HAMESTRING REHABILATATION

Farzaneh Saki (PhD, Sport Injuries and Corrective Exercises
Bu-Ali Sina University

Introduction

Following any type of athletic hamstring injury , sports medicine clinicians are constantly under pressure to facilitate a quick and safe return of the athlete to training and competition .

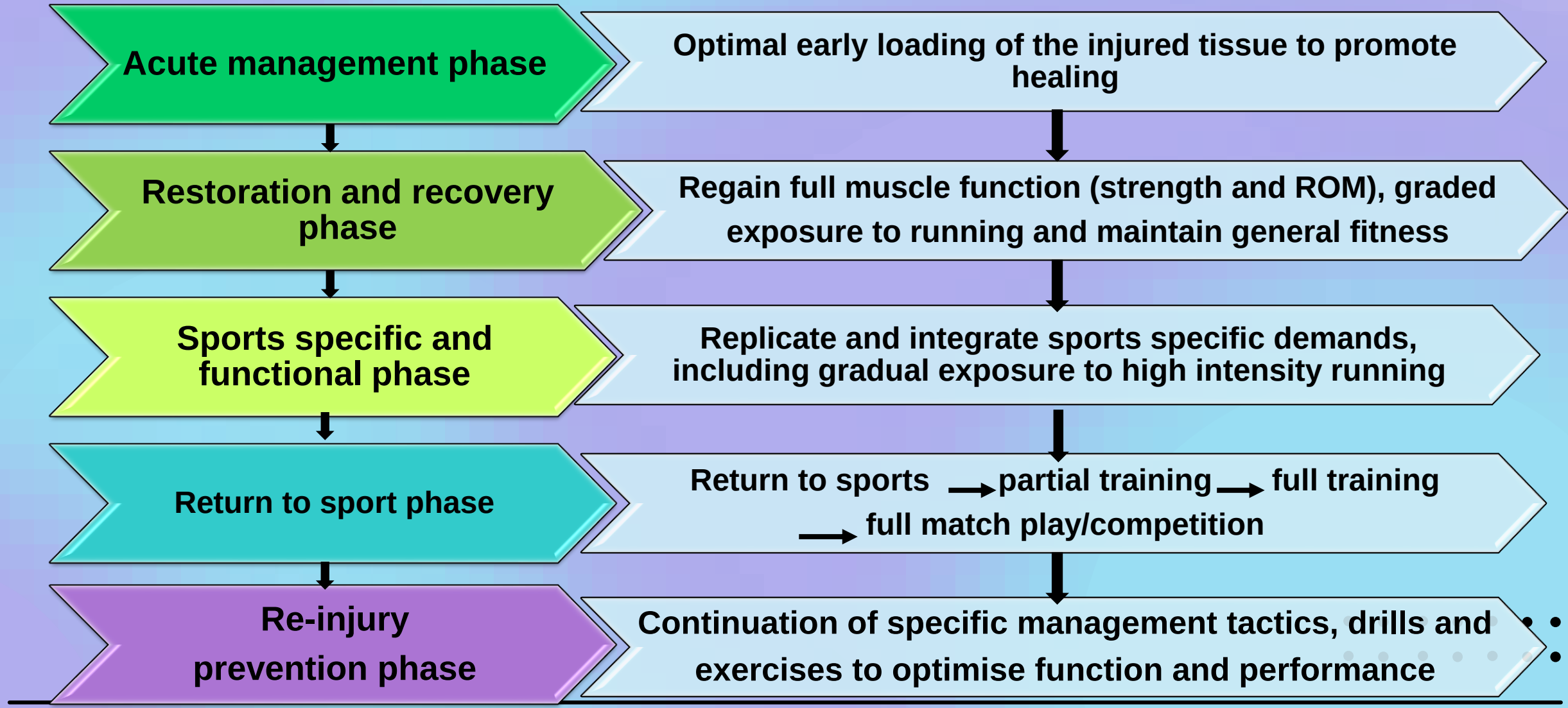
To meet these challenging requirements , it is essential to combine a range of training parameters to ensure that the athlete is able to work near the limit of his or her capacity while concurrently ensuring that sufficient time is allowed for the injured tissue to heal

- Hamstring injuries may vary significantly in type and severity and each type of injury requires specific and targeted rehabilitation.

- The main goal of a rehabilitation programme after hamstring injury should be to facilitate that the athlete is returning to sport at the highest possible performance level as fast as possible but with a minimal risk of reinjury.

An important element of the rehabilitation plan is effective goal setting

General rehabilitation phases and rehabilitation goals after hamstring injury



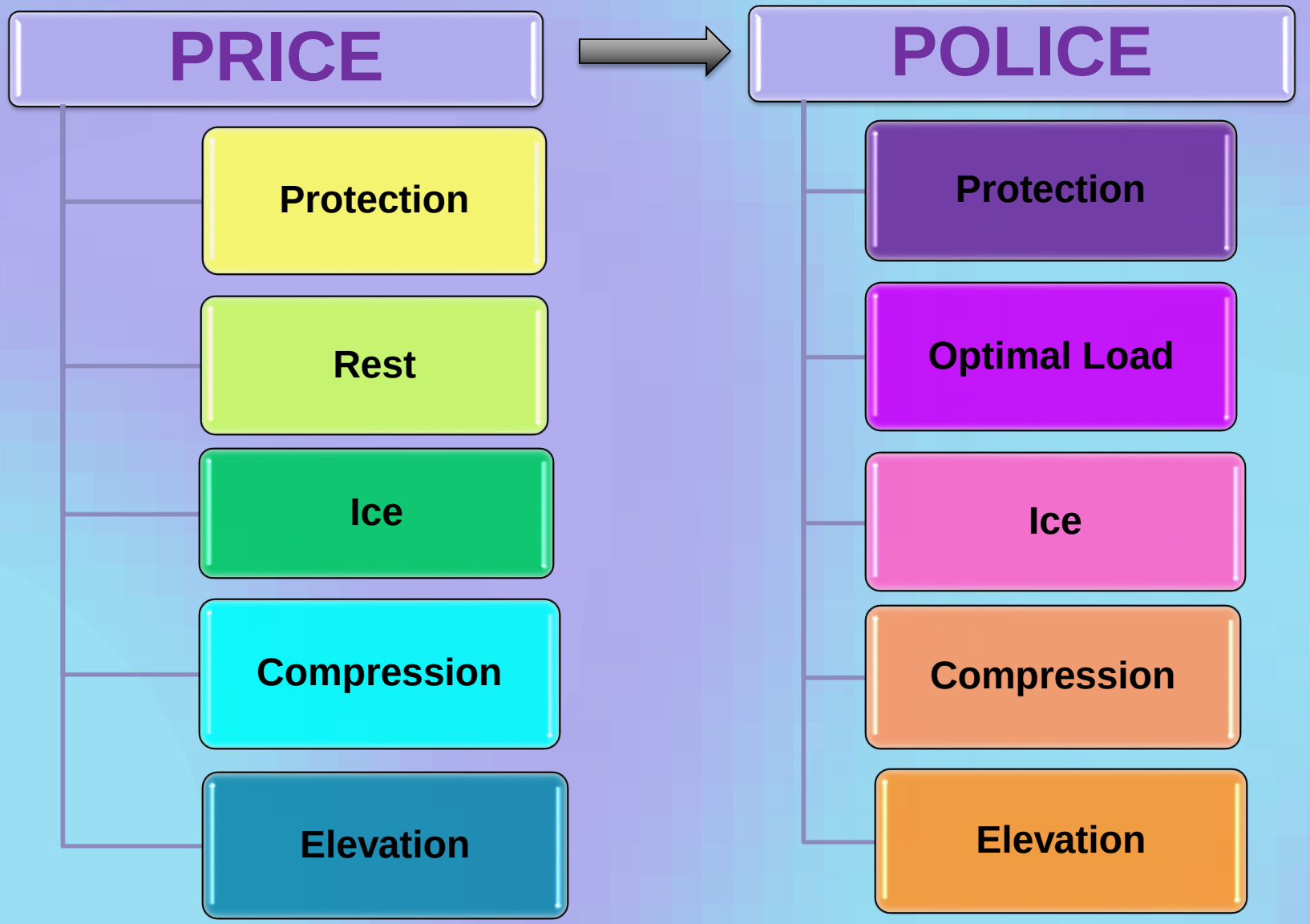
Rehabilitation of Acute Hamstring Muscle Injuries

- The high incidence of hamstring reinjuries remains enigmatic, and previous injury is reported as the most common risk factor for a subsequent injury.

- Reinjuries commonly occur early (within the first 2 months) after RTS.

Therefore , an effective rehabilitation process promoting muscle tissue repair and recovery of function after a hamstring injury is important not only for a quick RTS but also for minimising the risk of reinjuries .

Acute Management and Early Loading



There is, however, no consensus as to how fast or aggressive the initial mobilisation and loading should be.
It has recently been shown that starting rehabilitation early (2 days) after muscle injury rather than delaying rehabilitation (waiting for 9 days) significantly shortens the interval from injury to pain-free recovery and RTS by 3 weeks without any significant increase in the risk of reinjury, thus supporting the importance of early loading of injured musculotendinous tissue .

We therefore suggest that progressive loading is commenced according to the athlete's tolerance, and that simple daily activities, and regular active movements through functional ranges of motion be commenced as early as possible

Summary of Evidence

Reference	*N*	Population	Intervention A/intervention B	Follow-up	Primary outcome	Results	Effect
Cibulka et al. [40]	20	Patients with a clinical diagnosis of hamstring injury and sacroiliac joint dysfunction	A: SI manipulation + moist heat and passive stretching B: Moist heat and passive stretching	None reported	Hamstring peak torque (ft lbs)	A: 46.4 ft lbs (SD 17.47) B: 45.7 ft lbs (SD 22.70)	=
					Passive knee extension (ROM)	A: 155.0° (SD 14.2) B: 144.6° (SD 16.7)	
Malliaropoulos et al. [41]	80	Athletes with an ultrasonographic grade 2 hamstring injury	A: "Intensive" stretching B: "Normal" stretching	Until RTS	Time to RTS	A: 13.27 days (SD 0.71) B: 15.05 days (SD 0.81)	+
					Time needed for equalisation of active knee extension	A: 5.57 days (SD 3.3) B: 7.23 days (SD 0.53)	
Sherry and Best [42]	24	Athletes with acute hamstring injury, grades 1 and 2 based on PE	A: Core stability + agility + icing (PATS) B: Static stretching + progressive resistance exercises + icing (STST)	1 year	Time to RTS	A: 22.2 days (SD 8.3) B: 37.4 days (SD 27.6)	+
					Reinjury	A: 0/13 B: 7/10	
Silder et al. [26]	29	Athletes with suspected hamstring injury (≤past 10 days) confirmed by PE and MRI	A: Core stability + agility (PATS) B: Running + eccentric (PRES)	1 year	Time to RTS	A: 25.2 days (SD 6.3) B: 28.8 days (SD 11.4)	=
					Craniocaudal length of injury	A: 7.9 cm (95% CI 2.7–13.1) B: 15.9 cm (95% CI 8.4–23.4)	

Overview of RCTs (Level 1b) investigating the effect of exercise and/or rehabilitation interventions following acute hamstring injuries

Reference	*N*	Population	Intervention A/intervention B	Follow-up	Primary outcome	Results	Effect
Askling et al. [35]	75	Elite Swedish football players with MRI (<5 days after injury) confirmed hamstring injury	A: L-protocol[a] B: C-protocol[b]	1 year	Time to RTS	A: 28 days (SD 15) B: 51 days (SD 21)	+
					Reinjury	A: 0/37 B: 1/38	
Askling et al. [36]	56	Swedish elite sprinters and jumpers with MRI (<5 days after injury) confirmed hamstring injury	A: L-protocol[a] B: C-protocol[b]	1 year	Time to RTS	A: 49 days (SD 26) B: 86 days (SD 34)	+
					Reinjury	A: 0/28 B: 2/28	
Mendiguchia et al. [14]	48	Male football players with grade I structural hamstring injury (<4 days after injury) confirmed with US and PE	A: Individualised and multifactorial criteria-based algorithm (RA) B: General rehabilitation protocol (RP)	6 months	Time to RTS	A: 25.5 days (SD 7.8) B: 23.3 days (SD 11.7)	=
					Reinjury	A: 1 (4%) B: 6 (25%)	
Bayer et al. [7]	23/42[c]	Athletes from various sports (males and females) (<48 h) confirmed with US and CE	A: Early time-based rehabilitation (2 days after injury) (n = 11 hamstring injury) B: Late time-based rehabilitation (9 days after injury) (n = 12 hamstring injury)	12 months	Time to RTS	A: 62.5 days (IQR 48.8–77.8) B: 83.0 days (IQR 64.5–97.3)	+
					Reinjury	A: 1/20 B: 0/22	

Reference	*N*	Population	Intervention A/intervention B	Follow-up	Primary outcome	Results	Effect
Hickey et al. [43]	43	Recreational to sub-elite male athletes from various running-based sports with hamstring injury confirmed by PE ≤ 7 days of injury	A: Hamstring strength exercises and progressive running performed within limits of pain rated ≤4/10 (pain threshold) B: Hamstring strength exercises and progressive running performed within limits of pain rated <1/10 (pain-free)	6 months	Time to meet RTS clearance criteria	A: 17 days (95% CI 11–24) B: 15 days (95% CI 13–17)	=

C control, *CE* clinical examination, *HSI* hamstring strain injury, *I* intervention, *IQR* interquartile range, *MRI* magnetic resonance imaging, *PATS* progressive agility and trunk stabilisation, *PRES* progressive running and eccentric strengthening, *PE* physical examination, *ROM* range of motion, *RTS* return to sport, *SI* sacroiliac, *STST* stretching and strengthening, *US* ultrasonography, *Ft lbs*, foot-pound (torque)

[a]L-protocol—aimed at loading the hamstrings during extensive lengthening exercises

[b]C-protocol—conventional hamstring exercises with less emphasis on lengthening

[c]Number of hamstring injuries included out of the total number of muscle injuries

General Programme Including Progressive Running Programme

By Askling et al.

General programme including progressive running programme [35, 36]	
First part	• Performed three times a week, starting with the following: – Stationary cycling 10 min – 10 × 20 s fast foot stepping in place – 10 × jogging 40 m with short strides – 10 × 10 forward/backward accelerations
Progressive running programme	• Performed three times a week, initiated when the "first part" is performed without pain and/or discomfort – High-speed running drills 6 × 20 m – High-speed running drills 4 × 40 m – High-speed running drills 2 × 60 m

Rehabilitation of Acute Hamstring Muscle Injuries

The Extender

THE L-PROTOCOL

The Diver

The Glider

THE C-PROTOCOL

Stretching—contract/relax

Cable-pendulum

Pelvic lift

Progressive running schedule

by Silder et al.

