REHABILITATION AND RETURN TO SPORT AFTER HAMSTRING INJURY

BE WARY OF ANYONE WHO TELLS YOU THEY HAVE A SIMPLE AND EFFECTIVE SOLUTION FOR HAMSTRING INJURY

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INTRODUCTION

If there was a simple rehabilitation approach which "cured" all hamstring injuries and prevented their recurrence in a timely manner, then chances are, it would've been found by now. We might cheekily suggest that often in this area the strength of opinions held are nearly inversely proportional to the scientific evidence of effectiveness. We therefore enter this space cautiously, mindful that we are adding just another opinion, albeit backed with some evidence of outcomes in over 200 carefully controlled cases of hamstring injury rehabilitation[1], and perhaps as many more who weren't involved in randomised trials but formed part of our daily practice.

In our rehabilitation department at Aspetar we're lucky to be regularly visited by many practitioners from around the world covering many sports. And a recurring, almost ubiquitous question has been: "what do you use as your return to sport (RTS) criteria for hamstring injury?" The question itself seems fair enough – but we think it belies a fundamental error in the overall management of hamstring injury – specifically that there are separate "rehabilitation" and then later "RTS testing" components. If we have had any success in managing these problems, then we feel that a principal contributor to this has been the approach that the RTS process is a series of daily steps which involve "gaining the right" to progress to more challenging loading by proving competence at a lower level of loading. Viewed through this lens, it's easier to appreciate that each player will be considered individual in terms of their ultimate requirements for load tolerance. In the players we see, this is commonly repeated sprinting, kicking, and direction-change. This apparent simplicity allows for the clinical complexity of tailoring your daily rehabilitation to both the daily

Figure 1: The three elements of the return to sport (RTS) continuum. Clare L Ardern et al Br J Sports Med 2016. Recreated with permission.

examination findings – which are viewed as a response to the previous day's loading – and the abilities and requirements of the player at hand.

There are some aspects for which we have allowed theoretical considerations to enter the management: specifically, the notion that high-speed running is likely the most potent strengthening stimulus for the muscles which require rehabilitation, and that eccentric overload exercise of these same muscles confers local changes which are likely beneficial. Where high speed running is not clinically indicated, a range of relative overload exercises are suggested to be performed in lieu of running until running forms the majority of clinical loading.

WHY WE THINK ATTENTION TO RUNNING MECHANICS IS A WASTE OF CLINICAL TIME AND ATTENTION

Currently, we remain unconvinced of the usefulness of more complicated attention to individual gait analyses and therefore "biomechanical" contributors. This stems from several lines. Firstly, we are unaware of any evidence of good predictive association of any "bench" measures (e.g. posture, flexibility, strength, movement patterns) with actual overground high speed running mechanics, and we don't yet know how to measure high speed running mechanics in someone who is currently injured. Secondly, we suggest that the magnitude of any differences is likely to be small in comparison to the possibility for overload through simple changes in the volume and intensity of running which players regularly encounter as part of normal training and match variability. We are unaware of any evidence that physiotherapy interventions can meaningfully change high speed running mechanics and therefore loads. Finally, we suggest that a fundamental aspect of training principles is that individuals adapt to (over)load. Provided the changes in volume and intensity are sensible, any given individual is going to adapt to their mechanics whether they be "optimal" or not. For these reasons, other than attempting to address any obvious "limping", little if any attention is placed on an individual's running mechanics, and this aspect is left to a qualified sprint coach, if it is addressed at all.

The 2016 Consensus statement on return to sport from the First World Congress in Sports Physical Therapy, Bern has provided an evidence-based framework for clinicians to plan their management of injuries[2]. RTS is described as "...a continuum paralleled with recovery and rehabilitation – not simply a decision taken in isolation at the end of the recovery and rehabilitation process[2]". The overall RTS process should be considered as continuous, where the player returns to participation, then return to sport, and eventually, return to performance (Figure 1)[2].

In this article, we hope to present the reader with a criteria-based progression rehabilitation protocol, as well as clinical predictors used in RTS decision making.

A TYPICAL PRESENTATION AFTER A RUNNING-RELATED HAMSTRING INJURY

Let's set the scene – a 24-year-old professional football player presents to your clinic one day after he suffered a posterior thigh injury during a league game. The injury occurred without contact in the 80th minute while he was sprinting towards the ball with a slight change in direction. He was not able to continue playing and felt immediate severe localised pain in his posterior thigh when walking. Initial care was removal from the field, walking with assistance followed with ice, compression, and elevation as well as appropriate immobilisation ensuring no pain provocation was provided.

