Power D, Haddad F, Wallis S, Baar K. Ramping Isometrics for Accelerated Return to Play following Hamstring Tendon Repair: A Case Study. *Journal of Elite Sport Performance*. Published online June 1, 2023. doi:10.54080/MOMV6327

Case Studies

Ramping Isometrics for Accelerated Return to Play following Hamstring Tendon Repair: A Case Study

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Keywords: semimembranosus, intramuscular tendon, ramping isometric loading, post-surgical hamstring rehabilitation

https://doi.org/10.54080/MOMV6327

Journal of Elite Sport Performance

Semimembranosus injuries are becoming increasingly common in rugby union, often via an overstretch mechanism, particularly from the jackal action in deep hip flexion with simultaneous knee extension. This injury often requires surgical repair, leading to an estimated return to play (RTP) time of 16 weeks. This case study documents the RTP of an elite international rugby union player following a combined semimembranosus, semitendinosus, and biceps femoris injury, with surgical reconstruction of the retracted semimembranosus tendon. Using an early low-jerk ramping isometric protocol, the player returned to team training at 10 weeks with RTP at exactly 12 weeks post-operation. He continued to play at international and club level for the remaining 2 seasons, without re-injury. This case study demonstrates how the early introduction of a ramped isometric protocol can be safe for muscle-tendon injuries and may improve expected recovery rates.

INTRODUCTION

Injuries are common in rugby union.[1] Recent attention has been paid to player safety around the 'breakdown' or 'ruck' area, particularly the safety of "the jackler," or defensive player attempting to poach the ball from the opposition's tackled player before a ruck forms.[2,3] This position involves the jackling player adopting a wide stance for stability with maximal or near-maximal hip flexion while competing for the ball and absorbing significant chaotic impacts from opposition players who attempt to forcefully 'clear out' the jackling player. A growing concern with this position is forceful impacts causing excessive hip flexion leading to stretch-type injuries to the hamstrings, which may lead to partial or complete tears of the semimembranosus muscle. Tears of this muscle with combined tendon retraction often require surgical repair to restore tendon function.[4]

Previous case studies of proximal semimembranosus repair include an elite footballer who returned to training (RTT) 18 weeks post-surgery,[5] and epidemiological data suggests a high return to play (RTP) (95%) and low reinjury rates following semimembranosus repair in professional athletes.[4] More distal semimembranosus repairs in professional rugby have reported RTP at 20 weeks.[6] In this article, we share the clinical outcomes and reasoning behind the RTP process of a player who suffered a semimembranosus tendon retracted tear with concomitant biceps femoris long-head and semitendinosus injury, including the players' strength diagnostics and RTP criteria for such an injury.

There are a wide variety of exercise interventions in published research addressing hamstring strain injury rehabilitation; however, the quality of reporting is often low.[7] Here, we detail exercise progressions and how the early introduction of a novel low-jerk isometric loading strategy facilitated accelerated muscle and tendon adaptation and the early return to participation (12 weeks post-surgery).

CASE CHARACTERISTICS

The player involved was a 27-year-old male front-row rugby union player, who gave informed consent for the use of his information. He was an established senior international player and played as a hooker. He had no prior injury history to the affected hamstring or any significant prior lower limb soft-tissue injuries to note.

CASE PRESENTATION

MECHANISM OF INJURY

The player suffered a stretch-type injury to his right hamstring complex during team training, while competing for the ball in a defensive ruck (Supplemental Video 1). He was hit by an opponent while in a position of combined maximal hip flexion and knee extension. He instantly reported to the pitch-side physiotherapists the feeling of a 'popping' sensation in his hamstring and was immediately removed from the session. Due to the mechanism of injury, loss of active and passive range, limited function, and significant pain during clinical assessment, it was decided that an MRI scan was warranted.

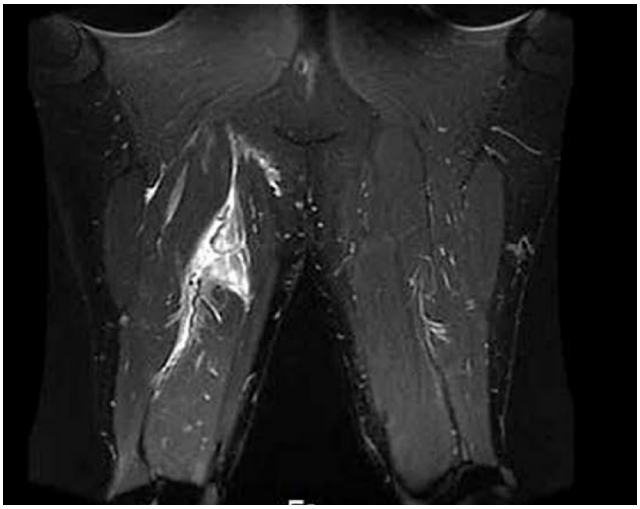


Figure 1. Post-Injury MRI

MRI reported a full thickness tear of the semimembranosus intramuscular tendon 16.5cm from the ischial tuberosity. Evidence of tendon disruption and retraction of the tendon (BAMIC Grade 4C).[8] Distal Semimembranosus and biceps femoris tendons are normal. No large haematoma. Normal signal intensity of the ischial tuberosity. Significant oedema noted tracking along the sciatic nerve and intermuscular septum. Myofascial oedema noted of the proximal biceps femoris and semitendinosus muscles surrounding the whole circumference of the muscle extending into the lower 3rd of the thigh, in keeping with a BAMIC grade 3a myofascial strain injury of the proximal biceps femoris and semitendinosus muscles.

INVESTIGATIONS

An MRI was performed 4 days post-injury, showing a "significant stretch injury of the semimembranosus which had disconnected from proximal to distal, with a stretch injury to the biceps femoris, semitendinosus and conjoint tendon, but these injuries did not look to be complete" (Figure 1).