Exercises

- Five minutes of gentle stretching before and after each session, 3 × 20 s each
  - Standing calf stretch
  - Standing quadriceps stretch
  - Half-kneeling hip flexor stretch
  - Groin or adductor stretch
  - Standing hamstring stretch
- Repeat each level three times, progressing to the next level when pain-free
- Maximum of three levels per session
- On the following session, start at the second-highest level completed
- Ice after each session, 20 min

	Acceleration distance, m	**Constant speed (maximum, *75%* speed) distance, m**	**Deceleration distance, m**
Level 1	40	20	40
Level 2	35	20	35
Level 3	25	20	25
Level 4	20	20	20
Level 5	15	20	15
Level 6	10	20	10
	Acceleration distance, m	**Constant speed (maximum, *90%* speed) distance, m**	**Deceleration distance, m**
Level 7	40	20	40
Level 8	35	20	35
Level 9	25	20	25
Level 10	20	20	20
Level 11	15	20	15
Level 12	10	20	10

Multifactorial Approach

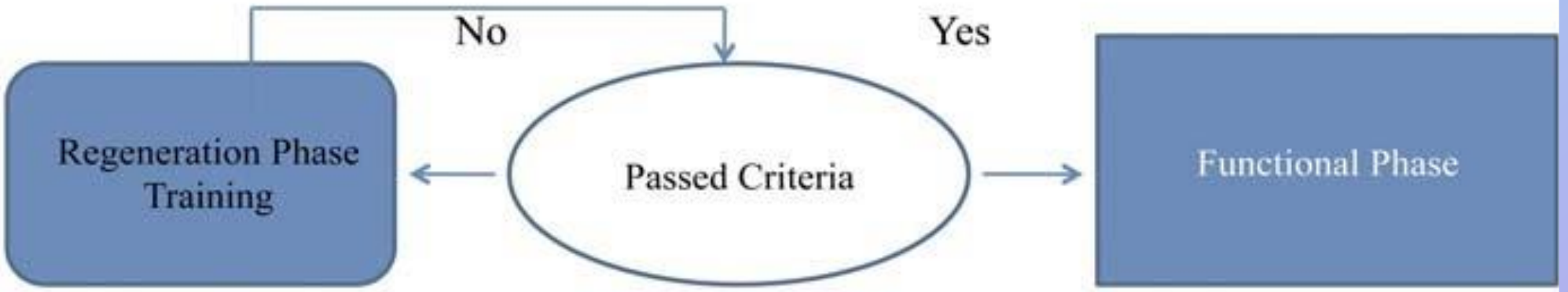
Criteria used to progress through each phase of Rehabilitation Algoritm

- Regeneration phase criteria
- Functional phase criteria

A

Regeneration Phase

Variable	Test	Criteria for Progression
Pain after injury	Prone with knee flexed to 15° (10)	No pain
Isolated strength at long muscle lengths	Prone with knee flexed to 15° (21)	< 10% asymmetry
Neural deficiencies	Slump test (6)	No pain
Hamstring flexibility	Active knee extension (AKE) test (31)	< 10% asymmetry
Hip flexor flexibility	Modified Thomas test (MTT) (17)	+5 symmetry below horizontal

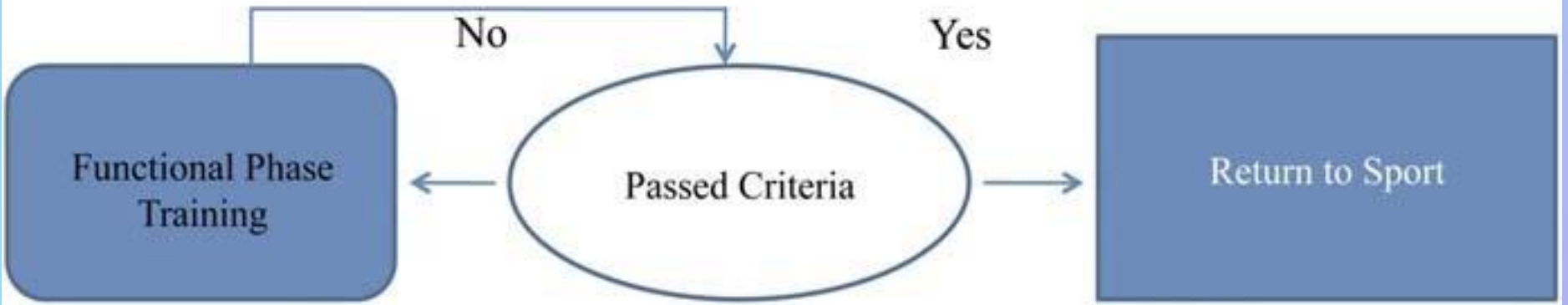



Andreas

B

Functional Phase

Variable	Test	Criteria for Progression
Pain	Palpation (10)	No pain
Peak torque (H/H) and conventional ratio (H/Q)	Isokinetic knee flexion/extension at $60°\cdot s^{-1}$ (8)	< 10% H/H and H/Q > 0.45 (Biodex) or > 0.47 (Cybex)
Hip extension strength	Prone hip extension (37)	< 10% asymmetry between legs
Distance	Triple hop test (16)	< 10% asymmetry between legs
Endurance (Repetition number)	Single leg bridge test (13)	> 25 and < 10% asymmetry between legs
Torsion capabilities	ASLR test (22)	No compensations
Insecurity and Pain	Askling H-test (2, 3)	No pain and insecurity

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Rehabilitation and RTS algorithm program for hamstring injury.

- Manual therapy
- Flexibility
  Gluteus
- Hamestring strength
- Polyometric
- Ankle stabilizers
- Lumbopelvic control
- Running technique

Manual therapy

REGENERATION PHASE	FUNCTIONAL PHASE
Manual therapy: - Plantar fascia, gastrocnemius and hamstring (avoiding injury site) massage - Lumbar Z-joint mobilization - Sliding Neural Mobilization (3 x 12 reps) NMES	Manual therapy: - Plantar fascia, gastrocnemius and hamstring (injury site included) massage - Lumbar Z-joint mobilization

1. 2. 3


Regeneration phase

Flexibility

REGENERATION PHASE	FUNCTIONAL PHASE
Psoas static flexibility with pelvic retroversion (4 x 15 sec) Quadriceps dynamic mobility (2 x 8 reps) Hamstring dynamic mobility with fitball (2 x 8 reps) Hamstring dynamic mobility supine (2 patterns) (2 x 8 reps)	Hamstring dynamic mobility + contralateral psoas flexibility (2 x 5 reps) Hamstring wall flexibility (Push/Pull) (3 x 3 reps)

2. 3

Flexibility and neural mobilization

Gluteus (Maximus & Medius)

REGENERATION PHASE	FUNCTIONAL PHASE
Gluteus Maximus (Choose an option daily as pain tolerated)**:**	**Gluteus Maximus** (Choose an option)**:**
Option A	**Option A**
Prone hip extension (2 x 10 reps x 3 sec)	Single leg hip thrust (10% BW; 3 x 4 reps x 3 sec)
Single leg bridge + contralateral kick (as tolerated) (2 x 5 reps x 3 sec)	Double leg hip thrust (60% BW; 3 x 8 reps x 3 sec)
Double leg bridge (50% BW; 3 x 6 reps x 3 sec)	Walking sled push (75% BW; 15 m x 2 reps)
Option B	**Option B**
Hip thrust (40% BW; 3 x 6 reps x 3 sec)	Single-leg foot and shoulder elevated hip thrust + contralateral kick (2 x 4 reps x 3 sec)
Single leg bridge + contralateral kick (as tolerated) (10% BW; 2 x 4 reps x 3 sec)	Single leg back extension + perturbations (2 x 4 reps)
Single leg hip thrust + contralateral kick (as tolerated) (3 x 6 reps x 3 sec)	Swing leg hip extension + contralateral hip flexion (2 x 3 changes)
Gluteus Medius:	**Gluteus Medius:**
Clamshell with band (3 x 6 reps x 3 sec)	Side step running with band (5 m x 5 go and back)
Side lying hip abduction with band (3 x 6 reps x 3 sec)	Monster running with band (5 m x 5 go and back)

2

Gluteus maximus

Hamestring strength & Polyometric

REGENERATION PHASE	FUNCTIONAL PHASE	
Prone isometrics (mid and long length) (2 x 5 reps x 5 sec) Standing long length isometrics (2 x 5 reps x 5 sec) Supine isometrics (tolerated degrees) (2 x 5 reps x 3 sec) Submaximal eccentric manual resistance in prone (intensity as tolerated) (2 x 8 reps)	(4 Hamstring strength exercises per session selecting 2 hip dominant and 2 knee dominant) **HIP dominant** Double leg deadlift with 4 kg medicine Ball (2 x 8 reps) Lunge (15% BW; 2 x 6 reps) Single leg deadlift with 15kg + step up (2 x 6 reps) **KNEE dominant** Double leg slide curl (2 x 6 reps) Nordic hamstring (2 x 4 reps) Sprinter eccentric leg curl (2 x 6 reps)	2
	Double leg hurdle hop with trunk flexion (2 x 4 reps) Double broad jump with 5 kg (2 x 4 reps) 2 consecutive explosive scissor jumps (3 times) Single leg horizontal jump (2 x 3 reps)	2

Examples of higher intensity hamstring exercises

Examples of double- and single-leg bridging exercises with a variety of progressions

Hamstring strength

Ankle stabilizers

REGENERATION PHASE	FUNCTIONAL PHASE
Double leg hamstring / gastrocnemius disassociation drill (3 x 6 reps) Single leg hamstring / gastrocnemius disassociation drill (2 x 6 reps) Step bounding side to side (25% BW; 2 x 10 reps)	Ankle drill 1 (20% BW; 10 m x 4 reps) Ankle drill 2 (20% BW; 10 m x 4 reps)

Ankle stabilizers

Lumbopelvic control

REGENERATION PHASE	FUNCTIONAL PHASE
Side bridge feet in bench + perturbation (2 x 5 reps x 5 sec) Birdog (2 x 5 reps x 5 sec) Long lever posterior pelvic plank (2 x 4 reps x 5 sec) Leg scissors arms on the floor (2 x 5 reps x 5 sec)	Stir the pot with fitball (3 x 2 reps) Leg Scissors arms on the chest (2 x 5 reps x 5 sec) Single-leg stand rotating reaches 4 kg (2 x 6 reps) TRX helicopter (2 x 4 reps) Sprinter push/pull with pulleys (2 x 6 reps)

2, 3

Lumbopelvic control

Running technique

REGENERATION PHASE	FUNCTIONAL PHASE
Frontal plane running drills Low- to moderate-intensity sidestepping (10 m x 5 reps) Low- to moderate-intensity grapevine stepping (10 m x 5 reps) Low- to moderate-intensity steps forward and backward over a tape line while moving sideways (10 m x 5 reps) **Sagittal plane** running drills (vertical emphasized execution specially first days or painful subjects) - 8 running exercise drills (statics in place dynamics over 8m) Running 5 m + 5 m deceleration (4 reps) Running 10 m + 5 m deceleration (3 reps) Running 15 m + 5 m deceleration (2 reps)	**Warm Up:** Hamstring Ballistic stretching (2 x 6 reps) Static "B" drill with resisted band (2 x 5 reps) Hurdle drills (1 set walking lower intensity, 1 set bounding higher intensity) Hurdle drill 1 (2 reps) Hurdle drill 2 (2 reps) Hurdle drill 3 (2 reps) Hurdle drill 4 (2 reps) Military march (15 m x 2 reps) Lunge + deadlift (4 reps for each leg) Lunge + "B" drill (4 reps for each leg) From Skipping to running (20 m x 4 reps) Sprint bounding (15 m x 3 reps) Running with hurdle jumps (15 m x 1 rep) Sprinting 5 m (3 reps), 10 m (3 reps), 15 m (4 reps), 20 m (3 reps), 30 m (2 reps) and 40 m (1 rep) (15 sec of rest per each 1 sec sprinting) Sled push resisted accelerations (30% BW) 5 m (3 reps) and 10 m (2 reps)

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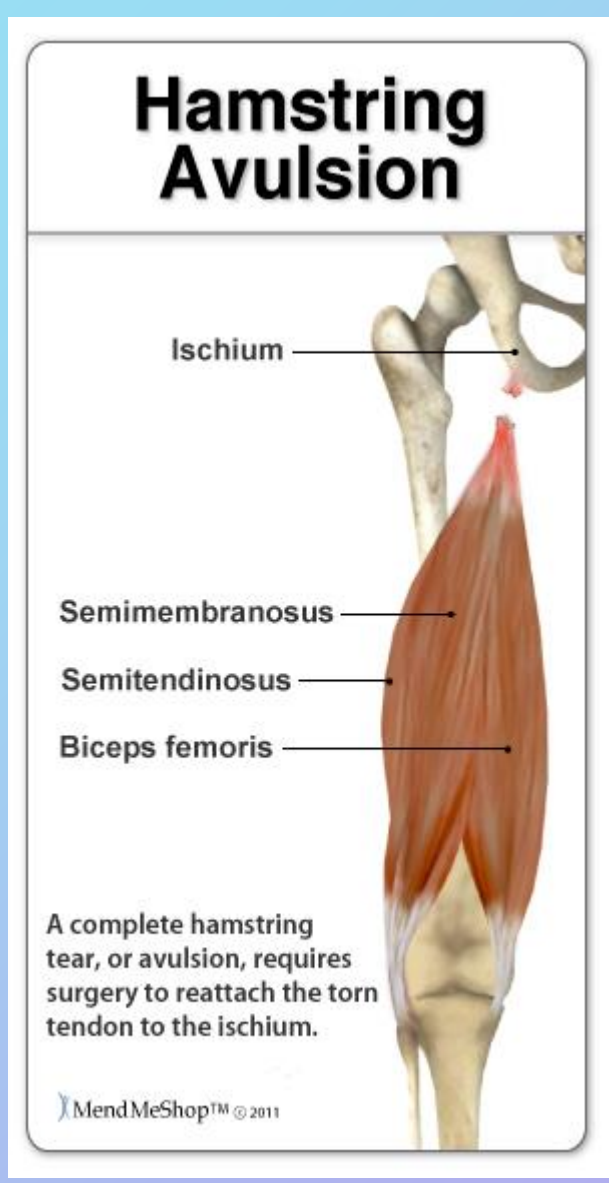
Running technique

Rehabilitation After proximal Hamstring tendon Avulsions

Summary of Evidence The vast majority of published literature on proximal hamstring tendon avulsions focuses on outcomes after surgical treatment.



Generally, postoperative rehabilitation includes an initial period of several weeks with restrictions in weight - bearing and range of motion. In this phase, the goal is to avoid excessive stresses on the repair and simultaneously load the tissue to minimise muscle atrophy.

In the early phase , it is important to regain good control (i.e. activation) of the hamstrings , so control and gait training are started early , followed by a progressive strengthening programme and sport - specific exercises . Return to sport is generally allowed from 6 months on.

Two of the main goals of rehabilitation are to minimize atrophy and the loss of flexibility, while providing adequate rest and optimal conditions for the healing of musculotendinous tissue .

In addition , it is very important to do exercises to regain control and muscle strength as well as good mobility of the posterior thigh and the entire lower limb .

