***Physical preparation of the football player with an intramuscular hamstring tendon tear; Clinical perspective with video demonstrations***

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***Case Scenario***

Hamstring strain injuries (HSIs) are common injuries in professional sport and the musculotendinous junction the most frequently injured site.[1, 2] MR imaging proves that the tendon extends into the muscle belly and has increased awareness of the intramuscular tendon injury. [3] Some argue that this subtype of HSI may require surgical repair. Currently, there is no consensus on intramuscular tendon injury management; there is agreement that players are at an increased risk of re-injury upon return to play (RTP).[3, 4]Evidence suggests that clinical decision making, based on achieving functional goals, is an essential element of successful rehabilitation.[4]

In this video-supported education review with a strong clinical slant, I outline the rehabilitation of an English Premier League footballer who suffered a proximal hamstring intramuscular tendon injury during competition. The conceptual goal was to mechanically load the muscle-tendon unit hoping to improve tensile strength, elastic stiffness, and cross-sectional area.[5] Adequate high and maximal speed running exposure and objective neuromuscular performance data informed progression through rehabilitation and RTP. The player returned to competition in 120 days and remains injury free 13 months later.

**Mechanical loading**

During rehabilitation following initial physiotherapy care, isometric hamstring exercises were prescribed, beginning with single-leg heel drives (Figure 1), progressing to unloaded, then loaded bilateral isometric hip extension holds (video 1), then single leg hip extension holds (video 2) emphasising pelvic control before adding dynamic perturbations (video 3). These high intensity isometric exercises, using maximal voluntary contractions (~3-5s) in cluster sets (i.e. 5 x 5-3-5s) were included with the theoretical aim of providing cyclic high-strain magnitudes postulated to increase tendon/aponeurosis stiffness, reduce tendon/aponeurosis strain, and enhance force development.[6, 7, 8]I mention these mechanistic elements for discussion while being clear that there is no evidence that these hoped for stimuli, or their downstream effects, are being delivered with this program. A future challenge is to try to study these processes in vivo.

In conjunction with isometric hamstring exercises, dynamic exercises, including bilateral gluteal bridging were introduced, and full range of motion unloaded split squats (video 4). In my mechanistic model this would promote collagen synthesis and fiber alignment, and improve tendon tensile strength.[9]Gluteal bridging was progressed in three ways; increasing the lever arm and effective load by elevating the feet, adding load (video 5), and selectively overloading the injured limb (video 6) to provide a stability challenge alongside increased load. Resistance bands (video 7 and 8) were also used, to vary the velocity of contraction and reactivity (figure 2).

The Romanian deadlift was the principle hip dominant exercise selected, progressing from bilateral (video 9 and 10) to unilateral, (video 11) increasing recruitment of the injured muscle group, to target hip extensor strength asymmetry.[10]The Reverse Lunge (video 12) was the principle unilateral knee dominant exercise selected to develop knee/hip extension strength, with focus on acceleration mechanics, providing a foundation for more advanced variants (Figure 3). Again, we postulate that this would promote intermuscular adaptations specific to the demands of high speed running (HSR).[11] Exercise progressions focused on increasing intermuscular co-ordination demands, similar to the proximal to distal activation pattern observed during the stance phase of gait, optimising energy transfer from hip to knee and from knee to ankle(videos 18-20).[12]

**Objective Criteria for load progression**

At week 7, my criterion for phase progression peak force (PF) asymmetry < 10% in a force platform isometric posterior chain (IPC) test[13] (Figure 6, 11) was achieved, allowing progression of exercise selection to emphasize hip extension and eccentric knee flexion. The eccentric-only sliding leg curl(video 13) was introduced, then progressed in volume from 2x4 reps to 4x5 reps, followed by the eccentric-concentric version (video 14), adding distal load (video 15) and resistance bands (video 16) to increase speed and strain rate of the eccentric phase, and reactive demands (figure 2).[14]

At week 9, IPC test PF asymmetry was < 10%, my criterion for jump-landing and plyometric activity integration (Figure 4), part of a multi-dimensional approach to enhance lower limb stiffness, neuromuscular control and landing biomechanics, and promote reduced joint loading.[15, 16, 17] During week’s 9-10 jump-landing derivatives were introduced, followed by progression to plyometric activities in weeks 11-14 (Figure 4) to target fast stretch shortening activities (<250ms) reflecting HSR ground contact times (video 21) Achieving < 10% PF IPC asymmetry was also my criteria for beginning outside preparation. Gradual exposure to high running velocities including >5.5ms-1 (video 22) began in week 10, and included periodised exposures to relative HSR early in the week (figure 9). An acute ramp in relative HSR began after IPC test force at 100ms (an indicator of rate of force development) asymmetry was <10%, suggestive of a positive adaptation specific to exposure to the increased load and velocity demands of HSR.[18] Progressive increases in involved limb PF and force at 100ms drove reduced asymmetry, and total PF reached 300 N during weeks 13-14 (Figure 6/7). In addition to IPF asymmetry, identified as a risk factor for HSI recurrence,[19] prior to RTP eccentric knee flexor strength, assessed using the “NordBord®”,(video 17) was 500 N (13% improvement relative to preseason on the involved side) well above the 350 N HSI risk threshold,[20] with asymmetry < 10% (figure 8).

Acceptable asymmetry was criterion for exposure to higher cumulative weekly HSR workloads and subsequent progression to loads reflective of relative game load HSR, maximal speeds and positional requirements (video 23), and to increasingly chaotic running patterns (Figure 5). Global Positioning systems data was used to ensure gradual return to acute and accumulated weekly HSR distances as large increments can increase the re-injury risk,[21] and adequate exposure to sprints above 90% maximum velocity (video 24), potentially protective against muscle injury.[22] The player achieved a new maximal speed during the RTP phase (figure 7).

In the “fast” elite sports environment,decision making throughout rehabilitation was underpinned by research, clinical evidence and experience.[23]Progression driven by delivery of specific loading stimuli in both on and off pitch conditioning, assessed with neuromuscular tests quantifying the player’s response to load. These data then informed decisions to facilitate a successful outcome, blending art and science.

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**Figures**

1. Progression of isometric strength exercises for hamstring-tendon loading.
2. Progression of strength exercises for hamstring-tendon loading.
3. Progression of strength exercises with intramuscular emphasis for hamstring muscle-tendon loading.
4. Progression of jump-landing and plyometric exercise for hamstring-tendon loading.
5. Outdoor physical preparation model for hamstring-tendon rehabilitation. Preparation begins with control moving towards chaos interlinking GPS performance variables (Red = High > Green = Low).
6. Isometric Posterior Chain (IPC) peak force and asymmetry during hamstring-tendon rehabilitation.
7. Isometric Posterior Chain (IPC) peak force and relative peak force during hamstring-tendon rehabilitation.
8. Absolute eccentric peak force and asymmetry testing using the “NordBord®” at baseline (PS) and prior to return to play (RTP), displayed 350N hamstring strain injury (HSI) risk marker.
9. High Speed Running (HSR) exposure and Isometric Posterior Chain (IPC) testing during hamstring-tendon rehabilitation.
10. Percentage of relative maximal speed and Isometric Posterior Chain (IPC) testing during hamstring-tendon rehabilitation.
11. Isometric Posterior Chain (IPC) Test.