A comprehensive initial clinical examination is performed by the sports medicine physician. The typical clinical signs are identified – pain on palpation, decreased strength and flexibility, and pain with functional movements. No previous history of a hamstring injury or any other major injuries in the past five years is reported, and there were no signs of any neural involvement, or any other adverse findings from the initial examination. and the clinical examination is supplemented with a magnetic resonance imaging (MRI) scan. The MRI revealed positive signs of injury, corresponding with a Grade II biceps femoris muscle tear, located at the proximal musculotendinous junction.

> *The central tenet of the rehabilitation protocol is a requirement for set criteria (specific physical testing) to be proven prior to allowing progression to the next stage.*

SOME THINGS TO CONSIDER

The central tenet of the rehabilitation protocol is a requirement for set criteria (specific physical testing) to be proven prior to allowing progression to the next stage. Daily measurements of subjective pain, pain with palpation, range of movement or flexibility, and strength allows the clinician to adapt the protocol for the player on the particular day of treatment depending on the presentation of the individual, as well as identify the response to the previous day's treatment.

Since loading healing tissue beyond its elastic limit might result in further exacerbations, signaled by the presence of pain with this loading, we advocate that generally all exercises should be performed close to pain free limit[3]. If the exercise or movement elicits pain from the injured area, the exercise is immediately adjusted or terminated.

Arbitrarily the rehabilitation protocol consists of six stages; three "physiotherapy" stages and three "sport specific" stages. The main feature of the protocol repeated in each stage is the early, but safe resumption of repeated high-speed running, and direction change movements. The extended basic description of the daily measurements and rehabilitation protocol was released for information purposes, and is freely available online (https://t.co/TkXOehNLm).

THE CRITERIA-BASED PROGRESSION REHABILITATION PROTOCOL

We present the six stages within the rehabilitation protocol and the corresponding criteria for progression into each of the stages (Figure 2). The goals for each stage is summarised in Table 1.

Stage 1

The main aim is to promote healing and simultaneously avoid any provocative activities which might delay the RTS process. Low load exercises during the early phase of healing are used. Functional exercises aimed at retaining and even improving movement patterns are also utilised. Typically, active movements in mid and inner range (of knee- and hip flexion), specific soft tissue mobilisation, and isometric or easy concentric exercises are performed.

Table 1

STAGE 1: PROMOTE HEALING AND EARLY OPTIMAL LOADING OF THE INJURED TISSUE

1. *Protect scar tissue development*
2. *Minimise muscle atrophy and pain*

STAGE 2-3: REGAIN FULL MUSCLE FUNCTION

1. *Regain full voluntary control over the injured muscle*
2. *Regain pain-free hamstring strength, initially in inner range progressing to longer hamstring lengths*
3. *Develop appropriate control of trunk and pelvis with progressive movement speed and increasing load on the hamstrings*
4. *Pain free running up to maximal speed and with changing directions, performed under fatigue*

STAGE 4-6: INTEGRATE FULL SPORTS SPECIFIC PARTICIPATION

1. *Symptom-free during all activities*
2. *Complete 3 progressive sports specific sessions with no pain (at the time of the exercise or later) and full effort.*

Table 1: Rehabilitation goals for each stage.

CRITERIA FOR PROGRESSION TO STAGE 2

Progression to stage 2 is allowed when the player can perform a pain free single leg squat, as well as stationary bike for five minutes, maintaining power output (in Watts) of 150% of their bodyweight (in kg).

Stage 2

Exercises are performed with increased load. Importantly, the practitioner monitors the exercises to ensure they are executed appropriately.

The running progression protocol is introduced in this stage. Lengthening exercises[4] can be introduced if appropriate. If there is a worsening in the patient's strength or range of movement measurements, or an increase in pain reported, then the loading is reduced. Here the clinician needs to clinically reason what component of the previous session was the likely culprit, and modify this accordingly. In this regard we can be guided by EMG studies, the player's reported perception of the load during the exercise, and the observed performance during rehabilitation.