CLINICAL HYPOTHESIS

Following MRI, as pain settled the player began low-intensity rehabilitation around the injured site, however, due to the extent of injury and evidence of tendon retraction, it was decided that a surgical opinion was required. An online call took place with the surgeon, player, and medical team 7 days post-injury. After a lengthy discussion, surgical repair of the semimembranosus tendon, followed by bracing and physiotherapy, was agreed to provide the best possibility for returned power of the hamstring muscle complex in the medium-long term. The surgeon explained that such injuries usually have a 16-week timescale of recovery, which varies from player to player.

SURGICAL INTERVENTION

The player consented to surgery which took place 9 days post-injury. Post-operative guidelines permitted mobilising, partial weight-bearing with crutches in a hinged knee brace at 60-120˚ for 2 weeks, followed by 30-120˚ for a further 2 weeks. From the beginning of week 5, the athlete was permitted to regain a short-step gait pattern with the removal of the brace. He used Aspirin and TED stockings VTE prophylaxis with pictures of his wound to be sent at 2 weeks (Figure 2), clinical reassessment at 8-10 weeks, and additional MRI imaging if there were concerns or slow progression.

A broad post-surgical protocol that is typically followed was given to the medical team for reference (Appendix 1). The initial plan outlined a return to play at 16 weeks, as per the suggested protocol, and along with the basis of prior research of similar cases.[5]

EARLY ISOMETRIC LOADING AND REHABILITATION PROGRESSIONS

PROTECTION PHASE (WEEKS 1-3)

The acute protection phase aimed to promote tissue healing via optimal loading,[9] maintenance of aerobic and anaerobic qualities, minimisation of atrophy, and establishing a clear plan among the multidisciplinary team to ensure psychological readiness for the challenges ahead.

Due to the expected length of RTP (16+ weeks), the player was offered a week off-site in the initial week post-surgery. During this phase, a multidisciplinary team case conference was held to discuss the player's rehabilitation plan and specific needs, with representatives from medical, athletic performance, sport science, nutrition, and rugby coaching present to provide a clear plan for the first four-week block of rehabilitation.

EARLY LOADING

The post-surgical protocol advised an initial protective period of 6 weeks before beginning specific loading of the hamstring muscle. Other studies have described no loading of the injured tissue until 7 weeks post-operation.[5] More recent work has suggested that early loading following musculoskeletal injury decreases RTP by 25%.[10] The possibility of earlier than routine isometric loading was proposed to the player's surgeon, who was happy to load before the recommended 6-week mark, provided this was monitored closely and that stretching of the hamstring muscles was avoided. The player began formal physiotherapist-led rehabilitation 7 days post-surgery.

RAMPING ISOMETRICS

To avoid potential damage early in the repair process, from the first rehabilitation session, a 'ramping' isometric protocol was used to avoid the potentially damaging 'jerk' at the injured site as a result of regular isometric contractions. This protocol involved the athlete increasing isometric contraction intensity over ~5 seconds, sustaining this level of contraction for 20 seconds, and then slowly releasing the load over ~5 seconds. The player used an Activbody Activ5® load sensor device (Activbody Inc., San Diego, CA, USA) which provided contraction time and live force output (N) feedback for the athlete via a phone app (ActivForce 2 App), to ensure progressive overload between sessions[11](Supplemental Video 2). While a general recommendation for low-jerk isometrics is to permit a 2-3/10 on a VAS pain scale,[12,13] the player was instructed to complete the loading in a pain-free state. This was considered pru-

