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[CASE REPORT]

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Rehabilitation and Return to Sport Following Surgical Repair of the Rectus Abdominis and Adductor Longus in a Professional Basketball Player: A Case Report

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SUPPLEMENTAL VIDEO ONLINE

Acute avulsion of the rectus abdominis and adductor longus via a traumatic mechanism is rare.[13,43,59] Chronic groin injuries, often falling under the athletic pubalgia spectrum, have been reported to be more common.[24,39,40] In this case, a professional basketball athlete sustained a contact injury while setting a static screen in competition, a mechanism similar to an injury reported in American football, in which the athletes performed blocking above the waist with the feet planted.[49] There is a paucity of literature detailing systematic, multimodal rehabilitation and return to competition in elite sport, particularly when following surgical treatment of avulsion injuries of the pubis or other sports-related groin pathologies.[17]

STUDY DESIGN: Case report.

BACKGROUND: Acute traumatic avulsion of the rectus abdominis and adductor longus is rare. Chronic groin injuries, often falling under the athletic pubalgia spectrum, have been reported to be more common. There is limited evidence detailing the comprehensive rehabilitation and return to sport of an athlete following surgical or conservative treatment of avulsion injuries of the pubis or other sports-related groin pathologies.

CASE DESCRIPTION: A 29-year-old National Basketball Association player sustained a contact injury during a professional basketball game. This case report describes a unique clinical situation specific to professional sport, in which a surgical repair of an avulsed rectus abdominis and adductor longus was combined with a multimodal impairment- and outcomes-based rehabilitation program.

OUTCOMES: The patient returned to in-season competition at 5 weeks postoperation. Objective measures were tracked throughout rehabilitation and compared to baseline assessments. Measures such as the Copenhagen Hip and Groin Outcome Score and numeric pain-rating scale revealed progress beyond the minimal important difference.

DISCUSSION: This case report details the clinical reasoning and evidence-informed interventions involved in the return to elite sport. Detailed programming and objective assessment may assist in achieving desired outcomes ahead of previously established timelines.

LEVEL OF EVIDENCE: Therapy, level 4.
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KEY WORDS: *adductor, athletic pubalgia, groin, return to sport, tendon rupture*

The bony pelvis serves to transfer weight to and from the appendicular and axial skeleton, as well as to disperse compression forces resulting from its stabilization of the body. Muscles that attach to the pubis play a significant role in stabilizing the entire lumbopelvic complex.[40,42] Shared connective tissue of the adductor longus and rectus abdominis across the pelvis requires athletes to have multiplanar extensibility and stability to withstand dynamic loads required for competition, especially in sports that require high-intensity change-of-direction maneuvers and contact forces.[5,59] Schlegel et al[49] have reported that National Football League players have been successfully treated with conservative measures when only the adductor longus was impacted. Extensive pathology in this region may call for surgical intervention.[39] Postoperative rehabilitation of the hip and groin in athletes is difficult due to the complex nature of anatomical structures, the number of forces imposed

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TABLE 1 Clinical Examination Findings

Clinical Examination	Clinical Finding
Observation	Mild effusion and bruising
Palpation	3 of 4: tender to palpation at adductor longus attachment, pubis, and left inferior quadrant of abdomen
Active ROM	Unable to perform on affected lower extremity
Passive ROM	Painful on all movements, specifically hip abduction stretch at 0° of hip flexion
Manual muscle testing	Painful resisted hip adduction
Special tests	
Squeeze test	Positive for concordant pain
Resisted curl-up	Positive for concordant pain
Valsalva maneuver	Positive for concordant pain

Abbreviation: ROM, range of motion.

on the pelvis, consideration of regional interdependence, the ongoing healing of a surgical repair, and the goal of returning to the demands of sport.