RUNNING PROGRESSION

The running progression programme addresses volume, intensity, and to an extent running mechanics. It is performed under supervision to ensure these components are executed well, and adjustments can be made where necessary.

Before running, the player performs an appropriate warm up routine, such as stationary cycling, slow running, or other lower limb cardio-type exercise. The player performs the sprinting technique "A" and "B" drills which emphasise the late swing, and triple extension phases of running, respectively. During these drills observations of symmetry and ranges of motion are observed, and corrections can be made as appropriate.

Importantly, when the running programme is introduced, the loading during running is progressively and carefully increased. For this reason, we ask the player to rate their perceived effort during running. This allows us to ensure that similar loads are maintained within sessions and enables careful increases in loading (running speed).

Typically, the player is presented with a line marked from 0% to 100%, explaining that a 100% run would equal a maximum effort sprint, while 0% would be the slowest possible speed that the player could run at (see Figure 3c). We perform the running

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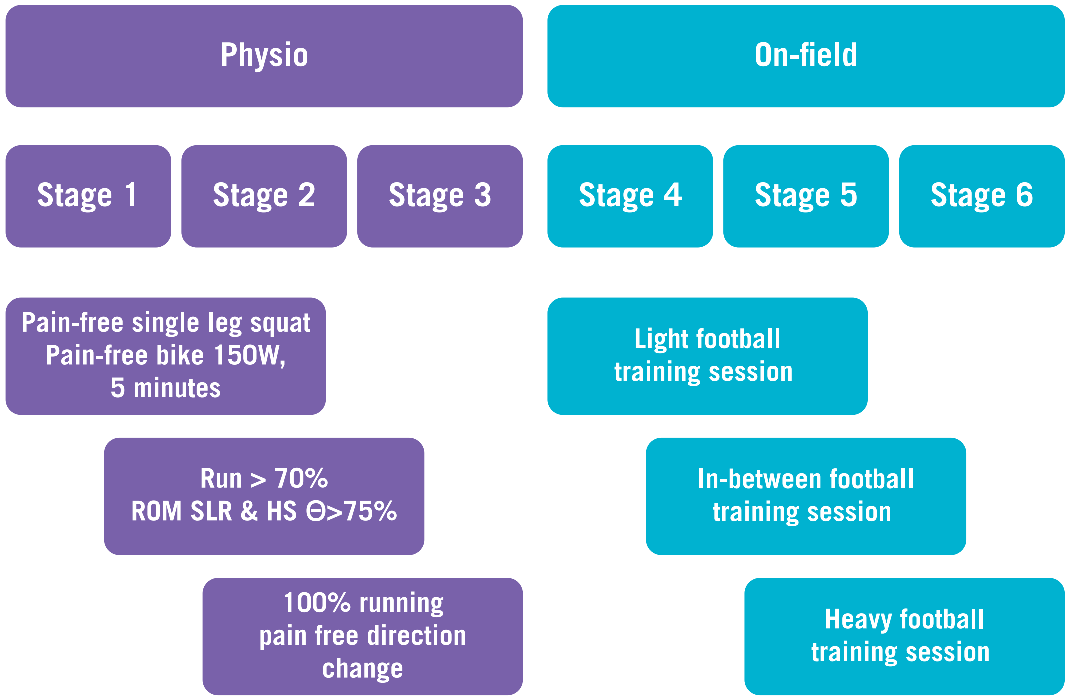
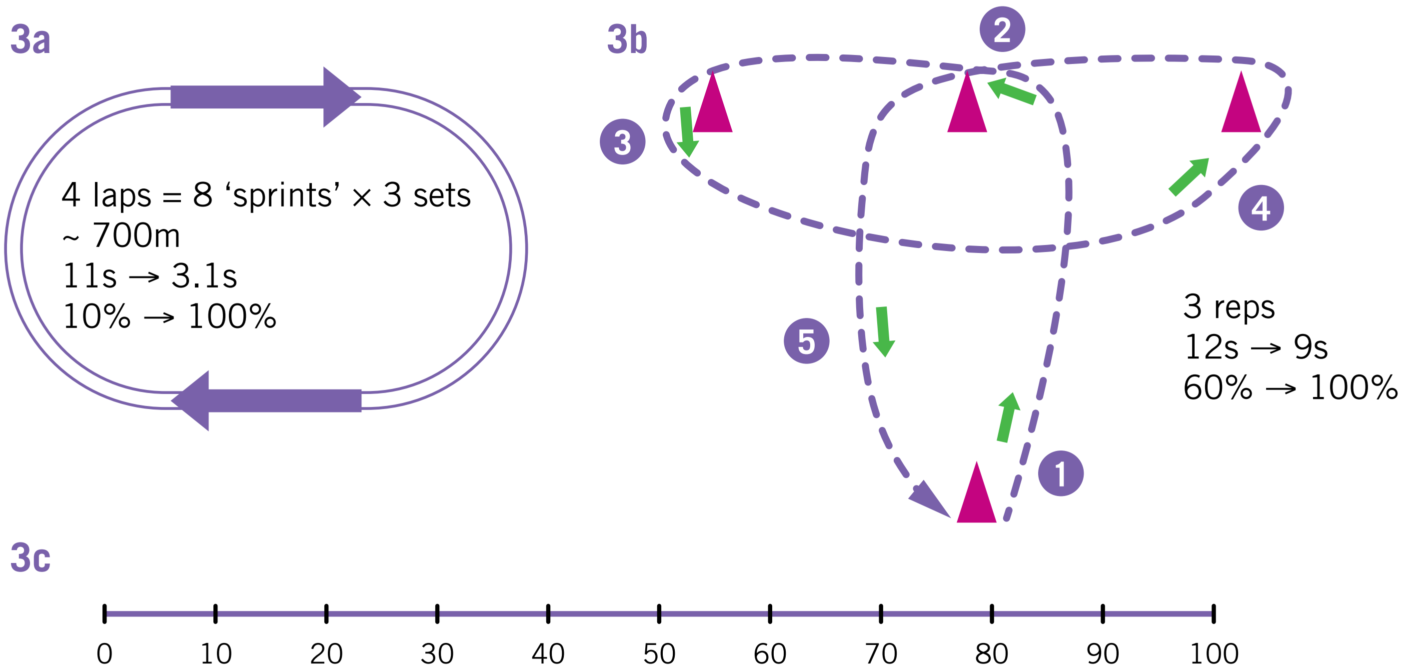