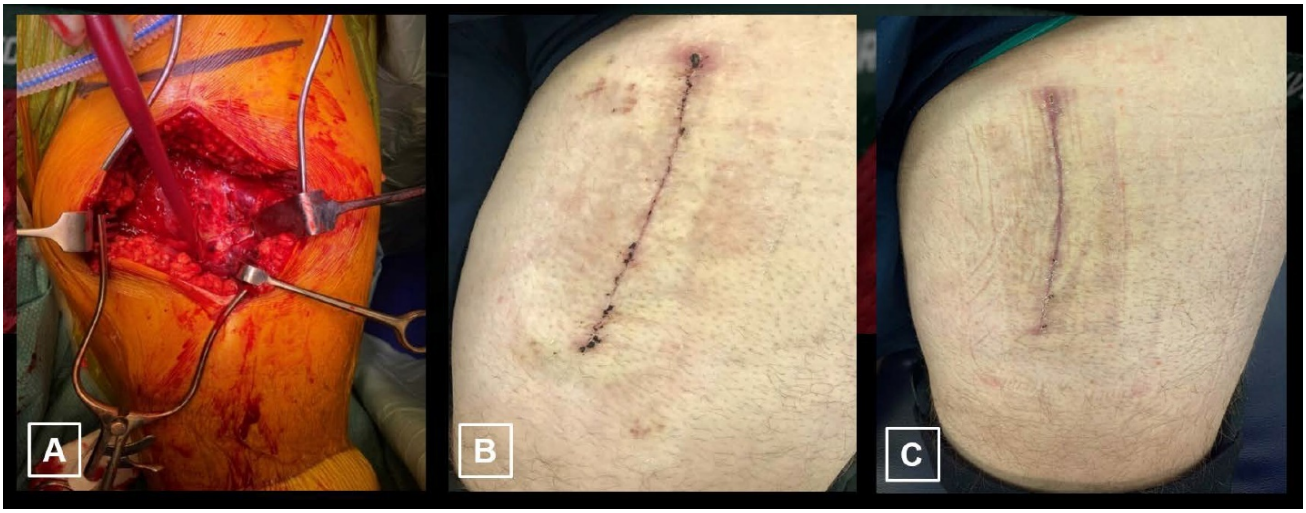


Figure 2. Surgical and Post-Surgical images

(A) Operative image. The procedure was undertaken under general anesthesia with Cefuroxime and tranexamic acid cover. He was placed in the prone position. A longitudinal incision was used. Diathermy haemostasis was obtained. The posterior cutaneous nerve of the thigh was retracted laterally with the main muscle mass and the medial window was opened. There was an oblique staggered tear of the semimembranosus with at least a 1- to 1.5-centimeter retraction. This was accessed without difficulty. Three sets of no. 5 Ethibond Kessler sutures were used to bring the main distal and proximal segments together which allowed tension restoration. This was then reinforced with 1 Vicryl, both transversely and longitudinally, to restore good tension to the semimembranosus tendon and membrane. A thorough washout was performed. The sciatic nerve did not need to be dissected. After a thorough washout, closure was effected with 3/0 Monocryl sutures to skin. Bio Occlusive dressings were applied. (B) Wound review image – 2 weeks post-surgery. (C) Wound review image – 3 weeks post-surgery.

dent due to the early nature of the loading and the likelihood that given the player's character, he would be likely to push excessively if encouraged to reach into pain.[14,15] The low-jerk ramping contractions were prescribed as collagen and muscle damage has been shown to increase with strain rate.[16,17] The 5-second strain ramp decreases strain rate while allowing the directional load through the tissue required for proper orientation of the matrix.[18]

Isometric loading range of motion was progressed within restrictions of the bracing. All contractions were done within the permitted range of the brace (60-120˚ for 2 weeks post-op, followed by 30-120˚ for a further 2 weeks) while avoiding combined knee extension and hip flexion to minimise stretch and potential disruption of the healing site.

EARLY ISOTONIC LOADING

Alongside the hamstring-specific isometric loading, isotonic loading of surrounding muscles and synergists took place immediately in rehabilitation with the aim of encouraging mechanotransduction and potential lateral force transmission to the healing site[19,20] along with nutritional support (See Table 1). The uninjured contralateral lower limb was trained to stimulate both a cross-education effect, with the aim of minimising atrophy and cortical inhibition of the affected limb,[21] and the promotion of a biochemical milieu that promotes collagen synthesis and matrix strengthening.[22] Upper body and trunk strength work was also progressed throughout the rehabilitation, while modified rugby-skills work was prescribed as appropriate.

Progressive slow standing 'slouching' exercises across multiple planes of hip rotation were introduced as early as tolerated, used as graded exposure to standing hip flexion and knee extension activities and restored confidence into 'jackal-specific' loading.[23] Range was progressed from lowering to touch a box, then to the floor, and to depth (Supplemental Video 3).

RELOAD (WEEKS 4-7)

The aims of the 'Reload' phase were to build injury-specific tissue capacity, restore the athlete's confidence for running and prepare for a return to on-field running. This required progressions through extensive plyometrics, pre-running coordination drills, AlterG® anti-gravity treadmill (AlterG®, California US) running progressions, and a return to full bilateral S&C participation.

RETURN TO STRENGTH TRAINING

At 4 weeks and 3 days post-op, the player began yielding isometric loading on compound lifts using barbell RDL (Romanian deadlift), split-stance RDL's and barbell split squats.[31] These quickly progressed to submaximal eccentric quasi-isometrics (EQI) using the same exercises, maintained with a long time under tension (~40 seconds) per rep to promote tendon adaptation and were used to build confidence in tolerating slow loading through range and segue to return to low-load compound lifts. Later the same week, he returned to isotonic bilaterally loaded RDL and hip thrust, split squat, single-leg goblet box squat, and continued to combine these with EQI's of progressing intensities. EQI exercise has been shown result in less muscle soreness, lower increases in echo intensity (a proposed measure of muscle damage and intra and intercellular metabolite accumulation), and smaller reductions in isometric and concentric torque at long muscle lengths when compared with traditional eccentric contractions.[32] Subsequent reviews argue EQI contractions would likely be valu-

Table 1. Nutrition Intervention

- From day 1 post-op, the player began collagen and vitamin C supplementation, with an aim to enhance tendon and muscle matrix adaptations to loading.
- The athlete was provided 20g of hydrolysed collagen in shot form, with 80mg vitamin C one hour before training and with breakfast on days when training was not completed. This intervention has been shown to double load-induced collagen synthesis[24] and accelerate RTP following ACL reconstruction.[25]
- To minimise muscle atrophy and reduce excess unnecessary inflammation, the player supplemented daily with 4g Omega 3 fish oil (2000mg Eicosapentaenoic acid (EPA), 1000mg docosahexaenoic acid (DHA)[26] and two 60ml turmeric shots (The Turmeric Co – Raw Turmeric & Ginger), promoting curcumin intake,[27,28] per day. The player was provided with support in periodizing his energy intake to meet the demands of his training, prioritising 3 hourly protein intakes of 40g[29] with the aim of achieving 2.3g/kg/BM (262g).[26]
- To expedite the accrual of muscle mass on the immobilised limb once loading commenced, the player commenced creatine supplementation. Initially loading with 20g/d (split into bidaily 10g doses) over 7 days followed by a 5g/d maintenance dose thereafter.[30]

able in rehabilitative settings prior to high intensity loading.[33]

Hamstring loading in this phase consisted of progressive isotonic loading through range using hamstring bridges off a box at inner, mid, and eventually outer range and progressing from bilateral, b-stance/split stance, to unilateral (Supplemental Video 4). At this point, he also added a single leg machine leg curl for knee dominant hamstring strength. Blood flow restriction (BFR) training was used to supplement these exercises while load compromised and this was performed using a commonly recommended protocol (75 reps - 30 x 15 x 15 x 15 reps @~30% 1RM, 30 secs rest).[34–36] The return to strength training phase also included the beginning of more reactive hamstring contractions to build confidence and prepare for the speed of contraction required in running.