Return-to-play progressions and decisions are challenging and often lack comprehensive subjective and objective criteria.[23,63] Internal and external pressures unique to elite sport add to the decision-making challenge and indicate the need for evidence-informed tools.[2] This case report details specific interventions tailored to impairment-based treatment, while considering anatomical, biomechanical, and physiological factors. Previous literature in similar cases has indicated complete recovery and return to sport in 6 to 12 weeks. This athlete returned to sport in 5 weeks.[13,17,49,53]

CASE DESCRIPTION

The patient was a 29-year-old male professional basketball player with a height of 2.08 m and body mass of 122 kg. Video analysis from the professional competition demonstrated that the athlete's stance was slightly wider than shoulder width, with the trunk stationary above its base. Upon contact, the left leg absorbed a violent contact force, moving the limb into abduction and external rotation. The trunk was rotated to the right, resulting in an excessive stretch of the adductor complex, rectus abdominis, the oblique musculature, and associated fascial and connective structures. The player was unable to continue participation following the incident and was moved to the athletic training room for examination by the team medical staff.

Initial Examination

The patient was examined immediately following the incident. The patient had a history of groin pathology (osteitis pubis and adductor tenotomy) contralateral to the newly affected side. Moderate effusion was observed in both the abdomen and groin. Pain was elicited on palpation to the proximal adductor complex, including the muscle belly and its associated cord-like tendon at its origin on the pubis, and in the left inferior quadrant of the abdomen. Passive abduction and manually resisted adduction also reproduced the concordant pain. There was an inability to perform resisted supine trunk flexion (curl-up test) and a positive squeeze test, in which the hook-lying patient was asked to maximally adduct against the therapist's fist, reproducing the concordant pain.[24,61] The athlete was asked to "bear down," and pain was felt with the Valsalva maneuver (**TABLE 1**). He was unable to stand or ambulate upright. The athlete was re-examined again the following morning, with no change in his clinical presentation. The athlete was treated with cryotherapy and compression following the initial examination and re-examination. Diagnostic imaging was requested at this time.

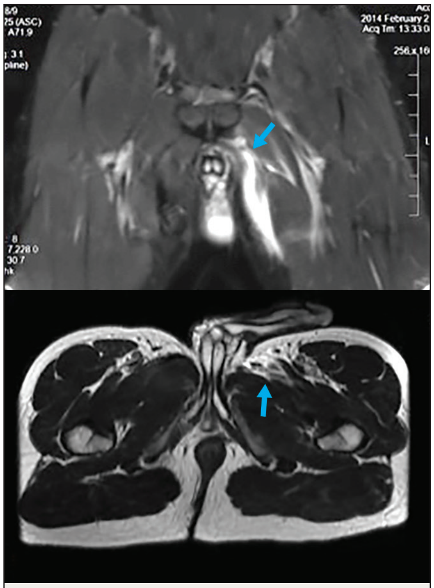

FIGURE 1. Magnetic resonance image displaying (A) acute avulsion of the left adductor longus from the pubic origin, with 4 cm of distal retraction and mild surrounding hematoma (arrow; frontal view). Also found was (B) a partial tear of the left adductor brevis (arrow; axial view) and mild strain of the left pectineus.

Diagnostic Imaging and Surgical Management

Initial magnetic resonance imaging confirmed acute avulsion of the left adductor longus from the pubic origin, with 4 cm of distal retraction and mild surrounding hematoma. Also found was a partial tear of the left adductor brevis and mild strain of the left pectineus (**FIGURE 1**). Further imaging obtained following surgical consultation revealed a partial tear of the rectus abdominis at the pubis and severe osteitis pubis, which was present before the contact injury. It was determined that the athlete was to undergo a surgical repair. The operation took place 3 days following the initial injury. An anterior pelvic floor repair[39] was performed, in which the pubis and its tendinous attachment were stabilized via 3-D reattachment and reinforcement of the anterior abdominals. The abdominal

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FIGURE 2. Single-leg squat.

FIGURE 3. Single-leg deadlift.

FIGURE 4. Slide-board reverse lunge.