Figure 2: Criteria based progression algorithm.

Figure 3: Running progression and direction change.



on an oval track with approximately 30m straights, and approximately 100m around (see Figure 3a). The players begin from a walking start into the "run" at the beginning of the straight and decelerate on the corners. Each time the player completes three sets of four laps they are asked to rate their speed compared to their fastest speed during each set. We also record their times across the 30m track using a hand-held stop watch. In practice 0-10% usually equates to approximately 13-15 seconds, while a full sprint (100%) might be as fast as 2.9 seconds.

During each session, if the player can complete a set without any increase in pain, he is allowed to increase the speed by 5-10%. If any discomfort is experienced, if the player does not feel confident or displays lack of adequate mechanics or control, the player is instructed to return to the previous set's percentage running. If any discomfort or pain is reported during the running, the player is instructed to stop, and no further running is attempted for that session.

At Aspetar, the typical amount of running (3 sets of 4 laps or 8 "runs") is approximately 700m.This compares well to the amount of sprinting an elite football player would sprint in a professional match[5].

CRITERIA FOR PROGRESSION TO STAGE 3

The player must be able to run more than 70% of maximal speed (self-rated). Additionally, we are guided by strength and flexibility, where 75% painless range of mo-tion as well as 75% of the players maximum strength was required to progress. This may still be a good guideline, however, in our players this was almost always the case when they were able to run at 70%.

	/ /20___ DAYS POST: Sign:______________________________	
	INJURED	UNINJURED
Average pain today	VAS /10	
Walking	No P NA	
Jogging	No P NA	
2 leg squat × 3	No P NA	
1 leg squat × 3	No P NA	
Trunk flexion	No P NA	
Total palp. length	cm P	
Mid range	kg P I no	kg
Outer range	kg P I no	kg
SLR	° P I no	°
MHFAKE	° P I no	°
Bent leg bridge × 3	No P NA	
Straight leg bridge × 3	No P NA	
Comments:		

Figure 4: Daily assessments form.

Stage 3

Further progression of strengthening- and lengthening exercises[4] are now included. Eccentric strengthening exercises are introduced, specifically the Nordic hamstring exercise[6]. Load and speed are added to the lengthening exercises to increase difficulty.