POST-SURGICAL REVIEW

Due to the player's accelerated progression in this phase, the post-surgical review was brought forward two weeks, due to the possibility of returning to play before the season's end if progress continued at the current rate. See Appendix 2 for timeline of injury progressions and consultations.

RETURN TO RUN

The decision to permit running was made based on objective strength measures, the completion of running technical drills, reactive hamstring exercises, and discussion with the surgeon. Due to the player's strength levels and the role of the semimembranosus in high-speed running,[37] the surgeon was happy to permit a progressive return to running.

Having built up a volume of pre-run drills indoors in a controlled environment over a two-week period, and with permission from his surgeon, running commenced on the AlterG® treadmill. This commenced 5 and a half weeks post-operation, with weight-bearing progressing from 70% bodyweight at various speeds to fully weight bearing in Week 6, before returning on-pitch.

PREPARATION FOR RUGBY (WEEKS 7-10)

The aims of this phase were to prepare the player for the specific demands of full-contact rugby training and match-play, with a shift in emphasis from local restoration to global performance. Strength work progressed in intensity to high-impact reactive loading and accentuated eccentric loading (AEL), with added focus on the right lower limb. Loading volumes of assistance exercises were mismatched as appropriate to target between-limb hamstring strength deficits.

Given the player's unique position, graded exposure to rugby-specific demands, namely jackal, scrum, and contact was required. Rugby skills were integrated into rehabilitation in the gym and on the pitch as soon as possible at each stage to encourage an external focus of attention, minimise fear avoidance, and promote corticospinal adaptation.[38,39] This was completed via a progressive framework and delivered via a combination of his physiotherapist, strength and conditioning coach, and a task-specific rugby coach.

Individual running sessions were planned and periodised to eventually reach the player's individual worst-case in-game demands, to best prepare for a return to training. Session themes were based on rugby demands and progressed in a modified control-chaos continuum,[40] adjusted towards rugby game and positional demands. Session difficulty was programmed by modifying running velocity, high-speed running and sprint distance, contact level, and repeated efforts in contact. Session frequency was also increased over several weeks with a view to replicating the team's weekly schedule.

HIGH-SPEED RUNNING

High-speed running (considered >5m/s for this athlete) was introduced in the form of linear and curved running as soon as deemed appropriate, to accumulate a large volume prior to returning to training,[41,42] and prepare for added stress of off-line running.[43] The velocity of runs were monitored live using a smartwatch (Apple Watch Series 6, Catapult Vector App). Each session consisted of pre-determined velocity and distance targets determined by his maximum velocity baseline pre-injury, to ensure stepwise exposure to incremental speeds.

KNEE-DOMINANT STRENGTH & POWER

At week 8 post operation, he resumed Nordic curl variations, having built prior capacity through machine leg curls, single leg eccentric slide outs, and Swiss ball and

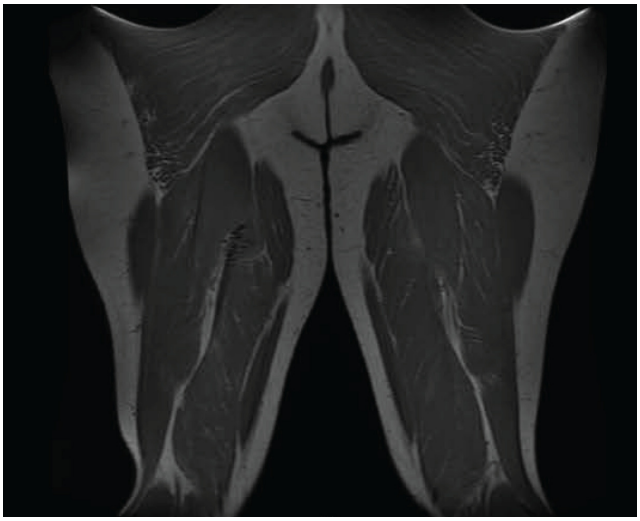


Figure 3. Repeat MRI Images (8 weeks post-operation)

"His MRI scan is very reassuring. His tendon is nicely reconstituted and muscle length is good. The oedema is very much as expected".

band-assisted Nordics. This then progressed to single leg band assisted Nordic curls in an aim to mismatch volume on the injured limb (Supplemental Video 5).

Knee-dominant reactive loading consisted of exercises across a variety of speeds including explosive single leg concentric machine leg curl with isometric catches, sprint mid-stance banded knee flexion oscillations and prone tantrums[44] (Supplemental Video 6).

At the end of week 8, the player had a repeat MRI which the surgeon was pleased with (Figure 3).

HIP DOMINANT STRENGTH & POWER

From week 9, having built up load with a split-stance variation for the previous 4 weeks, a single leg accentuated eccentric loading (AEL) RDL became his primary hip-dominant lift. This exercise was chosen due to its high load on the biceps femoris, without the need for the same load of a bilateral RDL and risk of lumbar spine becoming a limiting factor.[45,46] This progressed even further to add ~20 degrees of internal hip rotation in aim to further target the biceps femoris muscle.[47,48]

Hip-dominant reactive work consisted of exercises at a variety of speeds and from inner to outer range, in an aim to assist confidence in jackal-related positions, this included explosive concentric hamstring bridges with isometric catches, and concentric sled pushes, single-leg prone plate-catches and reverse sled walking in hip flexion (Supplemental Video 7). See Figure 4 and Figure 5 for isometric and eccentric testing procedures and progressions. For added detail on exercise order and testing, see Table 2.