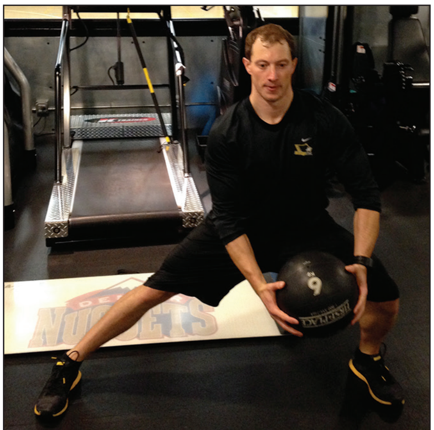

FIGURE 5. Lateral lunge with chop.

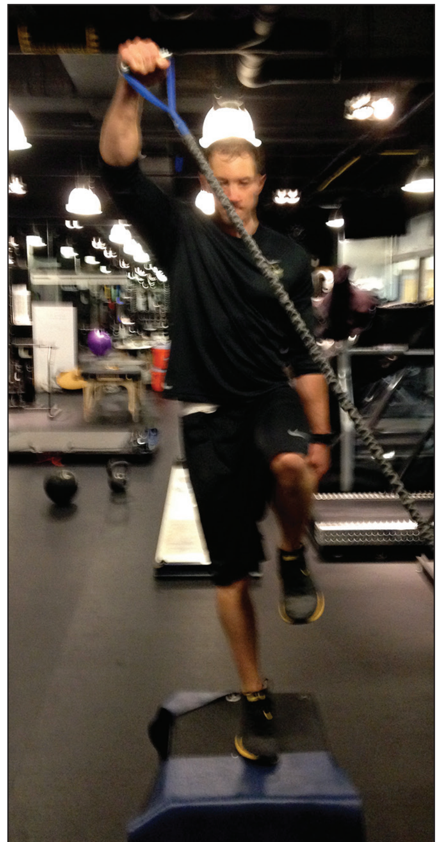

FIGURE 6. Lateral step-up with perturbations.

musculature was additionally stabilized from below by suturing the proximal adductor epimysium to the pubis and to the reattached rectus abdominis above. The rectus repair was aligned in the same vertical line as the adductor longus as much as possible. A complete anterior and lateral epimysial release was performed 3 cm distal, with the muscle still attached. A muscular repair was performed by incorporating remaining muscle into the intact muscle bellies. These repairs were performed with the epimysium and Z-plasty technique by advancing the muscle after mobilization and proximal repair with chromic suture to the adjacent intact muscle.

Intervention and Outcomes

Postoperative rehabilitation included 3 phases: (1) acute, consisting of the first week of postoperative care; (2) subacute, consisting of weeks 1 to 3; and (3) return-to-play reconditioning, during weeks 3 through 5. Criteria for phase progression included but were not limited to (1) time since surgery/stage of tissue healing, usual pain rating less than 5/10, and normalized gait; (2) normalizing (greater than 75% of contralateral side) range of motion (ROM) and strength, pain-free running, significant improvement on outcome questionnaires; and (3) resolution of ROM, strength, power, and movement asymmetries, return to baseline conditioning level, and pain-free sport participation. A detailed exercise protocol is outlined in the **APPENDIX** (available at www.jospt.org) and depicted in **FIGURES 2** through **10**.

Postoperative Phase 1: Acute Physical therapy was initiated on day 1 postoperation. A BLAKE drain (Ethicon US, LLC, Somerville, NJ) was in place for 5 days to control drainage and was monitored by team physical therapists. The patient was treated 1 to 2 times a day, 7 days a week. Cryotherapy, pneumatic compression, and ROM activities were initiated from the onset of treatment and continued throughout rehabilitation to enhance recovery by controlling pain and effusion.[32] Passive ROM was performed

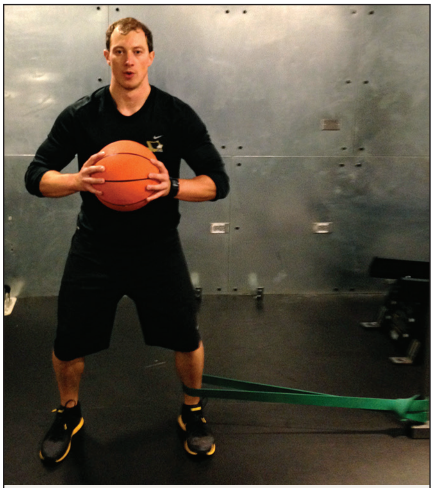

FIGURE 7. Adduction walkouts.