All exercises should be commenced and progressed with minimal pain or discomfort

Crutches	Crutches are generally recommended for approximately 6 weeks (outdoors), but there are some individual differences. Walking without crutches indoors can usually be performed earlier, but this may depend on the specific restrictions from the surgeon
Walking	In the first 3 weeks after surgery, only short steps are recommended to avoid excessive stretching of the hamstring muscles
Hip and knee ROM	Avoid excessive hip flexion bending the first 3 months, especially in combination with knee extension, to avoid excessive pull on operated hamstring muscles
Isolated hamstring exercises	Isolated exercises of hamstrings against resistance are not recommended before week 5
Passive stretching	Aggressive passive stretching to improve muscle flexibility is not recommended during the first 3 months after surgery. Active ROM exercises are preferred
Hamstring muscle activation and muscle atrophy	Voluntary activation of the repaired hamstring muscle group may be challenging initially in postoperative rehabilitation. Muscle atrophy is common, particularly involving the biceps femoris long head with compensatory hypertrophy of the short head [94]. The feedback technique by instructing the patient to put her/his hand on the operated muscle when trying to isometrically contract it may be useful to address this problem
Muscle strengthening	Muscle strength is difficult to regain, especially eccentric strength. Most patients need to perform muscle strengthening exercises during an extended period of time (often ≥1 year) to reach equal strength in both legs. A prolonged period of hamstring muscle strengthening is therefore recommended

General Postoperative Recommendations After Total Proximal Tendon Avulsions

Week by Week Rehabilitation Progression Guidelines

Week after surgery	Recommended rehabilitation guidelines
Week 1	• The operated hamstring muscles should be kept in a shortened and relaxed position to avoid traction on the reattached tendon • Sitting on the affected ischial tuberosity should be avoided, except when using the elevated toilet seat • The patient is allowed to place body weight on the operated leg in a neutral standing upright position with crutches, but only toe touch weight-bearing is permitted • "Safe" and simple exercises can be performed, including isometric contractions of the quadriceps and gluteal muscles, ankle pumps to avoid deep vein thrombosis, and carefully performed muscle flexibility exercises by allowing approximately 30–45° of knee flexion in supine position. These exercises are recommended to be performed four times daily with 3 sets x 10 repetitions within pain-free limit

Week 2	• Therapeutic exercises for the next 5 weeks are recommended. Since three out of four hamstring muscles span two joints, both hip and knee joint positions need attention when prescribing exercises • When 30° of hip flexion is reached in a straight leg raise, the patient is allowed to walk using crutches with full weight-bearing and short strides on the operated leg and also permitted to stand on the operated leg, single-leg stance, and perform minor knee flexion/extension exercises • "Safe" exercises such as supine isometric contractions of the hamstring muscle of the operated leg should be carried out as tolerated • Sitting for short periods of time in an elevated chair is allowed • In a prone position, passive knee flexion/extension exercises can be performed. These exercises should also be done with assistance at home twice daily, 3 sets x 10 reps • The main objectives during the second week are to be able to activate the hamstrings on the operated leg and to walk with short (foot long) weight-bearing strides with crutch assistance

Week 3	• If the exercises during week 2 are performed cautiously and without pain, the rehabilitation should progress with two complementary exercises: – First, standing on the nonoperated leg with full weight-bearing and careful knee flexion exercises of the operated leg with the ankle joint in plantar flexion are added – Secondly, stationary slow walking on a thick pad with increasing knee lifts is encouraged • Calf strengthening is permitted in a standing position with a straight leg and full weight-bearing
Week 4	• If there is adequate balance/postural control and motor control when standing/walking, there is no further need for crutches indoors • Pool training with a belt is allowed if the wound is healed • Stationary biking with the saddle in a high position is permitted when the patient can reach 70° of hip flexion combined with 90° of knee flexion • Isolated resistance exercises involving the operated hamstring muscles should still be avoided

Week 5	• All exercises from the first weeks may now be stopped (isometric contractions, passive flexion and extension exercises, and standing knee flexion) • Specific hamstring strengthening exercises with increased intensity but performed slowly are now included, such as static leg curls in a sitting position (Fig. 10.8) and single-leg catches with a cable • In addition, lumbopelvic exercises are also introduced (Fig. 10.7)
Week 6	• By this point, the patient's gait should be "normal," that is, ambulation without limping • During the sixth week, exercises for improving muscle flexibility, single-leg balance, and neuromuscular control including lumbopelvic control training are introduced, such as lunge walking, and specific isometric hamstring contractions in the prone position with resistance to the heel (in leg curl machine) – By performing this exercise with the leg in internal rotation, the medial hamstring muscles may be preferentially isolated. With the leg in external rotation, the biceps femoris (BF) muscle may be preferentially loaded

Week 7–	• Eccentric training of the operated hamstring is typically initiated together with at least 2 days of rest a week for this muscle group • A manual strength evaluation should be performed initially in the prone position with knee flexion and hip extension on a weekly basis. Later in the rehabilitation process, multiple test positions are utilised to assess strength and provoke pain • Evaluation of ROM of both the hip and knee joints should be included. A side-to-side comparison for strength and flexibility is recommended. It is advised that patients perform 2–4 hamstring exercises at each training session with a 100% focus on quality rather than quantity • A common problem is that the patient often uses the agonist muscles such as the GM, AM (both being strong extensors of the hip joint), and gastrocnemius, as well as the short head of BF, rather than the operated hamstring muscles • Cautious jogging, both forward and backward, with short strides, including accelerations/decelerations is now permitted. Stationary jogging with high knee lifts at increasing intensity over time can be performed. The single-leg bridge is a good example of an isolated hamstring exercise in the supine position with combined hip extension and knee flexion. In each training session, specific hamstring strengthening exercises should be combined with more complex exercises such as lunges, squats, and different types of jumps. Dynamic leg curls in both the prone and sitting positions should be a part of the strengthening phase of the programme

Sport-specific and functional phase	• More aggressive, sport-specific activities are integrated, allowing full unrestricted ROM in an effort to prepare the patient for return to prior level of sports activity • Outdoor training, slope training, video filming of the running technique, or other sport-specific movements are encouraged • The duration of this sport-specific and functional phase may vary depending on the individual athlete and the specific sports requirements
Return to sport (±6 months after surgery)	• It is recommended that patients can return to sports when sport-specific activities and functional abilities such as jumping, running, and cutting can be performed without pain, stiffness, or a feeling of insecurity • The time to RTS may vary depending on the progression of the rehabilitation and sport-specific and functional phase for the individual athlete. In many settings, specific predetermined criteria are required to be completed

Examples of isometric hamstring exercises for postoperative total proximal tendon avulsion

The Young Athlete :

Based on a recent systematic review of available literature, fragment displacement of > 15 mm warrants surgical consultation. For avulsion fractures with < 15 mm displacement , conservative treatment is recommended as primary treatment

Rehabilitation of Proximal Hamstring Tendinopathy

Reference	Phase I	Phase II	Phase III	Phase IV	Phase V	Phase VI	Comments
Ferlic et al. [103]	*Weeks 0–6*: • PWB (crutches)	• Isokinetic and isometric strengthening of hamstrings and adductors	• Concentric and eccentric strengthening of hamstrings and adductors	–	–	–	
Kujala et al. [104]	*Weeks 0–4*: • Rest from all sports • FWB allowed	*Weeks 4–8*: • Modified training	–	–	–	–	Phases I and II may be prolonged for a displaced fracture (>5 mm), delayed presentation (>1 month), or persisting symptoms
Metzmaker and Pappas [105]	*Days 0–7*: • No activity • PWB (crutches) after 3 days	*Days 7 to 14–20*: • Guided exercise with progression in ROM • PWB (crutches)	*Days 14–20 to 30*: • Progressive strengthening (resistance training)	*Days 30–60*: • Progression of strengthening exercises • Limited sport-specific training • FWB/cycling	*Days 60 to RTP*: • Sport-specific training • Aim at full ROM and strength	–	Progression is based on subjective pain, pain and findings on palpation, range of motion, muscle strength, level of activity, and radiographic appearance

Schoensee and Nilsson [106]	*Weeks 0–2*: • Neuromobilisation (ankle motion) • NWB (crutches) and protected sitting	*Weeks 2–4*: • Soft tissue mobilisation • Limited hamstring ROM • Isometric lower extremity strengthening • Core and upper body strengthening • PWB and protected sitting	*Weeks 4–6*: • Progression of previous exercises • Progression of PWB to WBAT	*Weeks 6–8*: • Eccentric strengthening • WBAT	*Weeks 8–12*: • Progression of previous exercises • FUNCTIONAL training • Running • FWB	*Weeks 16+*: • RTP phase	Rehabilitation programme is designed for symptomatic delayed union and is preceded by ultrasound-guided percutaneous needle fenestration RTP may be guided by criteria such as no pain and a functional hop test score of 90% (compared to the contralateral leg)
Schuett et al. [99]	*Weeks 0 to 4–6*: • PWB (crutches)	• Physical therapy with focus on flexibility					For subacute avulsion fractures, the initial phase consists of activity modification

Aspetar Hamstring Protocol

Physio

Stage 1

Stage 2

Stage 3

Painless single leg squat
Painless bike 150W, 5mins

Run > 70%
ROM SLR & HS O >75%

100% running
Painless direction change

On-field

Stage 4

Stage 5

Stage 5

Light Football Training Session

In-between Football Training Session

Heavy Football Training Session

ASSESSMENT

- In general:
  All exercises should be performed close to pain free limit. If the exercise/movement provokes pain (≥ 2 VAS) from the injured area, the exercise is immediately adjusted or terminated.

  • The patients should be instructed to perform the exercises with adequate control/stabilization of the hip and trunk.

  Variations:
  • Depending on the localization of the injury (medial/lateral), tibial IR or ER is applied when appropriate during exercises with knee flexion movements appropriate

GOALS:

STAGE I : PROMOTE healing OF THE INJURED TISSUE

1) Protect scar tissue development (promote neuromuscular control within protected ROM)
2) Minimize muscle atrophy
3) Minimize pain

STAGE II - III : REGAIN FULL MUSCLE FUNCTION AND neuromuscular CONTROL

1) Regain full voluntary neuromuscular control over the injured muscle
2) Regain pain free hamstring strength , from mid range progressing to longer hamstring lengths
3) Develop neuromuscular control of trunk and pelvis with progressive movement speed
4) Pain free running up to maximal speed and with changing directions

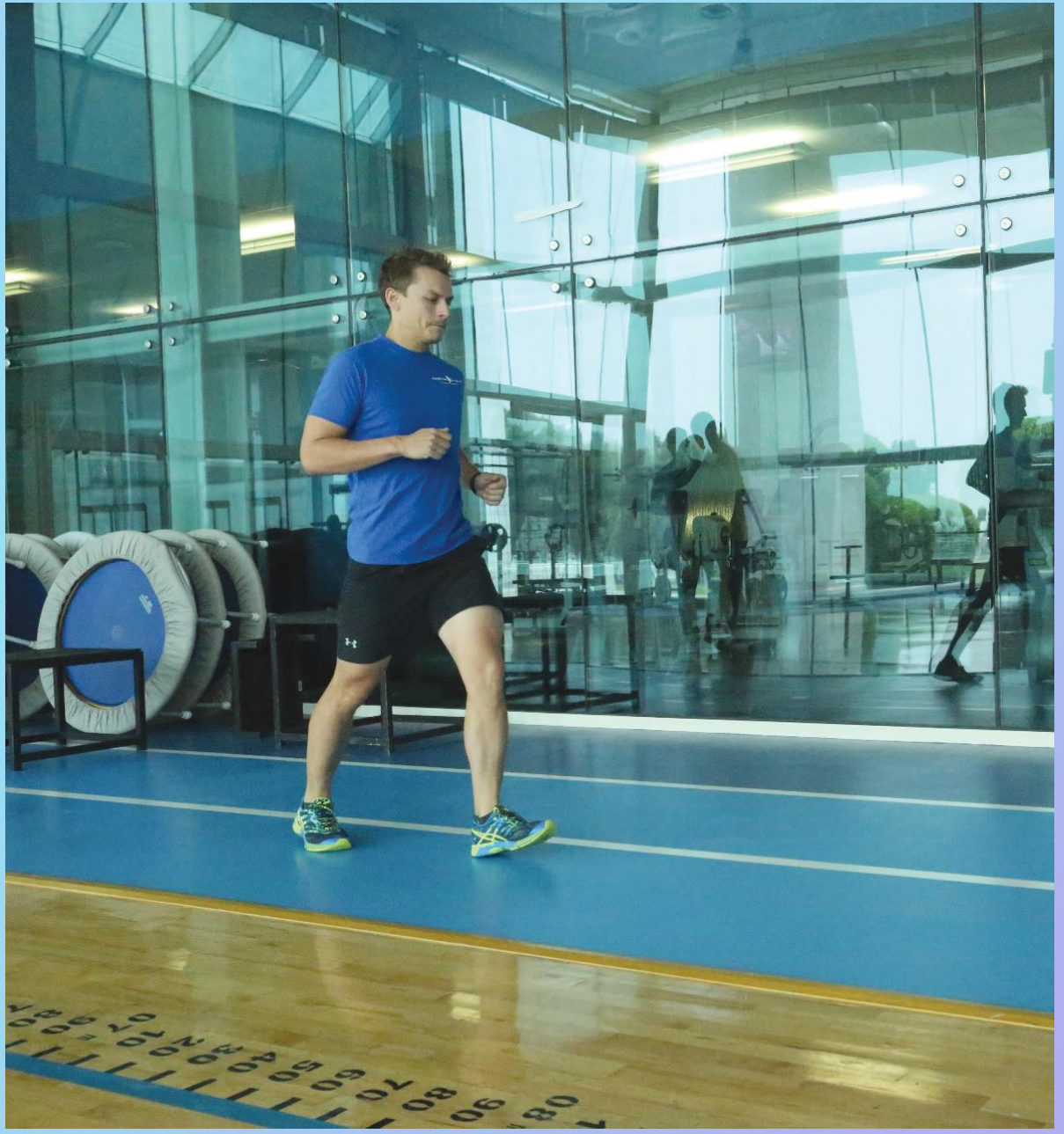
STAGE IV - VI : INTEGRATE FULL SPORTS SPECIFIC PARTICIPATION

1) Symptom free during all activities
2) Complete 3 progressive sports specific sessions with no pain and full

FUNCTION

GAIT – WALKING

The use of crutches and the ability to walk and jog without pain and/or antalgic pattern is noted as normal, antalgic, not able, or has not tried.



STANDING
TRUNK FLEXION

Start in upright position.