CRITERIA FOR RETURN TO TRAINING

By week 9, the player had reached all predetermined outcome measures for return to play faster than anticipated, bar eccentric knee flexor limb symmetry index (LSI) on Nordic assessment at which a deficit of 17.5% remained, due to the unforeseen output on his non-operated side. Considering previous trends in strength gains up to this point (+25-30N every other day), the player had prescribed target outputs on each Nordic assessment which would need to be reached to meet the desired strength level for return to play. It was anticipated that if he was to continue progressing in this nature that he would return to training with a 12-14% eccentric deficit while exceeding all other criteria. Interestingly, Nordic strength progressed in an almost perfect linear fashion with increased exposure (Figure 7).

RETURN TO TRAINING (WEEK 10)

At 10 weeks and 2 days post-surgery, he completed a 'game simulation' on-pitch conditioning session to mark the end of rehabilitation, based on the player's individual GPS metrics and exposure to potential worst-case scenarios to be reached in a match scenario. He successfully completed the session and returned to load-modified training with the squad two days later without issue. The return to training involved graded exposure to team activities such as positional group sessions, including controlled contact, scrum, and in particular, jackal and breakdown exposure.

It is acknowledged that the decision to permit the return to training with a 14% eccentric strength deficit on Nordic assessment may appear controversial; however, a recent systematic review and meta-analysis showed that eccentric strength alone is not predictive of future injury, whether strength was expressed as an absolute (N), relative to body mass ($N \cdot kg^{-1}$) or between limb asymmetry.[56] It must also be noted that changes of 2.71 (Δ 41 N; 11%) and 3.24 (Δ 47 N; 12%) xSWC are required to detect a small change in eccentric knee flexor peak force in the hamstring solo device, taking into account the typical error between tests.[53]

Given that strength was continuing to improve, he had passed all other return to play criteria comfortably, including positive isometric strength LSI, returning to baseline eccentric strength, absolute strength greater than his peers, significant body composition improvements (Figure 8) and was extremely confident in his ability to perform, the team was confident that he was ready.

RETURN TO PLAY (WEEK 12)

After a lengthy discussion with the player, medical team, performance staff, and coaches, the player successfully returned to play exactly 12 weeks post-operation with predetermined restricted playing minutes. The pre-game plan was to play 20 minutes; however, due to an injury to another player, he returned as a substitute at half time and completed 40 minutes. Seven days later, at 13 weeks post operation, he started the game, and was substituted after 60 minutes. He completed both games without incident and scored tries in both games. This marked the end of the regular club season and the player left for international duty.