Daily measurements of the player's response to training allows us to monitor the player's response to the loading, and if the player is ready for progression. If necessary, a "rest day" may be implemented to allow recovery between treatment sessions.

Strengthening exercises may now include more specific modifications for the individual player. Lengthening exercises are performed with added weights, and/or with increased speed to continue increasing the overall loading.

The player will also start with changes in direction during running and progression of running to 100% self-reported effort. Changes in direction is performed through a modification of the T-drill (Figure 3b). The player is asked to run from a standing start and touch each of the cones continuously in a forward motion. Change in direction is without any side stepping or backwards running. The goal is to allow changes in direction in a forward motion which would more accurately reflect football specific demands. In this sense, there is a low impact transfer to the on-field part of the rehabilitation.

The player starts with the direction changes only when the running is self-reported at 70%. The player is asked to start at 60% with the directional changes, and to increase the speed progressively as with the running. The total time is measured from the start of the drill to the end of the drill.

CRITERIA FOR PROGRESSION TO STAGES 4-6

When the player can run at 100% (self-rated) and perform the modified T-drill test at maximum speed (self-rated), he progresses to stages 4-6.

Stage 4-6 On-field rehabilitation

After completion of stage 3, the player progress to the on-field phase of the rehabilitation protocol. This requires completing three 30 – 45 min sessions of sport specific training, typically performed over three to four days. Depending on the player's response, we may allow for a recovery day between sessions. These sessions include running, sprinting, change in direction, multiple skill sets, such as passing and kicking, and perturbation. If the player is not able to meet the criteria or experiences any pain or discomfort in this stage, the programme is adapted in terms of the load. If the symptoms persist, the player returns to the previous stage in the protocol.

RTS ASSESSMENT AND RECOMMENDATION

After completion of all three sport specific rehabilitation stages (stages 4-6), the final re-assessments (clinical examinations) are performed before the player is discharged from rehabilitation.

Initial measurements of strength and flexibility are repeated, as well as the functional movement tests as seen in the daily assessment form (Figure 4). Additionally, we perform an isokinetic assessment and, the Askling H-test[7]. and the patient is asked to rate his own perceived readiness to RTS. Importantly, this information is not used as set criteria for RTS, but forms part of the shared decision-making process[8], which ideally includes the player, the coach, and treating physiotherapist as well as team doctor or sport medicine physician involved with the management of the player.

Isokinetic Assessment

Knee flexion and extension muscle strength were tested using an isokinetic dynamometer (Biodex Multi-joint System 3). Testing comprises three different modes and speeds. First, the players were tested over five repetitions of concentric knee flexion and extension at 60°/s. This was followed by 10 repetitions of concentric knee flexion and extension at 300°/s. Finally, they performed five repetitions of eccentric knee extension at 60°/s. The highest peak torque value observed from all repetitions performed for each of the three different tests were recorded.

Askling H-test

The patient is in supine with the contralateral leg and the upper body fixed. On the tested leg, a knee braces ensures full extension of the knee (0°). The H-test session begins with **the passive flexibility test** where the clinician slowly raises the examined leg towards maximal hip flexion range of motion. Endpoint is reached when the patient reports a strong, but tolerable stretching in the hamstring muscle.

The active flexibility test consists of one practice trial followed by a set of three consecutive test trials.

The patient is firstly instructed to perform the practice straight leg trial with submaximal effort, followed by the three active test trials, where the patient is instructed to perform a straight leg as fast as possible to the highest point without taking any risk.

After the three active trials, the patient is asked to estimate experience of insecurity and pain on a VAS-scale from 0 to 100[7].

When the player is discharged from rehabilitation, and deemed ready to return to training or match play, we recommend to the player and the coaching team to make a progressive RTS:

1. 1 X 50% training session
2. 2 X full training sessions
3. Reduced 1st match return to play (50% or 30min)
4. Full Match return to play

Figure 5: Palpation. Note the length of pain (in cm).

OUTCOME BASED REHABILITATION THROUGH DAILY ASSESSMENTS

We used the daily measurements to assist in the clinical reasoning of how to progress or adapt the treatment session of the player on a specific day. When the association between daily clinical measures and the progression of rehabilitation was analysed, we found the daily measures was seen to be non-linear, meaning that the change in the RTS time was not proportional to the different measures. The main clinical outcome measures that forms part of the decision making during rehabilitation is monitoring pain, strength, flexibility, and running.