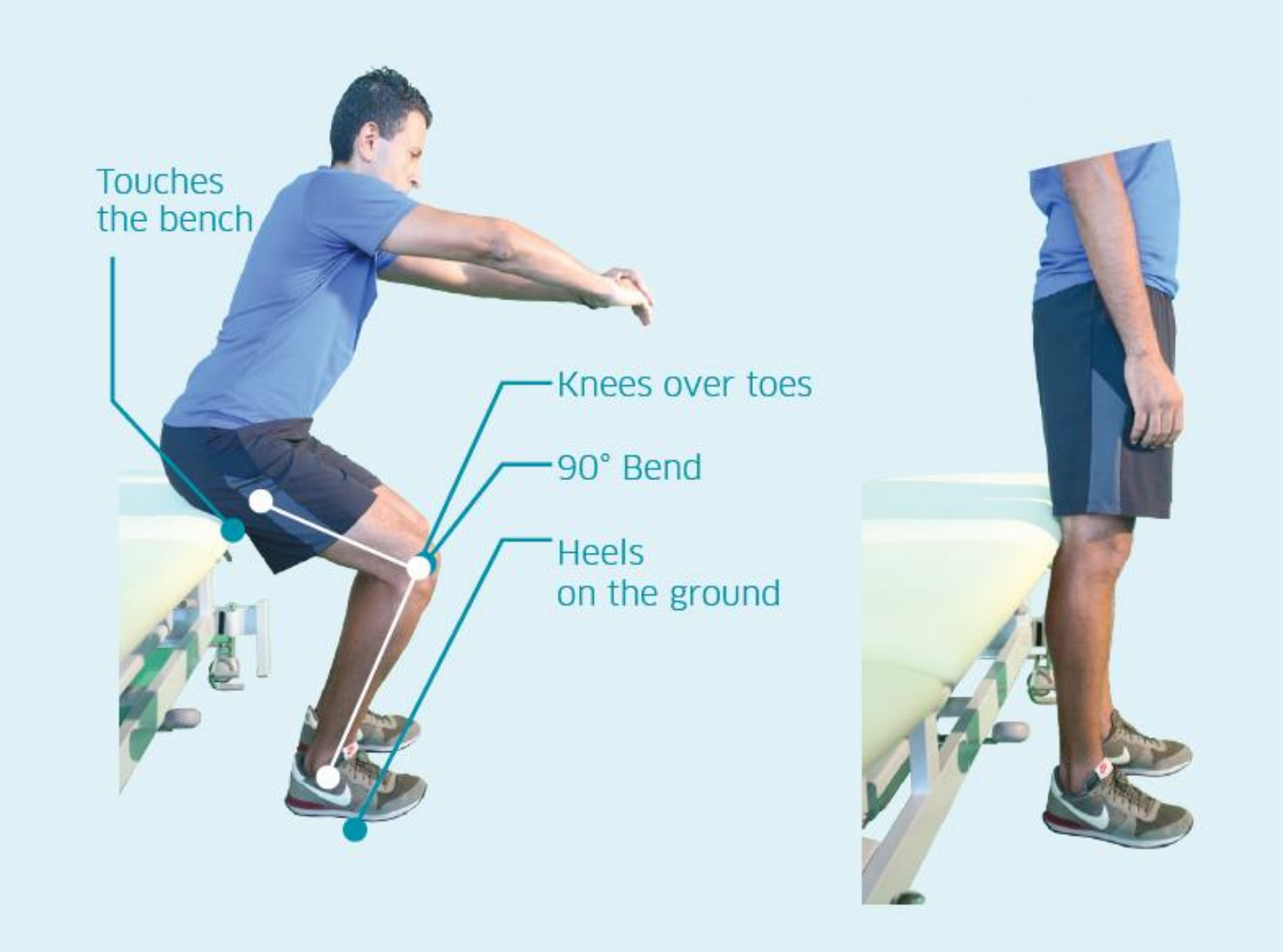
Trunk flexion is performed with hands touching the legs until pain from injured area or a general “stretching pain” is felt.

Level is noted as finger touch level: knees, mid-shins, ankles or floor

DOUBLE

LEG SQUAT ⟶ 90°

Standing with hands on hips with feet shoulder-width apart, examination table at height similar to the knee joint line.



- **The athlete is asked to lower his body by bending his knees until he touches the examination table.**
- **Maintain upright position.**
- **Knee joint aligned over 2nd toe**.

SINGLE LEG SQUAT ⟶ 45°

The patient is asked to lower his body by bending his knees until he touches the bench, keeping the knees directly in line above the feet (2nd toe).

The upper body is maintained in an upright position.

1 leg squat - bench position close up

1 leg squat - starting position

1 leg squat - end position

PALPATION

The athlete indicates the most painful area.

Palpation of the uninjured leg is used as reference to the athlete to identify the known pain.

The clinician palpates the full length of the medial and lateral hamstrings to localize painful area.

The painful area borders are marked cranially, caudally, medially and laterally.

The distance from the ischial tuberosity is noted.

The total length, width and the distance between ischial tuberosity and the area with maximal pain are measured in centemeters

RANGE OF MOTION

PASSIVE STRAIGHT : LEG RAISE (SLR) TEST

The athlete is lying supine while the clinician is fixating the untested leg.

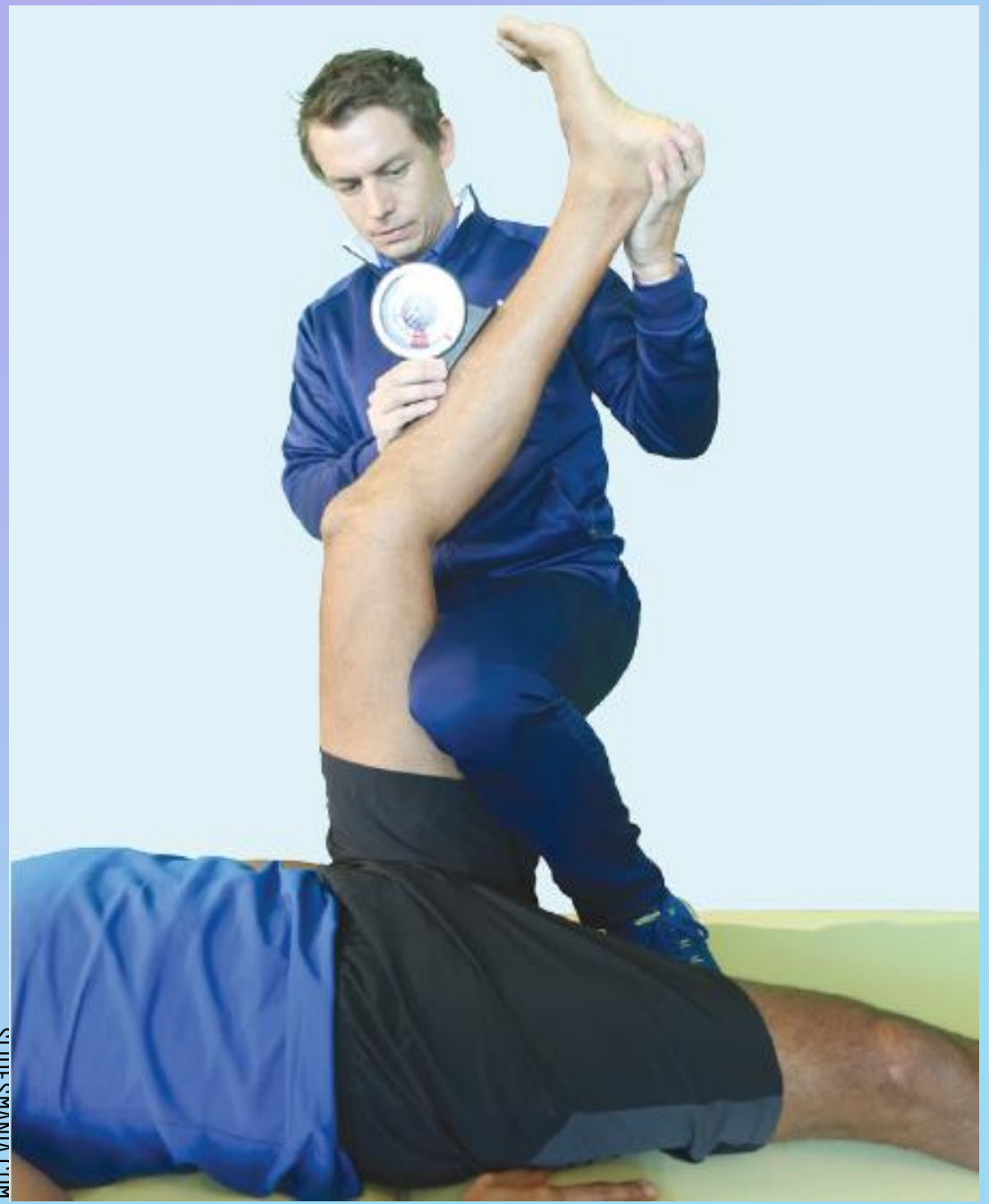
The clinician passively raises the leg, ensuring full knee extension or to the point where the athlete reports pain/onset of discomfort.

Range of motion (i.e. the hip flexion angle from the horizontal plane) is measured by a hand held inclinometer.

PAIN FREE PASSIVE KNEE EXTENSION TEST (PKET)

The athlete is lying supine with hip flexed to 90° while the clinician is fixating the untested leg.

The clinician gradually extends the knee to the point of resistance or the onset of pain/discomfort.



Range of motion (i.e. the knee extension angle) is measured by a hand held inclinometer.

MAXIMAL HIP FLEXION

ACTIVE KNEE EXTENSION (MHFAKE) TEST

The athlete is lying supine with hip towards the maximal flexion using the arms to pull the thigh to the chest.

The contralateral leg is fixated with a belt.

The athlete performs active knee extension until reaching maximal tolerable stretch or the onset of pain/ discomfort.

Range of motion (i.e. knee extension angle) is measured by hand held inclinometer.

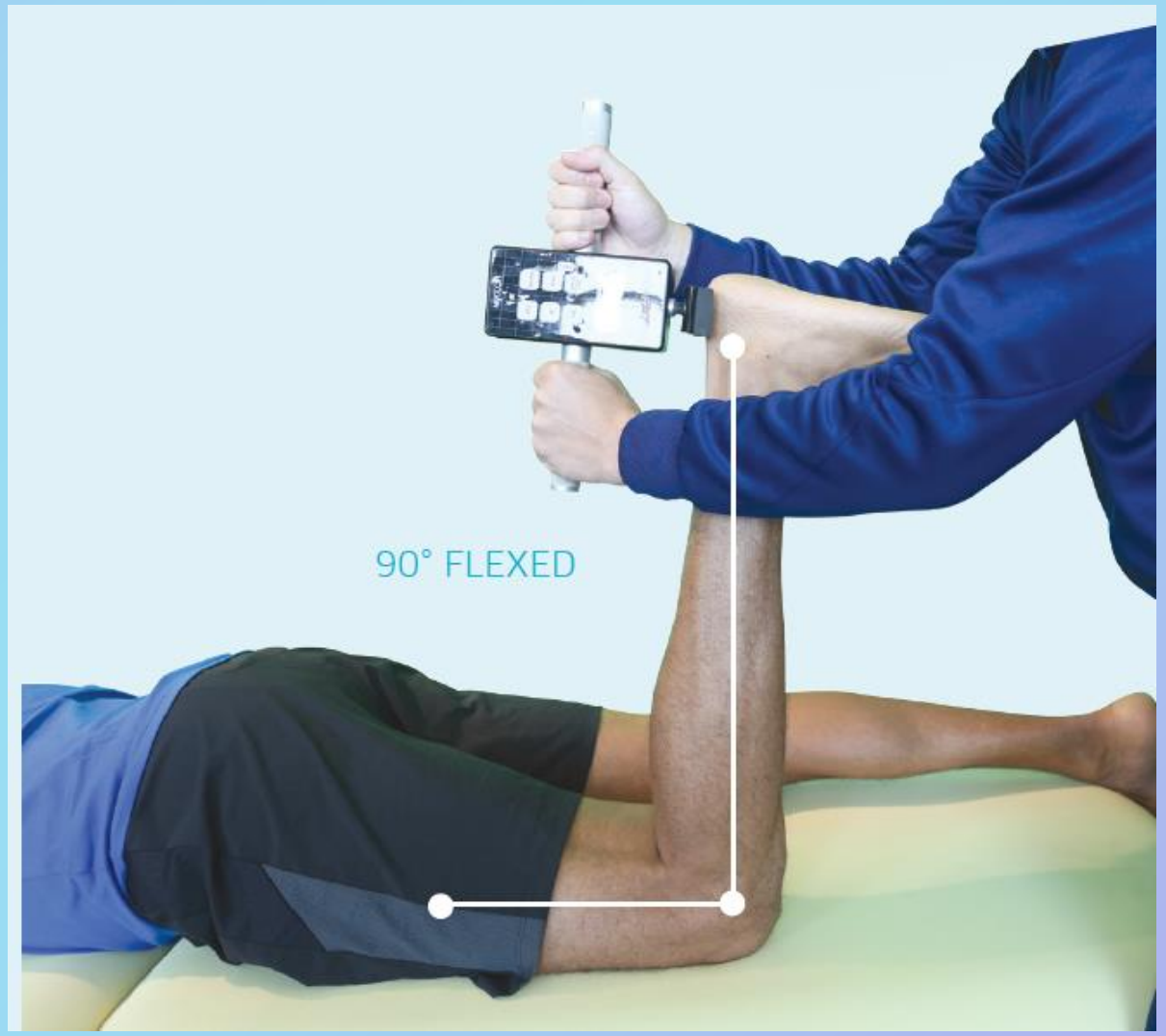
STRENGTH MEASUREMENTS

ISOMETRIC INNER-RANGE :
STRENGTH TEST

The athlete is prone with 90°knee flexion of the tested leg.

The clinician holds the HHD horizontally with both arms against the athlete's posterior heel.

The athlete performs 3 isometric knee flexion for 3 seconds.
(Maximal effort–hard as possible)



Standard instructions:
"Ready - GO! - Push-push-push-push"

ECCENTRIC MID-RANGE STRENGTH TEST

The athlete is lying prone.

The clinician raises the heel one foot length above the examination table holding the HHD vertically against the athlete's posterior heel.

The athlete performs 3 isometric knee flexion for 3 seconds. (Maximal effort–hard as possible)

The clinician applies an eccentric brake test.

Standard instructions:
“Ready - GO! - Push-push-push-push”

ECCENTRIC MID-RANGE STRE

ECCENTRIC OUTER-RANGE STRENGTH TEST

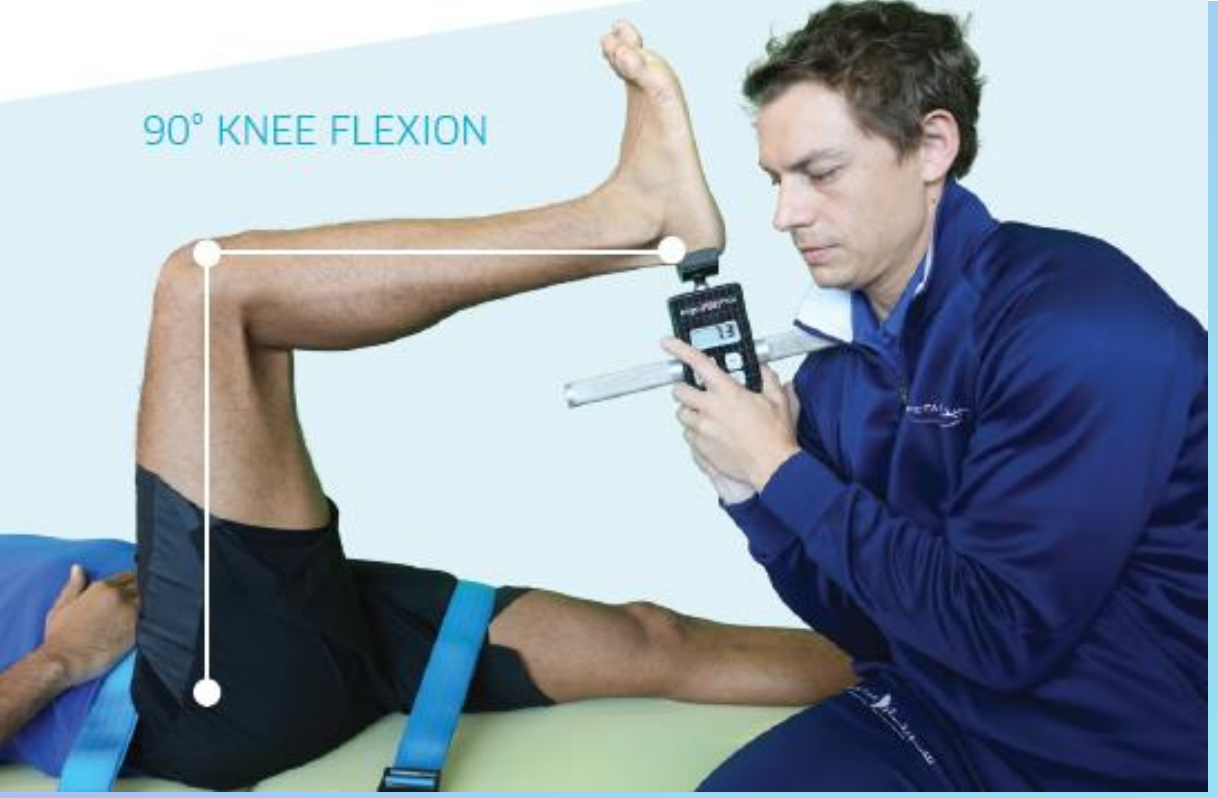
The athlete is lying supine while ASIS/pelvis and the contralateral leg fixated with a belt.