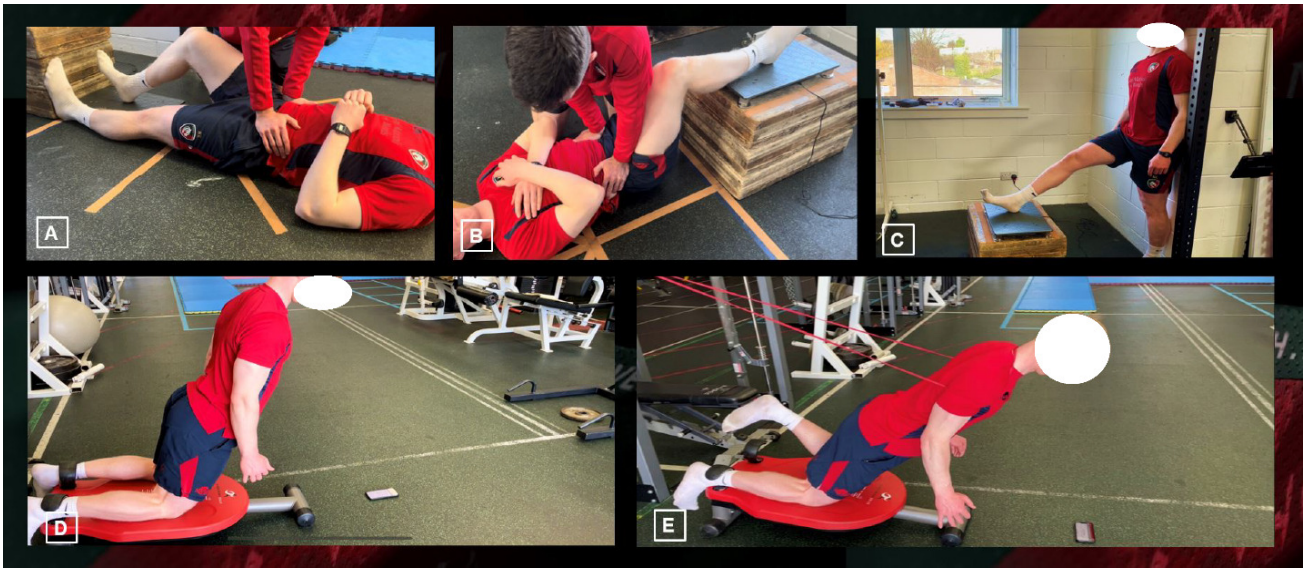


Figure 4. Knee and hip-dominant strength testing

A) Supine 45°:45° isometric heel dig. The 45:45 position was used as a rudimentary measure of inner-mid range isometric knee-dominant strength. While stabilised manually, the player was instructed to drive heel to your bum, to encourage a knee flexion pattern. (B) Supine 90°:90° isometric heel dig. This test progressed range from the 45:45, with increased range of motion across both the hip and the knee joints. The test has been shown to have good to excellent reliability between-sessions (ICC ⩾ 0.86).[49] (C) Standing 90:20 isometric heel dig. We decided to use the 90/20 IPC strength as a gross measure of hip dominant posterior chain strength and RFD in mid-outer range[50,51] and a key metric given the mechanism of injury. We used the force platform (ForceDecks, Vald Performance, Australia) to assess peak force and rate of force development (RFD) at 100ms for each test (Supplemental Video 5). Standardised positioning, instructions and verbal encouragement were given during each procedure, with a verbal command of "3, 2, 1 GO" countdown given before the initiation of a maximal contraction which was held for ~3 seconds, with a count of '3, 2, 1, relax'. See Figure 5: Isometric Strength & Asymmetry Progressions for progressions in each isometric test. (D) Double leg Nordic Hamstring Curl. As his primary knee-dominant eccentric hamstring strength exercise, a tablet device using the Hamstring Solo App (ND Sports Performance, Thomastown, Ireland) was used for each set of Nordics completed, to promote maximal intent with live feedback.[52] Peak force output was measured as a maximum score of 4 reps, with a 4 rep average also taken. Due to the continued improvement of his left leg strength on Nordic hamstring assessment to levels beyond relative strength levels quoted in literature,[53] the volume of strength training on his uninjured left side was reduced. (E) Band-Assisted Single Leg Nordic Hamstring Curl. Nordic curls progressed to a single-leg banded variation, progressing from a moderate (purple) resistance band to a light (red) band. It is acknowledge that the intensity of this variation may not be suitable for all players. Note that images displayed are of a model and not that of the player, therefore exact joint angles used in practice may not reflect those in the images due to individual anthropometric differences.

Table 2. Exercise Order

• As running intensity and volume progressed, strength work was programmed at either end of the running session, with primary lifts completed prior to running on work capacity days, and isolated hamstring and calf work programmed following the session. Speed-focused days were followed by more velocity-based or reactive hamstring loading, to fit the day's theme. • Once loading velocity increased, training days were completed with an outer range modified rear foot elevated split squat long isometric submaximal push (4x~30 seconds) to promote tendon adaptation (Figure 6). • It must be noted that the majority of eccentric hamstring strength assessment was completed in a fatigued state post running, due to a reluctance to pre-fatigue the injured structure prior to high-speed running and contact work and not cause eccentric damage for the following day.[54] We expect that this would have significantly impacted the validity of eccentric assessments. Isometric assessments were completed pre-session in a relatively fresh state and considered to be less fatigue inducing versus eccentric contractions, and the player was accustomed to running following strength training in his regular training week. • This may explain some of the difference between isometric and eccentric assessments, along with the different limb positions and supramaximal nature of the eccentric assessments.

FOLLOW UP

Following season completion, the player spent the immediate 17 weeks post-season on international duty.

STRENGTH FOLLOW-UP

While on international duty, through remote programming, the player maintained his end-stage loading with a continued emphasis on eccentric knee and hip-dominant strength. Repeat testing on return to club duty at week 30 post-op (17 weeks post-RTP) saw maintenance of isometric strength (Figure 5) and most encouragingly, Nordic Curl strength not only improved (+25N), the LSI now reversed to the point where the operated limb was dominant (+2.5%) (Figure 7). All testing was completed on match-day +2, to minimise disruption to the training week. It must be noted that this testing was done in a non-fatigued state, compared to prior assessments. For added detail on testing progression and LSI throughout the rehabilitation, see Appendix 3.

Figure 5. Isometric Strength & Asymmetry Progression

Figure 6. End Stage Isometric Loading

RFE Split Stance Isometric Push. To continue to promote tendon adaptation, the player finished his training days (post-strength and on-feet sessions) with a RFE Split Stance Isometric Push). Long submaximal pushes (4x30 secs) were completed at the end of training days to promote outer-range loading of both the hamstrings in the front leg and the quadriceps on the rear leg while actively maintaining a neutral pelvic tilt and stressing lumbopelvic control. The front leg was cued to drive 'down and backways towards the box', while the rear foot is cued to 'drive vertically downward into the box, as if trying to lift the rear knee off the floor to project the body vertically'. Within rehabilitation, this exercise was also progressed to be used as an outer range rate of force development (RFD) exercise and restore confidence in loading at a near-maximal stretch. Outer range isometrics have been shown to transfer strength gains in the mid-range, in comparison to reduced transfer of inner and mid-range isometric loading to outer ranges.[55] The player continued to use this exercise post-training sessions (4x30 secs) upon return to training and play.