PAIN

Our daily assessments include subjective pain using the visual analogue scale (VAS) and pain on palpation/tenderness (Figure 5).

The player reports the overall pain for that day, and the length of pain on palpation is measured. If pain worsens (either reported by the player or the length of pain on palpation) reduce the amount of load in that session.

FLEXIBILITY

Active knee extension range of motion is measured in maximal hip flexion, named the Maximal Hip Flexion Active Knee Extension (MHFAKE) test[9] (Figure 6). Keeping the hip in maximal flexion with the elbows locked, the player is instructed to actively extend the knee until reaching the point of maximal tolerable stretch of the hamstring muscle. The contralateral leg is fixed by the clinician. The absolute knee extension angle is measured as the endpoint of maximal tolerable stretch with the hand-held inclinometer placed on the anterior tibial border mid shin. We have found the MHFAKE test to be a better measure of flexibility than the traditional straight leg raise test, or other "usual" hamstring tests.

STRENGTH

Mid-range strength (Figure 7)

The player is positioned in prone and the clinician passively flexes the player's knee to one foot distance above the examination table (plinth). Standing behind the player, holding the hand-held dynamometer (HHD) with both arms against the posterior heel in a comfortable position, the clinician resists an isometric maximum voluntary contraction from the player against the HHD for three seconds, before performing break movement.

Outer-range strength (Figure 8)

The player is positioned in supine with a fixating belt over the pelvis in line with the anterior superior iliac spine (ASIS). The clinician passively flexes the player's knee on the testing leg to 90° while the contralateral leg remains flat. Standing at the side of the examination table, holding a HHD with both arms and vertically positioned against the player's posterior heel, the clinician resists an isometric maximum voluntary contraction against the HHD for three seconds, before a break is performed.

RUNNING

Lower perceived running effort (below 50%) was quite variable between different players. which measures correlate well with the progression through rehabilitation. Clinically, we have found that outer range strength tracked well with beyond approximately 50%.

CLINICAL IMPLICATIONS

Asking the patient about pain during their daily activities (such as a numeric pain rating scale), measuring strength in the outer range position, the maximal hip flexion active knee extension flexibility test, as well as length of pain on palpation were the most useful daily examinations to inform the progression during different

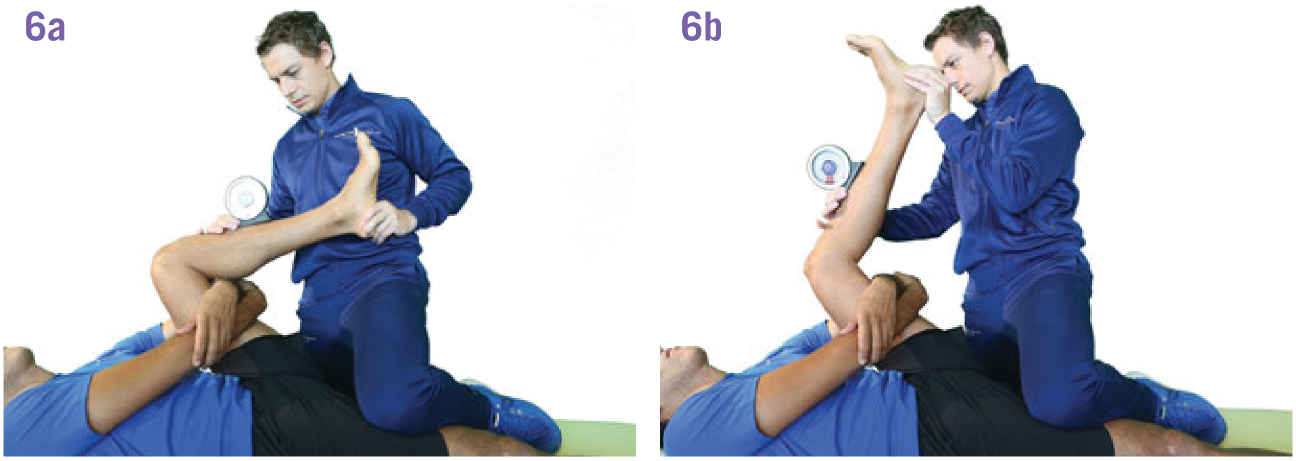


Figure 6: Maximal hip flexion active knee extension (MHFAKE) test.

