted versions of Injury-Psychological Readiness to Return to Sport scale (I-PRRS) in all target languages

(Chapter Five)

Confidence Questionnaire (English (Original); I-PRRS)

	Questions	Score on 100
1	Overall confidence to play	
2	Confidence to play without pain	
3	Confidence to give 100% effort	
4	Confidence in injured body part to handle the demands of the situation	
5	Confidence in skill level / ability	
6	Confidence to not concentrate on the injury	

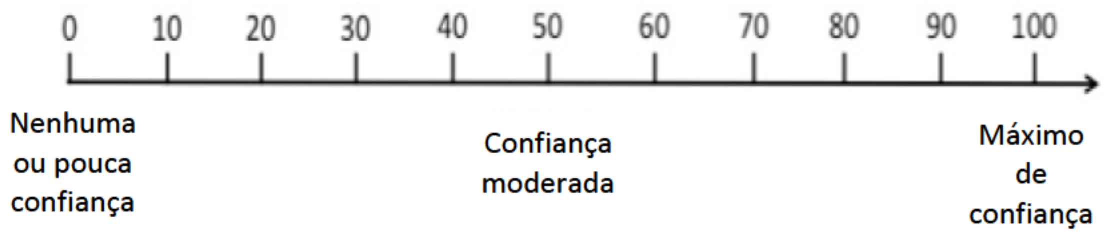
Study number of the player	



Questionário de confiança (Portuguese – Brazilian; I-PRRS)

	Questões	Pontuação 0-100
1	Confiança geral para jogar	
2	Confiança para jogar sem dor	
3	Confiança para dar 100% de esforço	
4	Confiança na região lesionada para lidar com a situação	
5	Confiança na capacidade técnica/habilidade	
6	Confiança para não se concentrar na lesão	

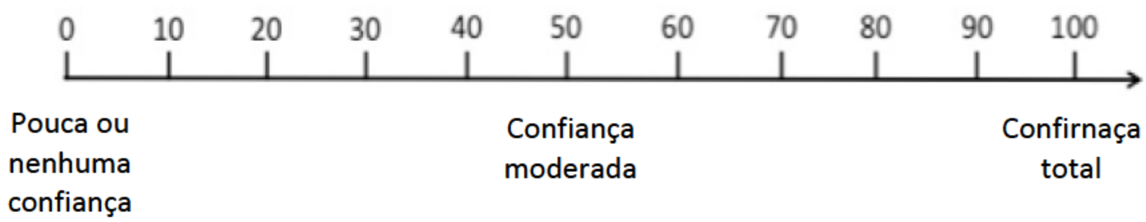
Número de estudo do jogador:	



Questionário de confiança (Portuguese; I-PRRS)

	Questões	Pontuação 0-100
1	Confiança geral para jogar	
2	Confiança para jogar sem dor	
3	Confiança para se esforçar a 100%	
4	Confiança na zona corporal lesionada para aguentar com as exigências impostas	
5	Confiança na sua capacidade/nível técnico	
6	Confiança para não se concentrar na lesão	

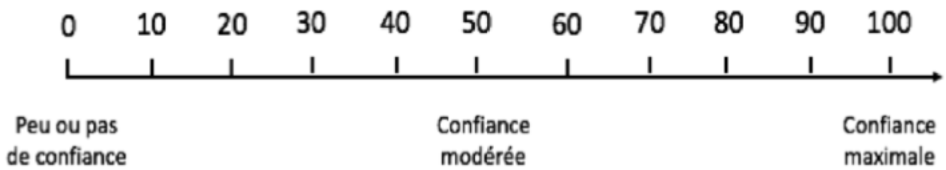
Número do jogador no estudo	



Questionnaire sur la confiance (French; I-PRRS)

	Questions	Score sur 100
1	Confiance globale pour jouer	
2	Confiance pour jouer sans douleur	
3	Confiance pour réaliser des efforts à 100%	
4	Confiance en la capacité de la partie blessée à suporter les exigences de la situation	
5	Confiance en votre niveau technique et vos habiletés	
6	Confiance en votre capacité à ne pas se concentrer sur la blessure	

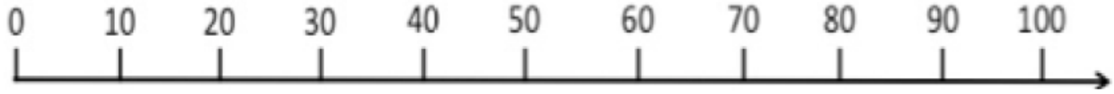
Numéro d'inclusion du joueur	



Cuestionario de confianza (Spanish; I-PRRS)

	Pregunta	Puntacion sobre 100
1	Confianza total de poder jugar	
2	Confianza de poder jugar sin dolor	
3	Confianza de poder esforzarte al 100%	
4	Confianza en que la zona lesionada responda ante las demandas del juego	
5	Confianza sobre mi nivel técnico/ habilidad	
6	Confianza de no pensar en la lesion	

Numero de identificacion del jugador	



De poca a ninguna confianza

Moderada confiaza

Mayor confianza posible

<u>Questionario Sicurezza (Italian; I-PRRS)</u>

	Domande	Punteggio su 100
1	Generale sicurezza a giocare	
2	Sicurezza nel giocare senza dolore	
3	Sicurezza a dare il 100% nello sforzo	
4	Sicurezza nella parte del corpo infortunata a sostenere le richieste	
5	Sicurezza nelle proprie competenze/ abilità	
6	Sicurezza nel non concentrarsi sull'infortunio	

Numero del giocatore nello studio