DISCUSSION

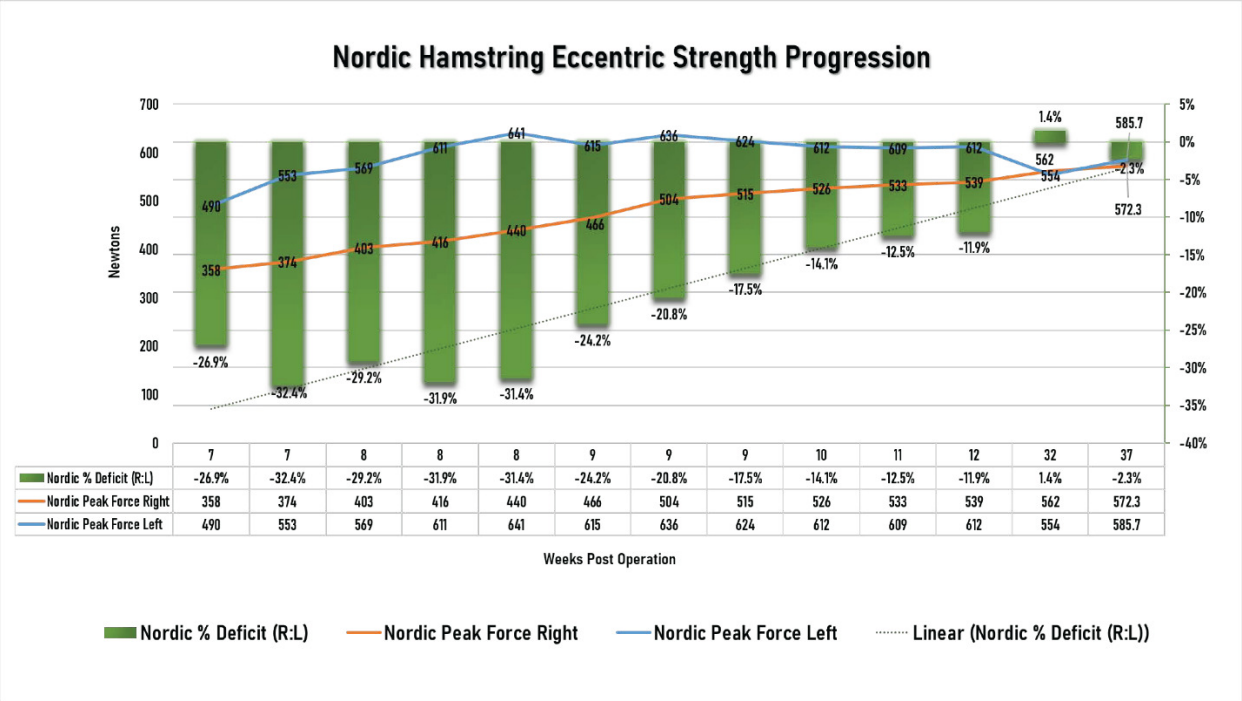
In elite sport, questions are always asked about how soon to begin loading post-injury and assessing player safety and risk of reinjury on return to play. This case showed that a player can safely load within a week of surgery and successfully return to play with a between-limb deficit in hamstring strength. It must be noted that these decisions were taken in consideration of the player's existing strength, position and the demands required of him in match play.

In sub-elite populations, early loading following musculoskeletal injury accelerates RTP.[10] Supplementing with dietary collagen during rehabilitation further accelerates return to play.[58] Following ACL rupture, elite rugby players who combined early loading and collagen supplementation were able to RTP in 30 weeks,[25] suggesting that a combined early loading and nutrition program could accelerate recovery following hamstring rupture and repair. One important consideration with early loading is the rate at which load is applied to the regenerating tissues. Since high loading velocities are associated with greater collagen[16] and muscle damage,[17] our early loading programme focused on minimising jerk (the rate of change of acceleration) where strain rate is highest. To achieve this, the athlete was instructed to increase and decrease force slowly over a five second period. The result was that early loading progressed without issue.

Significant work is still required to directly demonstrate the effect of ramping isometrics on acute muscle-tendon injury and the true effect on enhanced healing of connective tissue through the nutrition and exercise strategies outlined above. This report outlines a first attempt at translating basic science into an effective return to play protocol. Additionally, it demonstrates that well-planned purposeful exercise and nutrition interventions can minimise lean tissue and strength loss during periods of immobilisation. The attenuated loss of function may support an even more rapid progression through a return to play programme.

Between-limb strength imbalances are seen as a potential injury prognostic following RTP. A between-limb imbalance in eccentric knee-flexor strength of ⩾ 15% and ⩾ 20% has been shown to increase the risk of hamstring strain injury in rugby players 2.4- (RR = 2.4, 95% CI = 1.1 to 5.5, p = 0.033) and 3.4-fold (RR = 3.4, 95% CI = 1.5 to 7.6, 48 p = 0.003), respectively.[59] More recent work in a football cohort found that 37% percent of professional players in the control group and 50% in the injured group presented between-limb eccentric strength asymmetry >10%.[60] Even though their prospective study showed increased risk of hamstring injury with imbalances of ⩾15%,[59] when the same group performed a systematic review and meta-analysis, they found that eccentric strength was not predictive of future injury, whether strength was expressed as an absolute (N), relative to body mass (N kg-1) or between limb asymmetry.[56] Given that the player in this case had passed all other gym and pitch-based return to play criteria comfortably (including absolute eccentric strength greater than his baseline), and was extremely confident in his ability to perform, the team was confident that he was ready to return to play.

Finally, it should be acknowledged that the player undertaking this return to play programme was extremely diligent and compliant with the interventions outlined. With



	7	7	8	8	8	9	9	9	10	11	12	32	37
Nordic % Deficit (R:L)	-26.9%	-32.4%	-29.2%	-31.9%	-31.4%	-24.2%	-20.8%	-17.5%	-14.1%	-12.5%	-11.9%	1.4%	-2.3%
Nordic Peak Force Right	358	374	403	416	440	466	504	515	526	533	539	562	572.3
Nordic Peak Force Left	490	553	569	611	641	615	636	624	612	609	612	554	585.7

Figure 7. Nordic Hamstring Eccentric Strength Progressions

The player began Nordic testing 7 weeks post operation and continued to test x2-3 weekly until return to training (week 10), at which point volume of eccentric loading was reduced. During testing, the peak force was taken as the best score from a 4-repetition cluster. Average force out of the 4 reps was also recorded and monitored throughout to assess decrements within sets. The broken trend line shows the consistent nature of improvements on the injured right side while left side remained relatively consistent following early improvements. It must be noted that testing up to and including week 12 (following return to play) was all done post on-feet running sessions, in a fatigued state, which is likely to have reduced the validity of the findings. No testing from international camp was available in the time between weeks 12-32. At week 32 the player had completed the full international championship and returned to club duty, with the injured leg now stronger on his right side (5N.kg relative strength). It must be noted that these measures were taken within the normal team schedule and completed in a fresh state on a Monday, which may explain differences between previous tests.