The clinician passively flexes the player's leg to 90° knee flexion, holding the HHD vertically against the athlete's posterior heel.

The athlete performs 3 isometric knee flexion for 3 seconds. (Maximal effort – hard as possible).

The clinician applies an eccentric brake test.

Standard instructions:
"Ready - GO! - Push-push-push-push"



DOUBLE TO SINGLE LEG BRIDGE

Lift buttocks into hip extension with:
Stage 1-3

Two legs (knees flexed to ±90°)
Stage 4

Single leg (knee flexed to ±90 °)
Stage 5

Injured leg positioned on a bench or the clinicians shoulder

RETURN TO SPORT (RTS)
(All assessments repeated)

Askling H-test _ Nordic Hamstring Exercise _ Isokinetic Strength Test

DYNAMIC FLEXIBILITY
H-TEST BY ASKLING

The athlete is lying supine with the contralateral leg and the upper body fixed with a belt.

A knee braces ensures full extension of the tested knee (0°).
No warm-up exercises!

Passive flexibility test where the clinician slowly raises the testing leg towards maximal hip flexion. Strong, but tolerable stretching in the hamstring muscle.

The active flexibility test consists of 1 practice trial (submaximal effort)3 consecutive test trials:The athlete performs a straight leg raise as fast as possible to the highest point without taking any risk.

The athlete is asked to estimate experience of insecurity and pain on a VAS-scale from 0 to 100.

NORDIC HAMSTRING EXERCISE WITH NORDBORD

The athlete is kneeling on either the Norbord with ankles fixed in the stirrups.

The athlete is then instructed to fall forward, and resist the fall to the ground for as long as possible using his hamstring muscle.

Hip and lumbo-pelvic control alignment good control throughout the movement

1 set of 3 repetitions

ISOKINETIC STRENGTH TESTING

The athlete is seated upright on the dynamometer and fixated with straps instructed to grip the chair handles throughout the test .

The axis of knee rotation is aligned collinear to the lateral femoral condyle and gravitational correction is performed at 30° of knee flexion .

During the test, the athlete is given vigorous verbal encouragement to exert maximal effort throughout the test .

quadriceps and hamstrings concentric 60°/s (5 trials) concentric 300°/s (10 trials) hamstrings Eccentric 60°/s (5 trials)

EXERCISES

2 LEG SQUAT EXERCISE

Instructions:

The athlete is asked to lower his body by bending his knees until he reaches 45°-90° (or pain is felt).

The upper body is supposed to be as straight as possible.

*Knees over toes, heels on the ground.
3 x 15

Progression:
The exercise is performed with weights
3 x 8

EXERCISE BIKE

1st session:
start at 50 Watt for 30 sec. Increase the load/intensity with 25 W every 30 seconds until it reaches the highest level of cycling continuously for 5 minutes.

Aim:
2 X Bodyweight = Power output (W)
5min warm up, 5min hard!

SUPINE 2 LEG BRIDGE

Starting position

One knee is flexed and placed beside medial knee joint line of the other leg, which is then placed similarly, leaving both knees flexed approximately 90°.

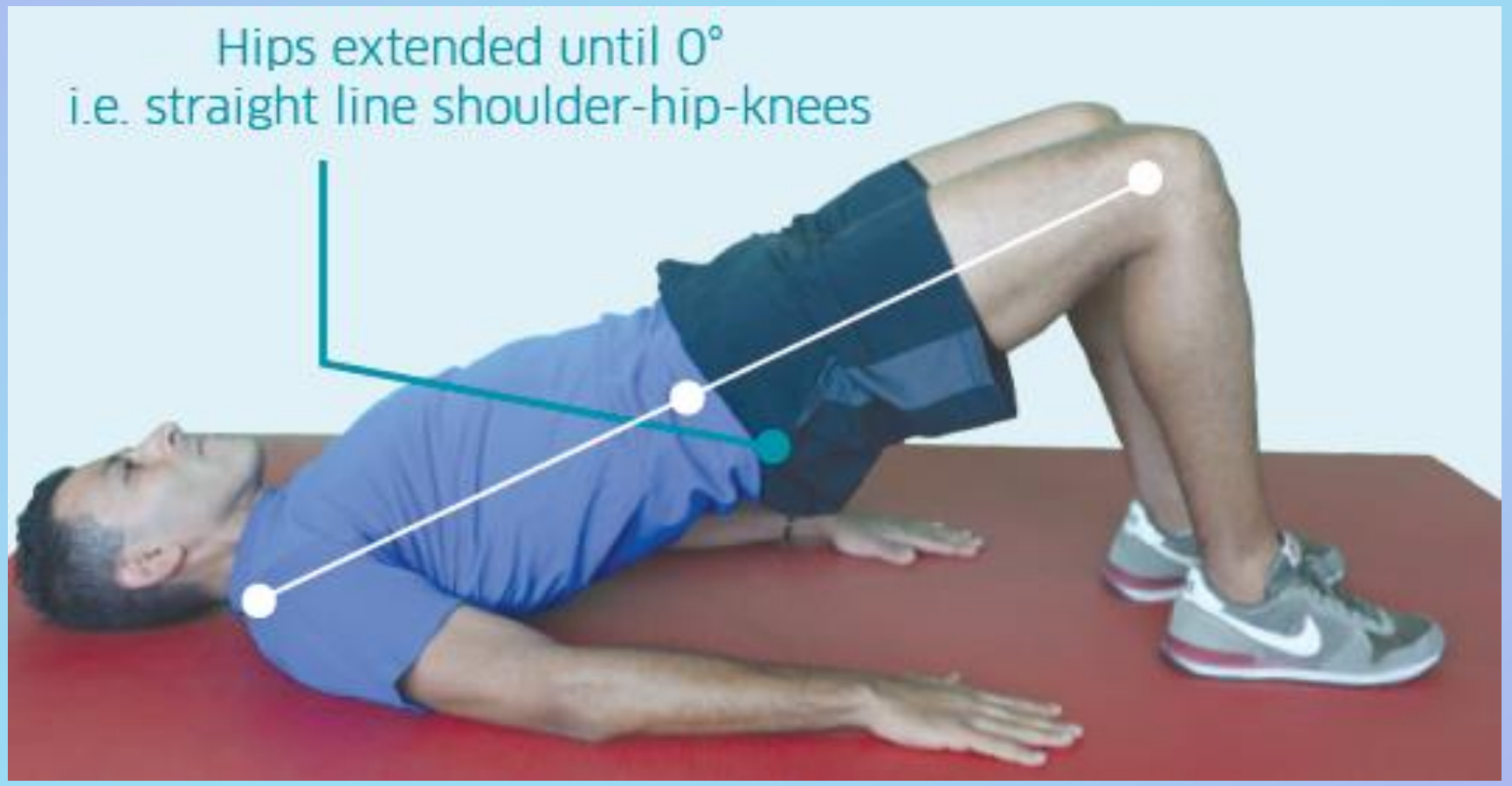
Instructions:

The athlete is instructed to perform 3 repetitions of hip extension, where he pushes down through the heels and lifts the hips off the ground towards full hip extension.

3 X 12

***Good quality, i.e.: ASIS/pelvis horizontally throughout the whole movement**

Hips extended until 0°, i.e. straight line shoulder – hips - knees



SUPINE ISOMETRIC HEEL DIGS

Starting position The athlete is lying supine or sitting on the bench with the knees flexed at an angle of approximately 90 °.

Instructions:

The athlete is instructed to push down through the heel by activating the hamstrings and hold the position for approximately 5 seconds .

3 X 12

Isometric contractions in different angles towards end
ROM; 90° - 60° - 30°

SINGLE LEG SQUAT EXERCISE

Starting position

The athlete is standing with the uninjured leg slightly bent with hands on hips.

Instructions:

The athlete is asked to lower the body in a squatting position by bending his knees while the knee in the standing leg is directly in a line above the feet (2nd toe).
3 X 8

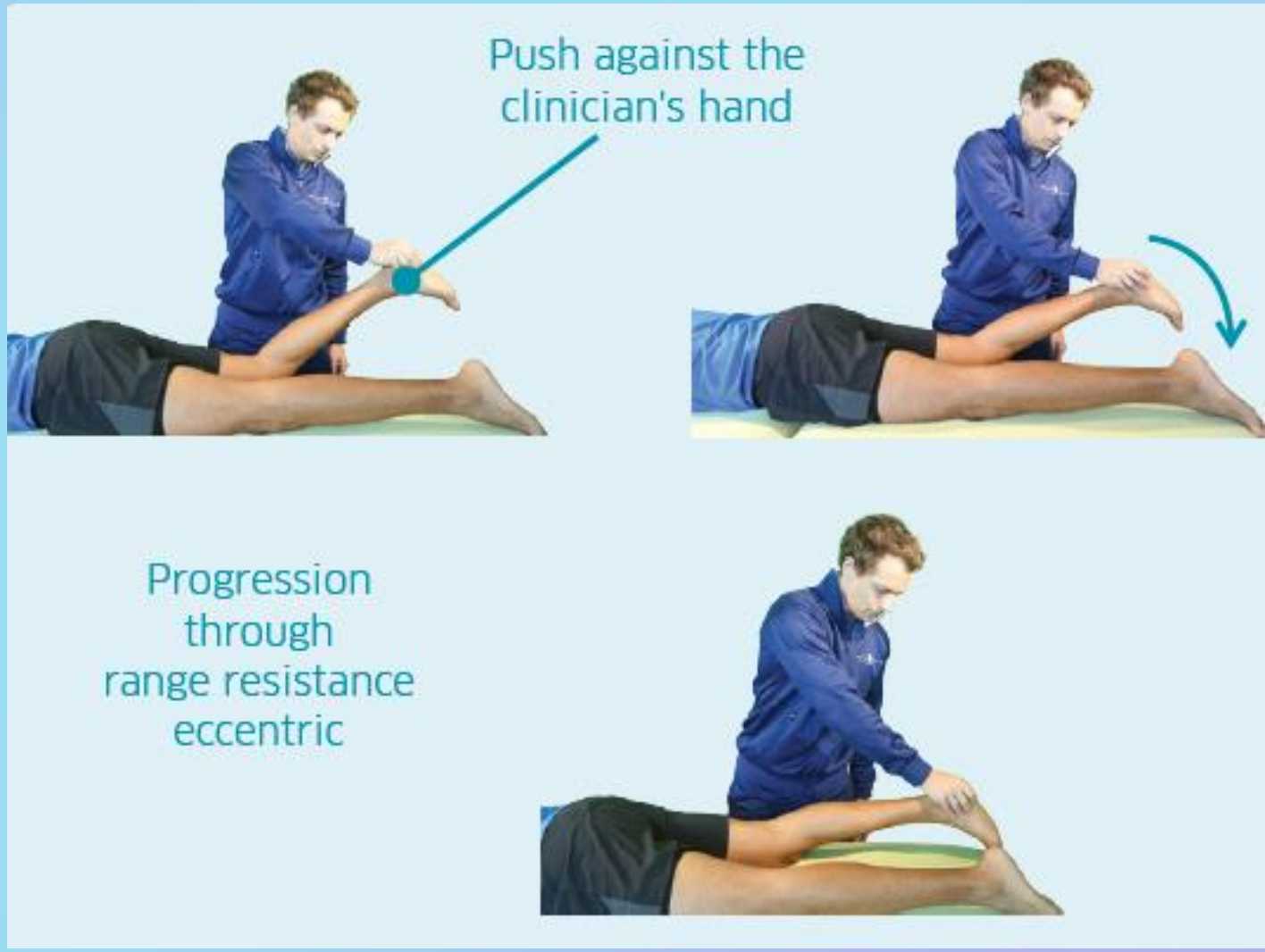
Progression:
The exercise is performed with weights

MANUAL RESISTED : HAMSTRINGS

Starting position
The athlete is lying in prone position with knees flexed. The therapist applies isometric resistance in varying angles.

Instructions:

The athlete is instructed to push against the therapist's hand, which is placed on the posterior calcaneus.
3 X 12



Progression:
In supine position with hip flexed: resistance towards the end ROM (eccentric)

MANUAL RESISTED : Soft tissue mobilization

Starting position

The athlete is lying in prone position. Effleurages/lymphatic drainage is performed distal and proximal to injury site.

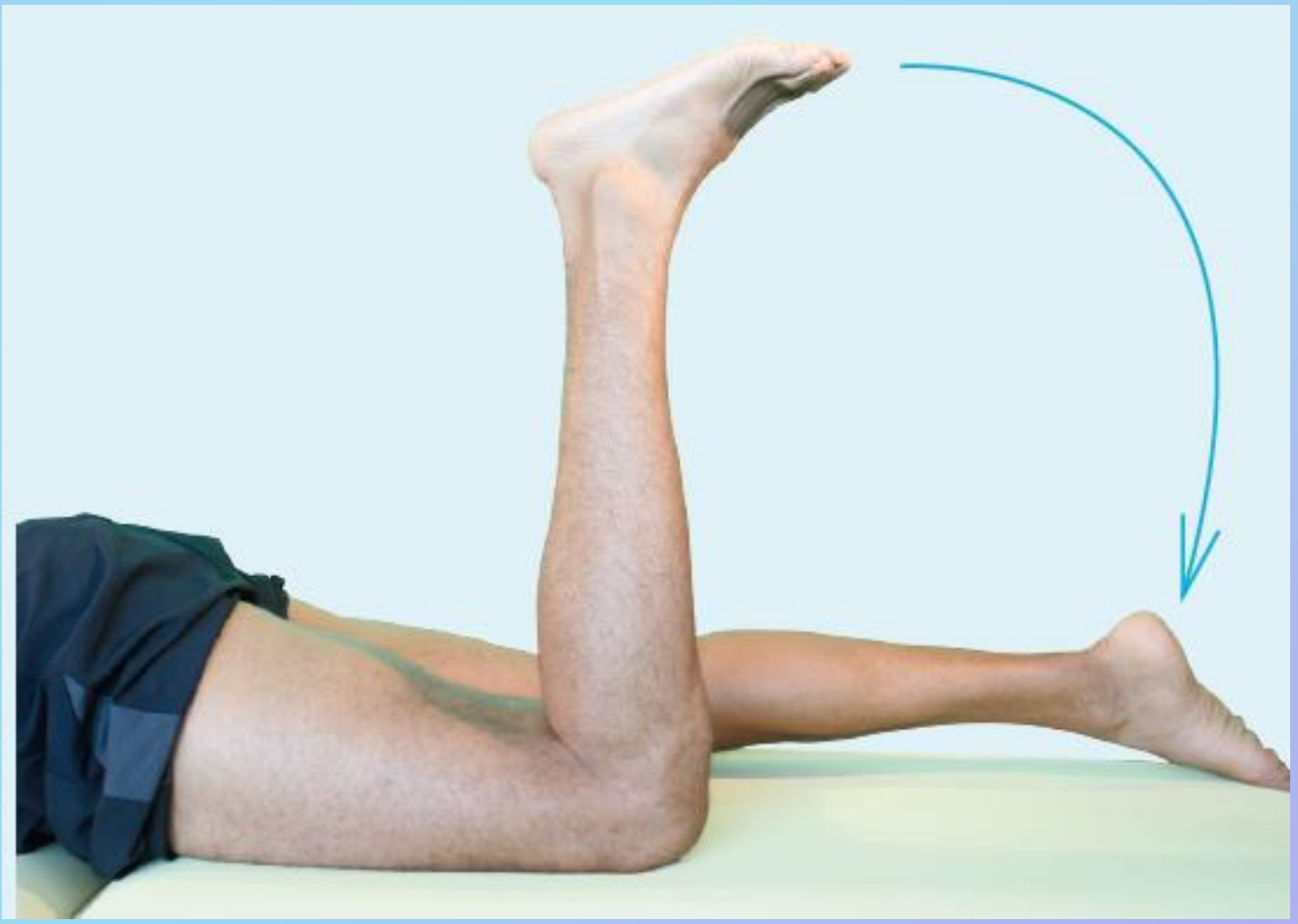
Instructions:

The athlete is instructed to be relaxed and report if he feels pain or any kind of discomfort during the treatment.
5-10 minutes

Progression:
Massage of the injured area allowed in Stage 2

ACTIVE RANGE OF MOTION (ROM)

Starting position
Athlete is lying in prone position with both legs extended.
Instructions



Instructions:

The athlete is instructed to actively bend the knee of the injured leg until the heel touches the buttock and then slowly extend the knee towards a straight leg position again.