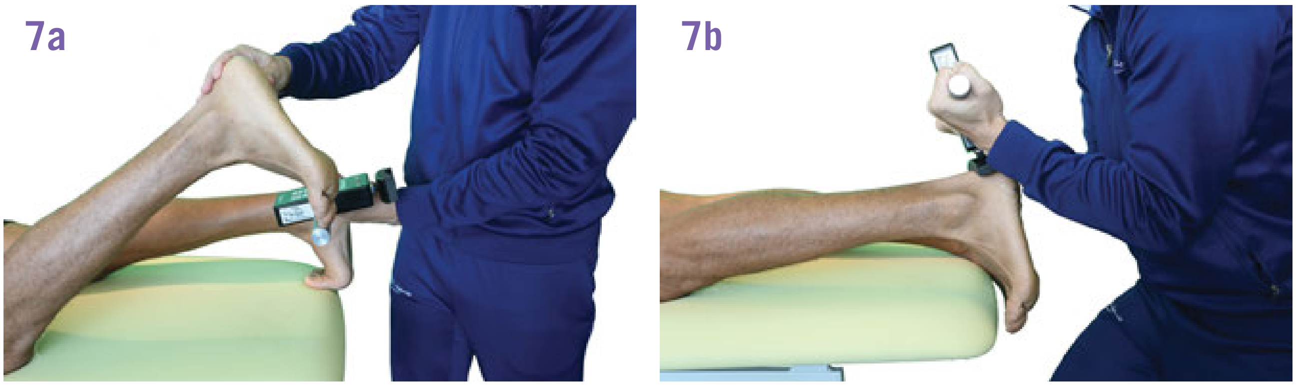


Figure7: Mid-Range strength test.

Figure 8: Outer Range strength test.

stages of rehabilitation through to return to participation (Box 1).

CLINICAL PREDICTORS FOR RETURN TO SPORT (RTS)

There is still lack of consensus regarding which clinical measurements are useful to predict time to RTS.

A combination of clinical findings at the day 7 follow up clinical examination could provide some reasonable predictive ability in the duration of RTS[9]. For this investigation, RTS was 23 (±5) days.

The important subjective features associated with RTS time were:

- Maximum pain (VAS scale 1-10) reported at the time of injury
- A delay in starting physiotherapy
- Time taken to walk pain free.

The physical findings that were found useful were strength testing related variables:

- Change in pain on the mid-range strength test over the first week
- Pain during the outer range strength test and single leg bridge at day 7
- Outer range strength at day 7 expressed as a percentage of the uninjured leg,
- Peak isokinetic strength of knee flexion of the uninjured leg.

Careful attention to these measurements might provide the clinician with greater insights into the duration of RTS for an injured football player.

SUMMARY

In the literature, several different rehabilitation protocols have been described; these approaches have been valuable in growing our knowledge and understanding of what constitutes an appropriate rehabilitation protocol. The difficulty remains in understanding how and when they will benefit an individual player. We have presented our rehabilitation protocol for a football player with a typical running related hamstring injury, where criteria-based progression is followed throughout the rehabilitation process. If we integrate objective measures as well as subjective measures into the clinical reasoning process, we can provide a rehabilitation program that is aligned with our RTS goals.

At Aspetar, we value of a multi-disciplinary team approach, and shared decision making as described in the literature, has been a valuable feature in our experience[2,10-11]. During the rehabilitation process, the communication with the player, the team doctor, and especially the coaching, is critical if we want to achieve successful outcomes for our players.

Box 1: Clinical implications for daily outcome measurements during rehabilitation

- *If pain worsens (either reported by the player or the length of pain on palpation) reduce the amount of load in that session*
- *When the length of pain on palpation is half (reduced by 50% from the initial examination), it is likely that the rehabilitation process is 50% completed.*
- *The maximal hip flexion active knee extension (MHFAKE) is the best measure of flexibility more so than straight leg raise (SLR), but it normalises half way through the rehabilitation process.*
- *Outer range strength seems to be the best measure to guide strength progression, and normal outer range strength should be approximately 50% of the player's bodyweight*
- *Players can estimate their running effort in a meaningful way, but only above approximately 50% of their perceived maximum.*
- *The percentage perceived running effort roughly correlates to the outer range strength (measured as a percentage of the uninjured side at the initial examination)*

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