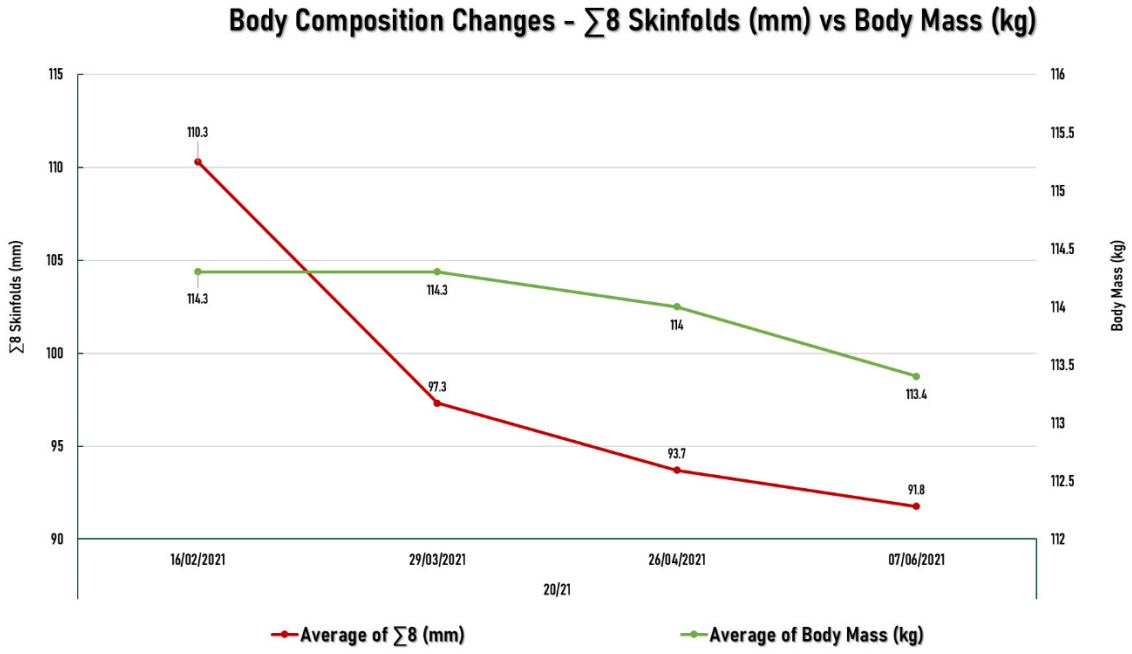


Figure 8. Body composition changes over a 16-week period, inclusive of the 12-week return to play period.

The figure shows an 18.6mm reduction in the sum of eight skinfolds and 0.9kg body mass loss, suggesting favourable preservation and optimisation of lean mass over this period.

Table 3. Performance on Return to Play

- The players' high speed running distances following return to play were higher than pre-injury (which is encouraging as in football players recovering from hamstring strain injury, a suppression in high speed running distances was common.[57]
- He hit a personal best for maximum velocity sprint speed (8.2m/s; +8.1% max velocity) recorded by GPS, approximately 7 weeks after return to play (Week 19 post operation).
- On international duty, he averaged 12 tackles per match and defended with an outstanding success rate of 97.3 percent. He secured an average of one 'jackal' turnover per match from six matches and had the highest tackle count from all teams in the competition, with 72.

Summary

- Semimembranosus injuries usually occur during stretch-type activities and are becoming increasingly common in rugby union. Injuries with a high degree of tendon retraction may warrant surgical repair.
- The early introduction of a progressive 'ramping' isometric protocol was safe for isolated hamstring muscle-tendon loading post-surgery.
- Rehabilitation followed progressive loading increasing in range, intensity and volume, while isometric loading continued throughout the rehabilitation. Return to play was achieved with absolute eccentric strength above prior baseline levels and a moderate between-limb eccentric strength imbalance.
- This study may impact future clinical guidance for isometric loading post-surgery and inform return-to-play decision-making.

the potentially small benefits these interventions may provide, having motivated and compliant athletes is essential to success. This can be encouraged by a medical and sports science team that provides individualised and highly structured training plans and a supportive and encouraging environment.

ACKNOWLEDGEMENTS

James Nolan for providing strength and conditioning support to the player, David O Sullivan, Joe Barton and Dr. Harjinder Singh for assisting in the physiotherapy care and Neill Kelly for assistance with video demonstrations.

CONTRIBUTIONS

FSH surgically operated on the player, consulted on the rehabilitation and reviewed the paper, DP provided physiotherapy care and led on-and off-pitch rehabilitation, planned and wrote the manuscript, SW provided nutritional care and assisted in writing the manuscript, KB advised on the isometric protocol used and provided assistance in writing the manuscript and feedback.

PATIENT AND PUBLIC INVOLVEMENT

Patients and the public were not involved in the design, conduct or analysis of this study. The player was, however, informed that the early isometric loading protocol was novel, and consented fully to participation.

FUNDING

This research received no specific grant from any funding agency in the public, commercial or not-for-profit sectors.

COMPETING INTERESTS

None declared.

PATIENT CONSENT FOR PUBLICATION

Written consent was gained by the player for use of medical information.

PARTICIPANT CONSENT FOR PUBLICATION

Written consent was provided by the video participants for use within the study.

DATA AVAILABILITY STATEMENT

All data relevant to the study are included in the article or uploaded as supplementary information.

Submitted: April 05, 2023 BST, Accepted: May 28, 2023 BST

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SUPPLEMENTARY MATERIALS

Supplementary Video 1

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Supplementary Video 7

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Appendix 1 - Post Surgery Rehabilitation Plan

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Appendix 2 - Timeline of Injury and Progression

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Appendix 3 - Hamstring Strength Progressions

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