3 X 8

THE EXTENDER

Starting position

The athlete is lying supine, holding and stabilize the thigh of the injured leg with the hip flexed approximately 90°.

Instructions:

The athlete is instructed to perform slow knee extensions to a point just before pain is felt.

(3x12) x 2

Progression:
Increase speed.

THE DIVER

Starting position

The athlete is standing with full weight on his injured leg and the opposite knee slightly flexed backwards.

Instructions:

The athlete is asked to perform the exercise as a simulated dive (hip flexion from an upright trunk position) of the injured, standing leg and simultaneous stretching arms forward and attempting maximal hip extension.
3 X 6

***Good quality, ASIS/pelvis horizontally throughout the whole movement**
***Maintain 10–20° knee flexion in the standing leg.**

THE GLIDER

Starting position

The exercise is started with the patient positioned with upright trunk, one hand holding on to a support and legs slightly split. All the body weight should be on the heel of the injured leg with approximately 10–20° knee flexion

Instructions:

The athlete is instructed to perform a gliding backward movement on the other leg and stop the movement before pain is reached. The movement back to the starting position should be performed by the help of both arms, not using the injured leg.

3 X 6

Progression is achieved by increasing the gliding distance and performing the exercise faster.

SUPINE ONE LEG BRIDGE

Starting position

The athlete is lying supine with arms placed in a comfortable position with knees flexed.

Instructions:

The athlete is instructed to raise his untested leg off the examination table and then perform repetitions of hip extension, where he pushes down through the heel of the tested leg and lifts the hips off the ground towards full hip extension.

4 X 15

Progression
Exercise performed on a step/clinician's shoulder

STRETCHING

The athlete is instructed to relax and the therapist perform a gentle stretch with the leg in:

1) **Straight leg raise (SLR) position**
2) **2) Maximal hip flexion + knee extension (MHFAKE position).**

Instructions:

Towards the end ROM where the athlete either reports a stretch or onset of pain, 5 isometric contractions areperformed (hold-release), before a gentle passive stretch is applied further.

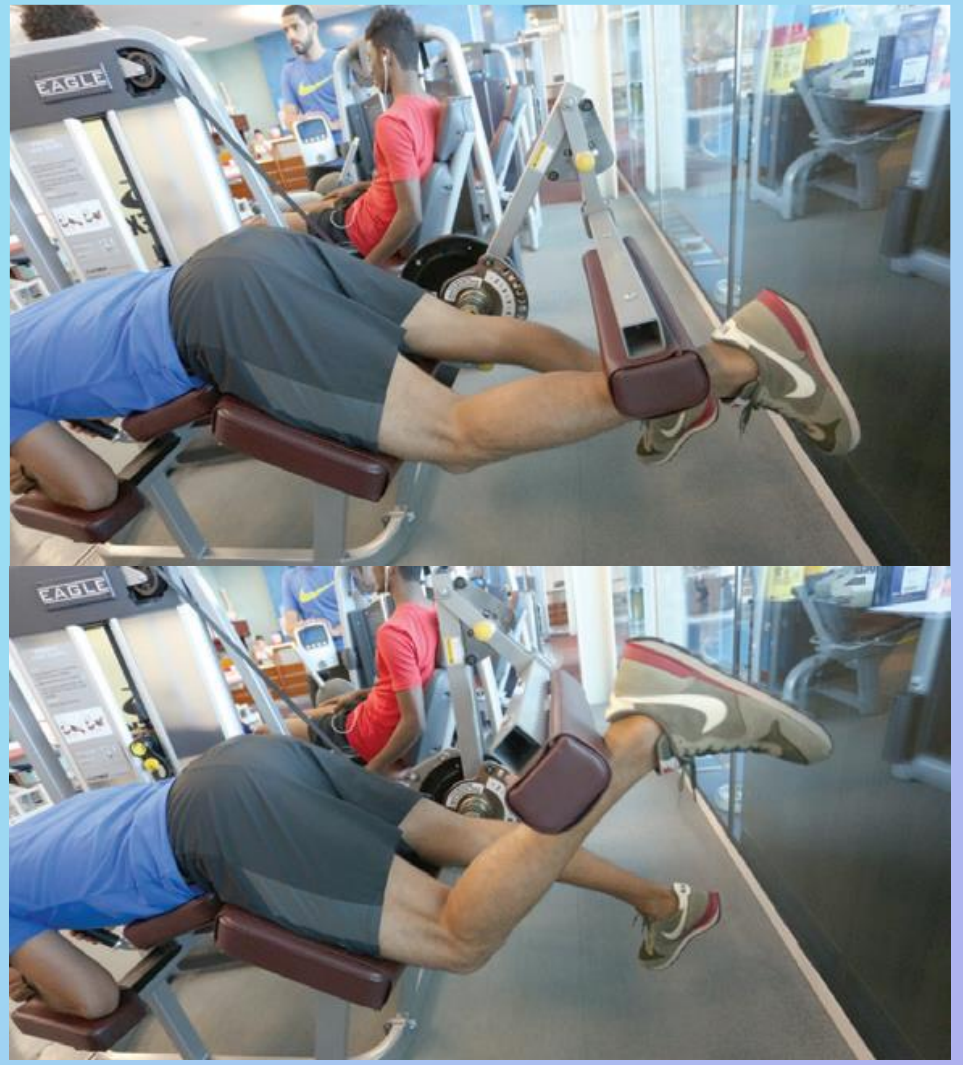
3 x 30 seconds

MHFAKE position

RESISTED HAMSTRING CURL EXERCISE

Starting position:

The athlete is lying prone in the leg curl machine. Make sure the length of the lever arms are adjusted to the patients leg length.



Instructions:

The athlete is instructed to perform slow continuous knee flexions and knee extensions with the injured leg, only, starting with a load that is acceptable and pain free.

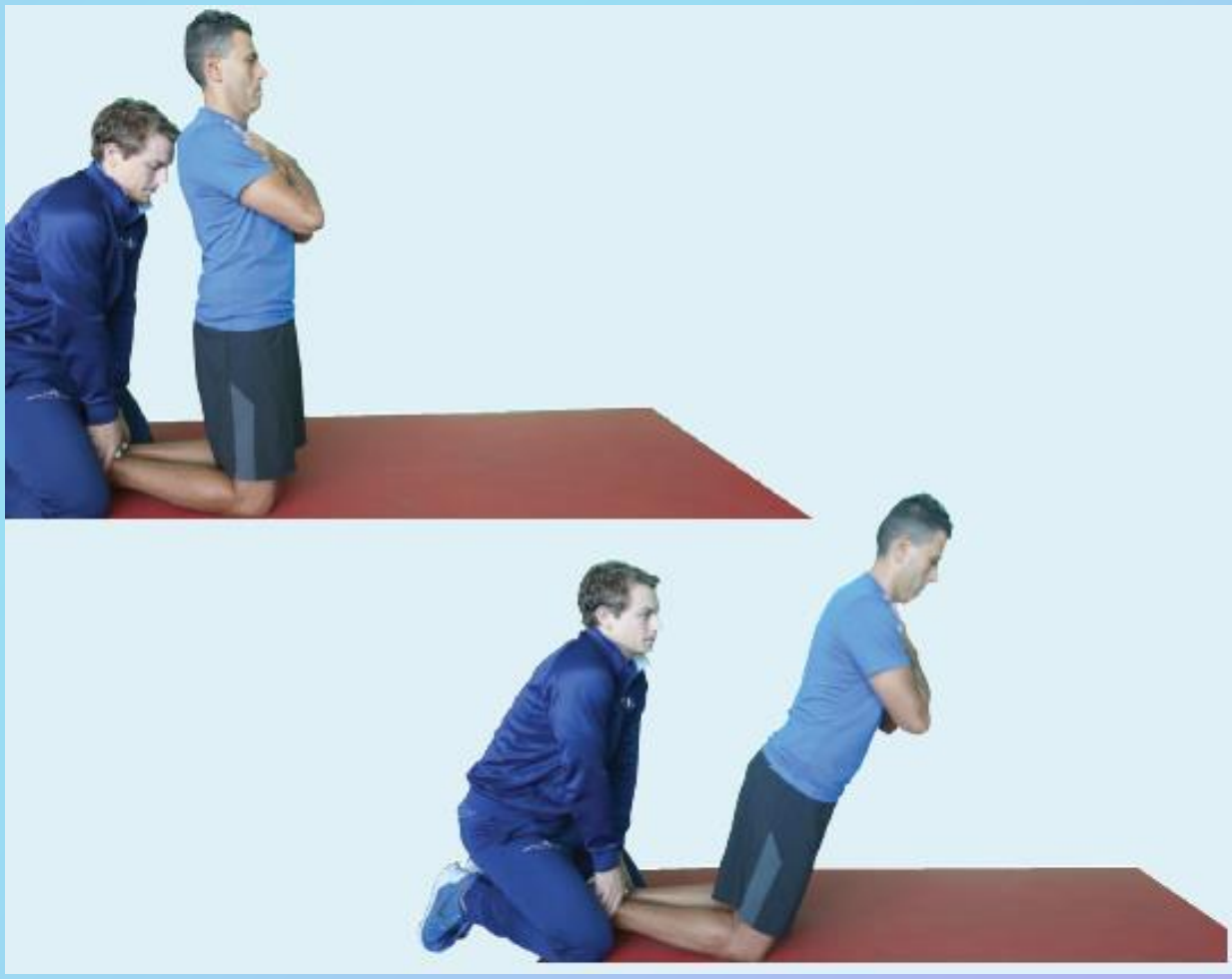
Progression:

I: Increasing load (kg)
II: Increasing load in eccentric phase

ECCENTRIC NORDIC HAMSTRING EXERCISE

Starting position:

The athlete is kneeling on either the Nordbord with ankles fixed or on a mat with the therapist fixating the ankles.



Instructions:

The athlete is then instructed to fall forwards, and resist the fall to the ground as long for as possible using their hamstring muscle.

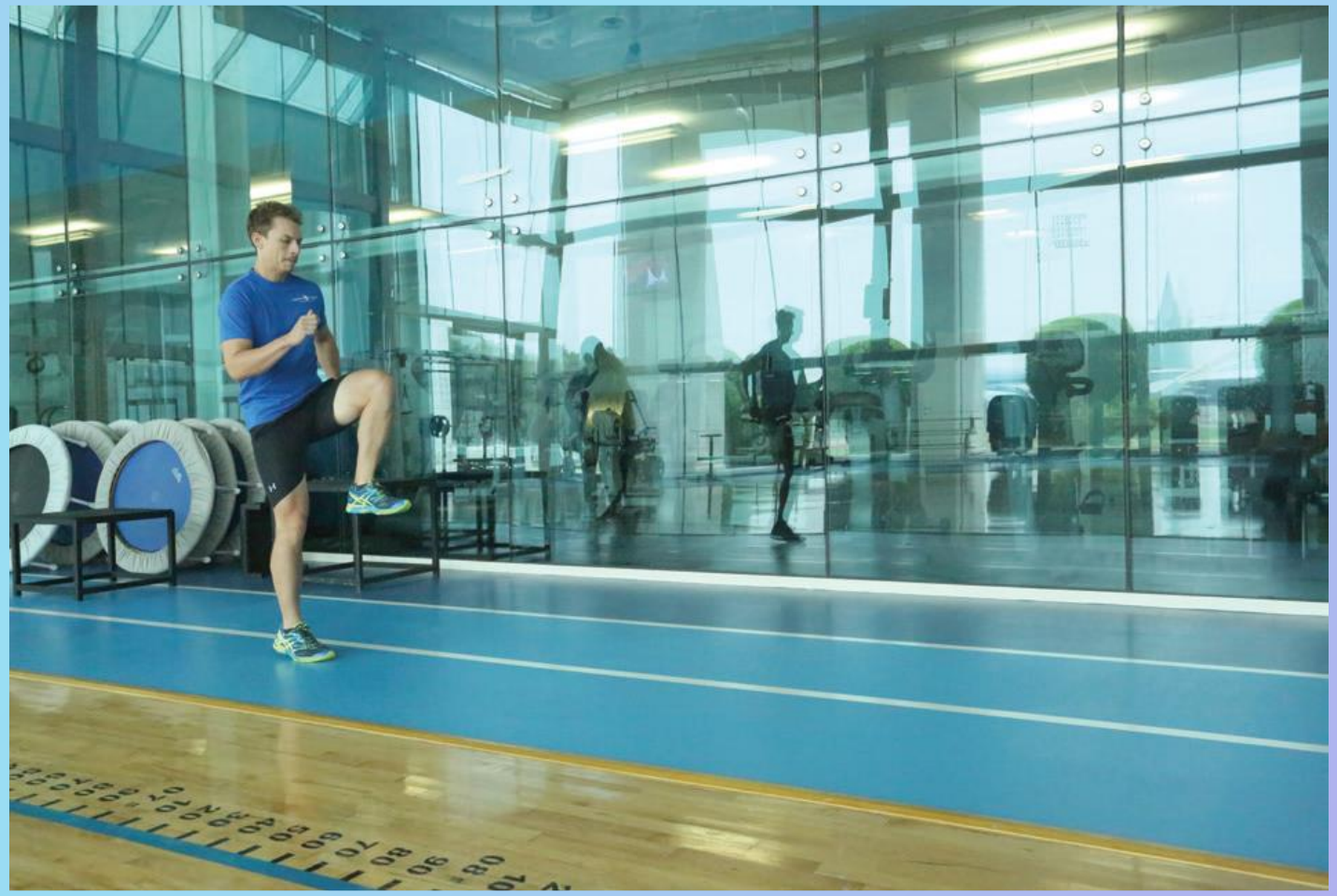
- ✓ **Complete 2 painfree sessions before progression to next level**
- ✓ **Complete all 3 sessions, drop only, then progress through session again with drop and curl**

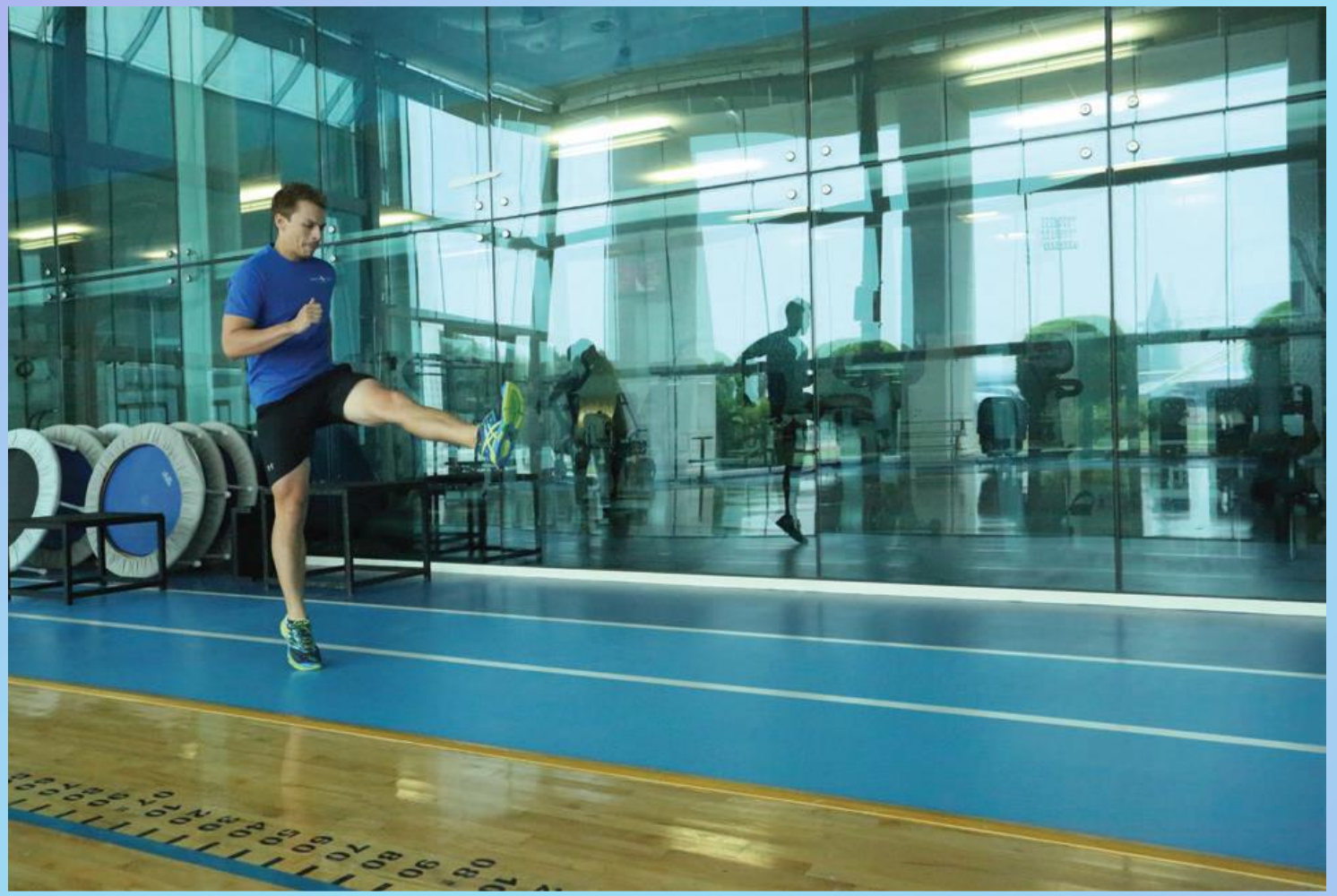
***That the loading of the injured leg is similar to the uninjured leg (without pain) 3 times per week**

1) 2x 5 reps, drop only
2) 2(3)x 5 – 8, drop only
3) 2(3)x 8 – 12, drop only
4) Repeat sessions 1-3 with drop AND curl

RUNNING PROGRAM A DRILL–HIGH KNEE WITH KICKS

“A” Drill
High knee with “Kicks”
(Each lap = 25-50m x2)





Instructions:

The athlete is instructed to lift his knee as high as possible and extend the knee down in a circular motion “sweeping” the floor.
3 X 4 laps

RUNNING PROGRAM TRIPLE EXTENSION WALK HIGH KNEES

Triple Extension Walk
High knee only
(Each lap = 25-50m x2)

Instructions:

The athlete is instructed to lift the knee as high as possible in a jumping motion, and repeat on the other side.

3 X 4 laps

RUNNING PROGRESSION

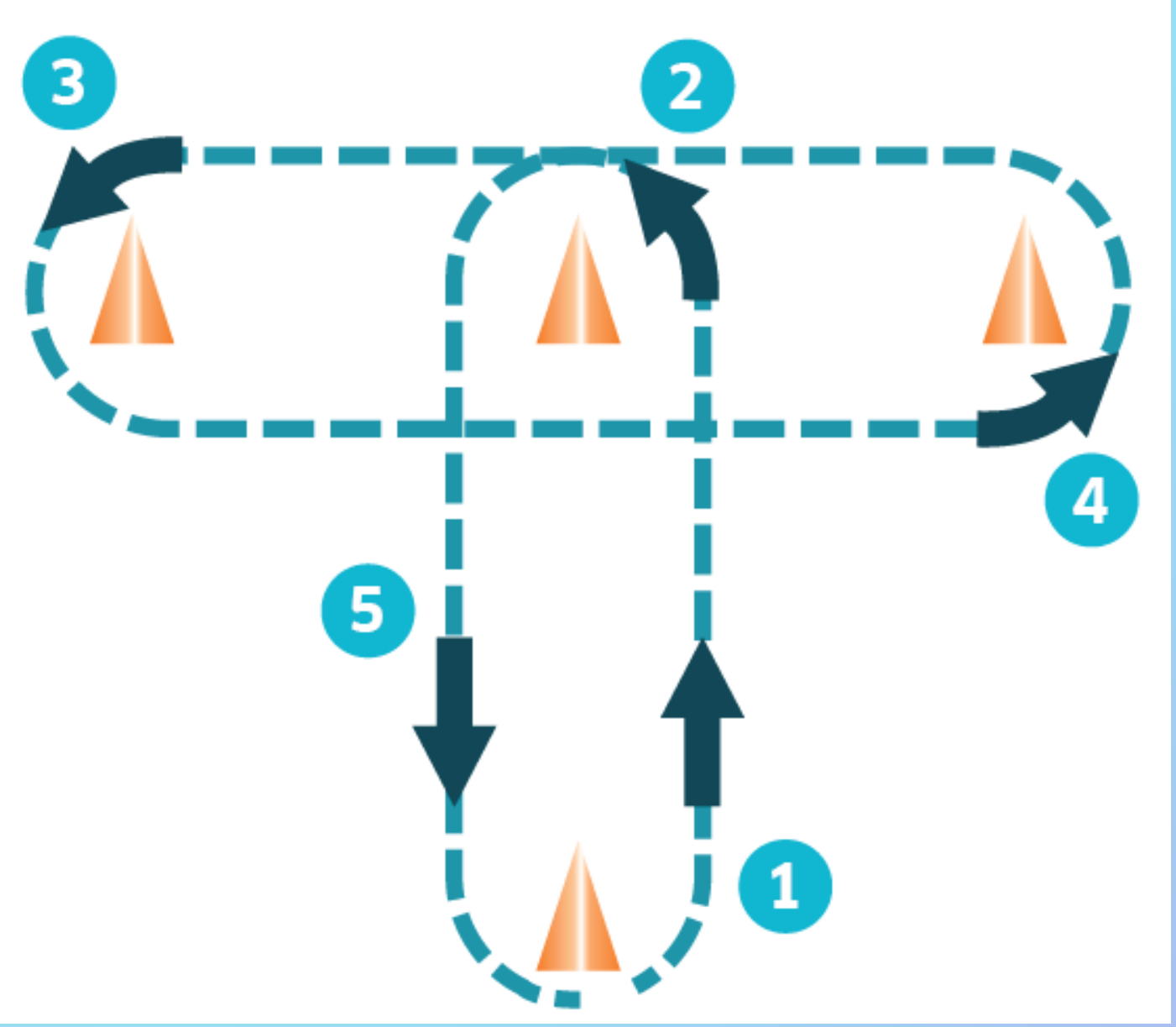
The running progression programme includes volume, intensity and running mechanics. It is performed under supervision to facilitate these components are executed Well.

When the athlete starts with the running progression, he is asked to rate the running from the very first lap.

Both the % rated by the athlete, as well as the timed run/ sprint is recorded to allow for gradual progression of the running.

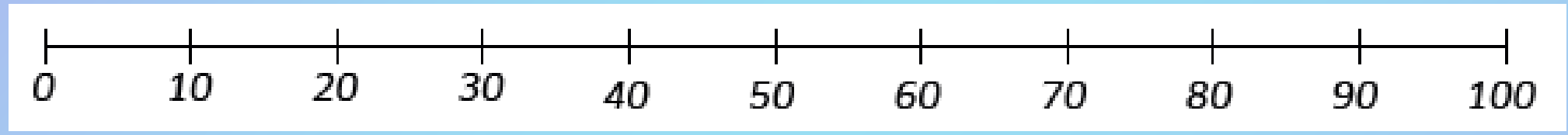
3 X 4 laps
Progression
0 – 100%

3 reps
12s → 3s
60% → 100%



Modified T-drill where the run starts at 1 and follows the numbers sequentially running around cones

% linear scale where the athlete is asked to indicate the speed at which he/she is running



The athlete is asked to run (from a standing start) and touch each of the cones, continuously in a forward motion while changing direction without any side stepping or backwards running

HAMSTRING PROTOCOL
Daily assessments

Injured leg: LEFT RIGHT No = no pain, P = pain, NA = not able, SLR = straight leg raise, MHFAKE = maximal hip flexion active knee extension, ° = degrees, kg = kilograms

	/ /201_ Days Post: Sign:		/ /201_ Days Post: Sign:		/ /201_ Days Post: Sign:		/ /201_ Days Post: Sign:		/ /201_ Days Post: Sign:	
	INJURED	UNINJURED	INJURED	UNINJURED	INJURED	UNINJURED	INJURED	UNINJURED	INJURED	UNINJURED
Self-reported readiness	0 10 20 30 40 50 60 70 80 90 100		0 10 20 30 40 50 60 70 80 90 100		0 10 20 30 40 50 60 70 80 90 100		0 10 20 30 40 50 60 70 80 90 100		0 10 20 30 40 50 60 70 80 90 100	
Average pain today	VAS /10		VAS /10		VAS /10		VAS /10		VAS /10	
Walking	No P NA		No P NA		No P NA		No P NA		No P NA	
Jogging	No P NA		No P NA		No P NA		No P NA		No P NA	
2 leg squat x 3	No P NA		No P NA		No P NA		No P NA		No P NA	
1 leg squat x 3	No P NA		No P NA		No P NA		No P NA		No P NA	
Trunk flexion	No P NA		No P NA		No P NA		No P NA		No P NA	
Total palp. length:	cm P		cm P		cm P		cm P		cm P	
Mid range	kg P | no	kg	kg P | no	kg	kg P | no	kg	kg P | no	kg	kg P | no	kg
Outer range	kg P | no	kg	kg P | no	kg	kg P | no	kg	kg P | no	kg	kg P | no	kg
SLR	° P | no	°	° P | no	°	° P | no	°	° P | no	°	° P | no	°
MHFAKE	° P | no	°	° P | no	°	° P | no	°	° P | no	°	° P | no	°
Bent leg bridge 3x	No P NA		No P NA		No P NA		No P NA		No P NA	
Straight leg bridge 3x	No P NA		No P NA		No P NA		No P NA		No P NA	
Comments:										

	/ /201_ Days Post: Sign:		/ /201_ Days Post: Sign:		/ /201_ Days Post: Sign:		/ /201_ Days Post: Sign:		/ /201_ Days Post: Sign:	
	INJURED	UNINJURED	INJURED	UNINJURED	INJURED	UNINJURED	INJURED	UNINJURED	INJURED	UNINJURED
Self-reported readiness	0 10 20 30 40 50 60 70 80 90 100		0 10 20 30 40 50 60 70 80 90 100		0 10 20 30 40 50 60 70 80 90 100		0 10 20 30 40 50 60 70 80 90 100		0 10 20 30 40 50 60 70 80 90 100	
Average pain today	VAS /10		VAS /10		VAS /10		VAS /10		VAS /10	
Walking	No P NA		No P NA		No P NA		No P NA		No P NA	
Jogging	No P NA		No P NA		No P NA		No P NA		No P NA	
2 leg squat x 3	No P NA		No P NA		No P NA		No P NA		No P NA	
1 leg squat x 3	No P NA		No P NA		No P NA		No P NA		No P NA	
Trunk flexion	No P NA		No P NA		No P NA		No P NA		No P NA	
Total palp. length:	cm P		cm P		cm P		cm P		cm P	
Mid range	kg P | no	kg	kg P | no	kg	kg P | no	kg	kg P | no	kg	kg P | no	kg
Outer range	kg P | no	kg	kg P | no	kg	kg P | no	kg	kg P | no	kg	kg P | no	kg
SLR	° P | no	°	° P | no	°	° P | no	°	° P | no	°	° P | no	°
MHFAKE	° P | no	°	° P | no	°	° P | no	°	° P | no	°	° P | no	°
Bent leg bridge 3x	No P NA		No P NA		No P NA		No P NA		No P NA	
Straight leg bridge 3x	No P NA		No P NA		No P NA		No P NA		No P NA	
Comments:										

Weight:
Leg injured: □ LEFT □ RIGHT

Patient label

WEEK:			/ /201_ Sign:			/ /201_ Sign:			/ /201_ Sign:			/ /201_ Sign:			/ /201_ Sign:			/ /201_			/ /201_ Sign:		
STAGE and Volume difficulty	TREATMENT	SETS/ REPS	Sets	Reps	Load	Sets	Reps	Load	Sets	Reps	Load	Sets	Reps	Load	Sets	Reps	Load	Sets	Reps	Load	Sets	Reps	Load
1	2 LEG SQUAT *Prog: with weights*	3 x 15 3 X 8																					
1	EXERCISE BIKE *(Watt: 2x BW) 5min + 5 min*	5 mins																					
1 2	SUPINE BRIDGE 2 LEGS	3 X 12																					
1 2	SUPINE ISOMETRIC HEEL DIGS	3 X 12																					
1 2	SINGLE LEG SQUAT → 45° *Prog: with weights*	3 X 8 3 x 15																					
1 2	MANUAL RESISTED HAMSTRINGS	3 X 12																					
1 2	SOFT TISSUE	5 mins																					
1 2	ACTIVE ROM	3 x 8																					
1 2 3	"THE EXTENDER" *Daily*	(3 x 12) x 2																					
1 2 3	"ARABESQUE/DIVER" *Every 2nd day*	3 x 6																					
1 2 3	"THE GLIDER" *Every 3rd day*	3 x 6																					
2 3	SUPINE BRIDGE 1 LEG *2 sec up/2 sec down* *2sec up/1 sec down* *On step* *On exercise ball*	4 x 15																					
2 3	STRETCHING (SLR and PKET)	3 X 30 s																					
2 3	RESISTED HAMSTRINGS 1. Prone leg curl 2. Prone leg curl eccentric 3. Heavy Squats	 4 x 15 4 x 8 4 x 8																					
3	ECCENTRIC STRENGTHENING Nordic hamstring	2 x 5/3 x 6																					

Criteria for progression

Criteria for progression from Stage 1 to Stage 2:

1. Painless Single Leg Squat
2. Painless Bike, W: 2x Body Weight, 5 minutes (level 6-7)

Criteria for progression from Stage 2 to Stage 3:

1. Run ≥ 70% Patient-rated
2. Pain mid-range test ≤VAS 2

Criteria for progression from Stage 3 to Sports Spec Rehab:

1. 100% running speed
2. Painless high speed direction changes
3. Must demonstrate ability to acceleration/decelerate without any discomfort during high speed running

HAMSTRING PROTOCOL
Running Progression

Patient label

Leg injured: □ LEFT □ RIGHT

WEEK:			Date / / 201_ Sign:			Date / / 201_ Sign:			Date / / 201_ Sign:			Date / / 201_ Sign:			Date / / 201_ Sign:			Date / / 201_ Sign:			Date / / 201_ Sign:		
STAGE	PREPARATION EXERCISES	SETS/ LAPS	Sets/ Laps			Sets/ Laps			Sets/ Laps	Best Time % max		Sets/ Laps			Sets/ Laps			Sets/ Laps			Sets/ Laps		
2+3	Triple Extension Walk *High knee only* *(Each lap = 100m x2*	3 x 1																						
2+3	"A" Drill *High knee with "Kicks"* *(Each lap = 100m x2)*	3 X 1																						
	RUNNING ROGRESSION	SETS/ LAPS	Sets/ Laps	Best Time	% max	Sets/ Laps	Best Time	% max	Sets/ Laps	Best Time	% max	Sets/ Laps	Best Time	% max	Sets/ Laps	Best Time	% max	Sets/ Laps	Best Time	% max	Sets/ Laps	Best Time	% max	Sets/ Laps	Best Time	% max
2+3	Walk – Jog (10 -70%) Jog –Run (70 - 100%)	3 x 4																						
3	*Timing*		Set I: Set II: Set III:			Set I: Set II: Set III:			Set I: Set II: Set III:			Set I: Set II: Set III:			Set I: Set II: Set III:			Set I: Set II: Set III:			Set I: Set II: Set III:		
3	Modified T-Drill (70 – 100%) (≤ 11 sec.)	3 x 1																						
	Timing		Set I: Set II: Set III:			Set I: Set II: Set III:			Set I: Set II: Set III:			Set I: Set II: Set III:			Set I: Set II: Set III:			Set I: Set II: Set III:			Set I: Set II: Set III:		
	Comments																							
	PROGRESSION	**Walk – Jog:** *Begin running at 10-25% (patient-rated), progression by 10% step to max.70%.* **Jog – Run** and **Modified T-Drills:** *Begin running at 70% (patient-rated), progress as able by 10%. At 90%, progress by 5%.*																						

Return to Sport After Hamstring Injuries

Return to Sport Principles After Hamstring Injury

- Three steps as part of a RTS continuum:
  1. Return to participation (modified training)
  2. Sport (full training)
  3. Performance (back to the same level of competition standards)

"Underlining that **workload** (sport-specific preparation) is an important element in the criteria-based RTS process."

- To seamlessly map and implement ongoing strategies designed to reduce recurring and subsequent injury, we recommend that tertiary prevention is added as the 'plus one' to the three-step RTS continuum outlined by Ardern et al.

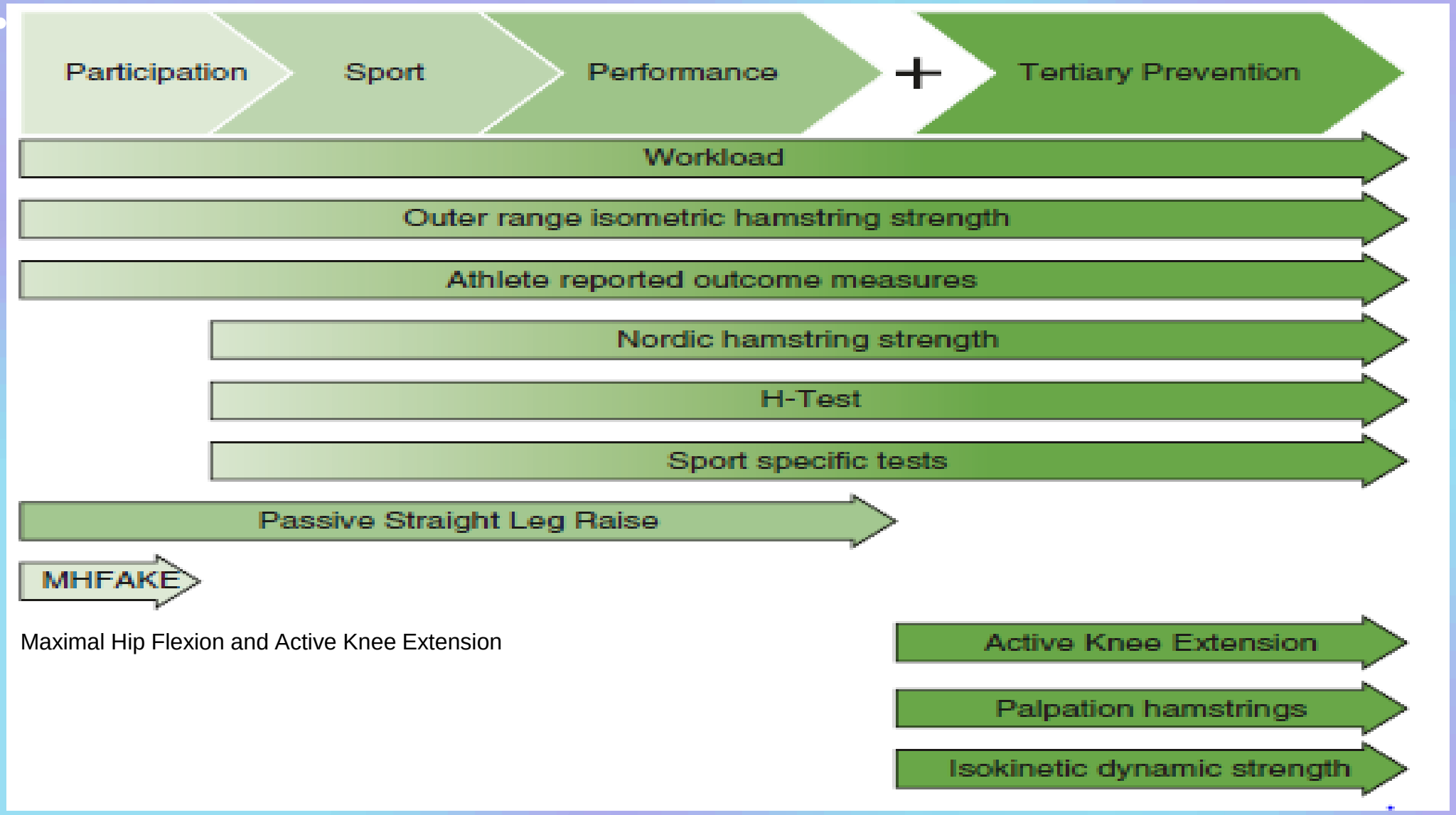
Throughout the rehabilitation and RTS process, athlete progress can be evaluated **using clinical and functional tests.**

Such tests can be considered not only for RTS criteria but also for **tertiary prevention.**

This approach involves performing a range of **intrinsic objective and subjective tests** on the athlete in the clinical setting, evaluated by medical staff.

Functional testing reflects the physical demands of the sport, athlete position, and level of competition.

The return to sport continuum

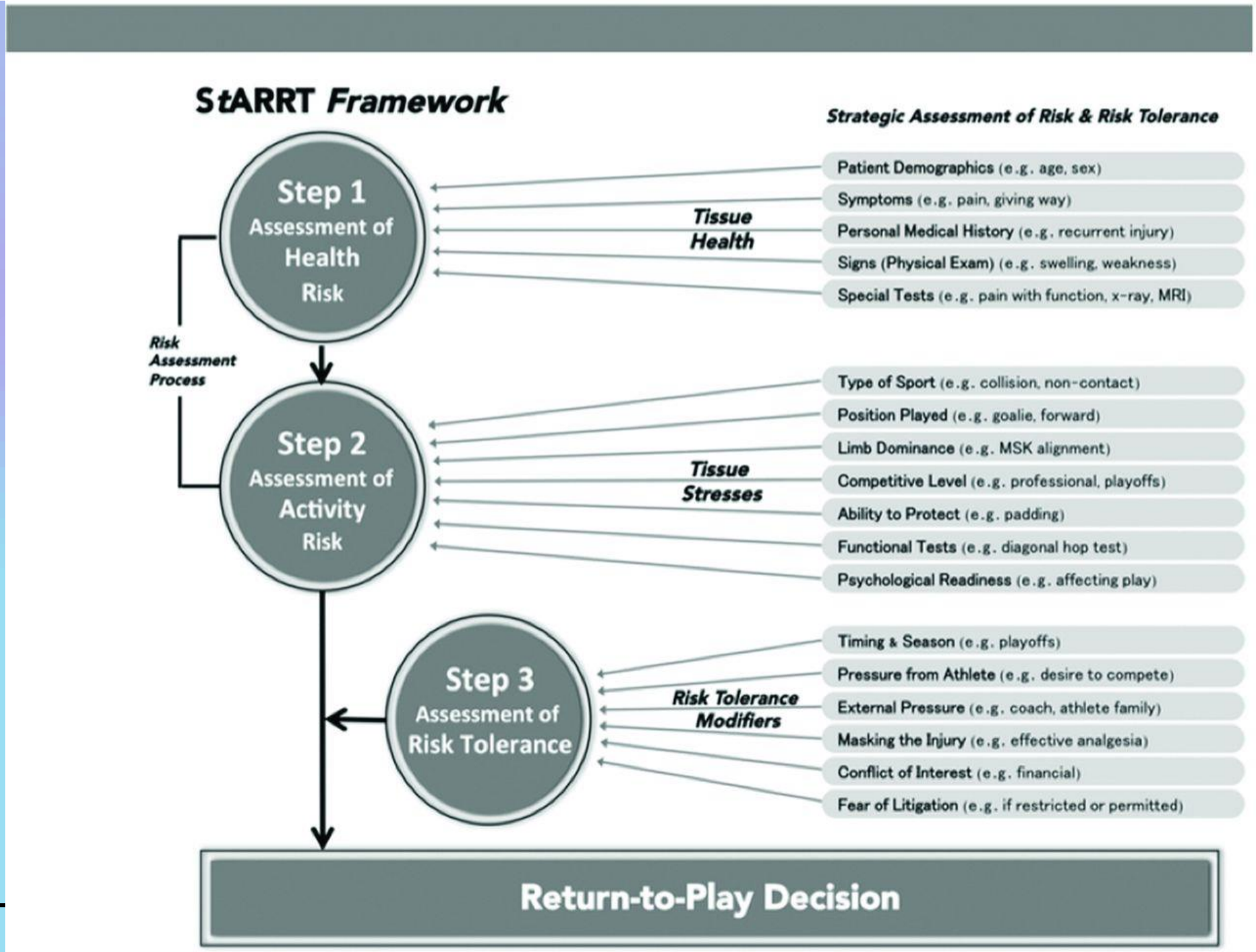


Return to Sport Decision

Elite athletes undertake a host of clinical tests during the year;

- ✓ baseline screening
- ✓ in-season monitoring
- ✓ injury diagnosis
- ✓ evaluation of rehabilitation progress

Such an approach reflects the steps in **StARRT**: assessment of health, activity risk, and overall context-specific risk tolerance.



Three-step process to consider when returning an athlete to sport after injury.

The initial step involves examining medical factors to ascertain the current health status of the athlete.

The second step reviews sporting risk specifically in relation to modifiable variables such as type of sport, playing position, or level of competition.

Finally, externally influencing factors such as time of season and pressure from athletes or third parties are considered in the process.

Multidisciplinary Review of Standards

Most athletes RTS with hamstring impairments, which may increase the risk of re-injury. A multidisciplinary and shared decision-making process is therefore recommended

- Once a multidisciplinary, shared criteria-based RTS decision has been made, the athlete should remain in tertiary prevention irrespective of whether they have returned to training, competition or top performance.
- Based on available data, this should be in place for at least 3 years post-injury.
- Planning (including roles and responsibilities) and producing the tertiary prevention programme should be part of finalizing RTS processes.
- This is warranted due to the high rates of recurrence and subsequent injury and will involve an array of interventions. including exercise programmed, load and athlete monitoring
- A truly shared decision-making model collects broad perspectives that include nonphysical measures to gain understanding of the athlete's psychological and physical readiness to RTS.

Psychological Factors in Return to Sport

- At the time of RTS, athletes may develop negative psychological responses including anxiety, low self-esteem, and fear.
- Athlete anxiety is a potential predictor for recurring and subsequent injury at the time of RTS.
- Premature RTS can lead to fear, anxiety, recurring and subsequent injury, depression, and poorer performance.

Sport-Specific Readiness

- During the RTS process, athlete sport-specific readiness is ascertained to establish if sufficient training, workload and performance have occurred to successfully RTS at the desired level of the continuum.
- This process involves a **gradual increase** in **training and workload** that is monitored and managed towards performance criteria.

Workload

1

Load is generally classified as internal or external

2

Load monitoring and associated athlete management

3

number of training sessions

Workload

External Load Monitoring

Monitoring workload with individual global positioning system (GPS) units produces data that might be of interest in returning athletes to sport after hamstring injury.

Internal Load Monitoring

Internal load monitoring is also commonplace and typically includes rate of perceived exertion (RPE)

Acute-to-Chronic Workload Ratio

- The acute-to-chronic workload ratio (ACWR) is an index of an athlete's workload in the most recent 1-week period (acute load) usually compared to their cumulative average workload over the last 3 or 4 weeks (chronic load).
- The index is based on internal and/or external load data to provide information on sport-specific readiness.
- Inclusion of ACWR as a RTS criteria has been recommended since rapid increases in acute workloads are associated with increased injury risk in a host of sports as are low chronic workloads.

Ongoing Monitoring and Prevention

- Once an athlete has sustained a hamstring injury, they host a potent non-modifiable injury risk factor: previous injury.

Management should commence early, within 7 days, upon RTS.

This represents the stage of tertiary prevention.

- Components of tertiary prevention in relation to hamstring injury in sport include regular exposure to eccentric hamstring stimuli, high-speed running and sprinting, load monitoring and management and in season athlete monitoring of hamstring function.

In-Season Athlete Monitoring of Hamstring Function

- In-season monitoring of hamstring strength in athletes that never had a hamstring injury is a secondary prevention strategy.
- It involves a two-step clinical screening process that occurs in the subclinical stage of injury.