FIGURE 8. Core X walking lunge.

FIGURE 9. Core X adduction rotation.

FIGURE 10. Core X squat press.

in all cardinal planes, with limitations present in hip abduction, extension, and combined rotation, and also included hip circumduction at 0° and 90° of hip flexion. Grade I and II long-axis hip distraction mobilization was introduced for its neurophysiological effects[62] (**TABLE 2**).

Open-kinetic-chain exercises for the neuromuscular re-education and strengthening of the rectus abdominis, transversus abdominis, internal and external obliques, adductor complex, and gluteal musculature were initiated 1 day postoperation.[17,64] Low-intensity closed-chain hip and core exercises were added on day 4. Multiplane hip strengthening and core strengthening have previously been identified as effective in return to sport for similar injuries, and were progressed from the initial onset of treatment through the return to sport.[20,32,53,64] A modified, undulated periodization program with a focus on providing foundational exercise dosage was imposed to attain neuromuscular adaptations within each stage of rehabilitation.[8,35,43]

Upon surgeon recommendation, progressive weight-bearing activities were initiated as tolerated, with no assistance, 1 day postoperation and involved ambulating 1.6 km. Ambulation occurred in multiple planes, including forward, backward, and lateral stepping, with discomfort and endurance monitored to control the duration and intensity of effort. Significant pain was reported at rest and with activities of daily living for the first 3 days postoperation, peaking at 10/10 on the numeric pain-rating scale (NPRS). Subjective reports of resting pain reduced significantly[18,45] (5/10 at worst) on day 4, with a coinciding improvement in antalgic gait that consisted of a flexed trunk and hip circumduction. Multiple sets of stair climbing were added on day 5 of rehabilitation. Gait speed and cardiovascular workload were progressed according to resolution of impairments.

Sleep and nutrition were monitored and modified from the onset of treatment to maximize tissue healing and reduce pain. This involved internal and external organizational consultation, with recommendations including a minimum of 8 hours of sleep (8-10 hours), utilization of a structured nap schedule, and sleep hygiene recommendations.[20,21] Player travel was temporarily eliminated to help achieve goals. Nutrition goals were set based on fat-free mass obtained via duel-energy X-ray absorptiometry, previously established playing weight, and tissue healing considerations. Protein consumption and nutrient timing strategies were utilized to promote improved recovery.[4] A smoothie containing a minimum of 30 g of carbohydrates and 20 g of protein was consumed immediately postworkout, with a large, nutrient-dense meal consumed within 30 to 60 minutes of workout completion.[4] Recovery modalities included cryotherapy, including cold-tub submersion once

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TABLE 2 Selected Adjunct Therapeutic Interventions

Technique	Phase of Rehabilitation	Prescription	Plan
Cryotherapy	1 through 3	2-3 times	Daily
Hip circumduction PROM	1 through 3	3 × 10	2-3 times weekly
Pain-free hip ER/adduction PROM	1 through 3	3 × 10	2-3 times weekly
Hip long-axis distraction	1 through 3	3 × 30	2-3 times weekly
Posterior hip capsule mobilization	2 through 3	3 × 30	2-3 times weekly
Hip, groin, and abdomen soft tissue mobilization	2 through 3	Until decrease of tone and/or soreness	2-3 times weekly
Cold-water immersion	2 through 3	10-12 min	2-3 times weekly
Pneumatic compression	2 through 3	30-45 min	2-3 times weekly
Dry needling to the rectus abdominis	2	1-4 twitch responses	As needed
Dry needling to the adductor longus muscle belly	3	1-4 twitch responses	As needed
Hip extension stretch/mobilization	2 through 3	2-3 × 12-15	2-3 times weekly
Active hip mobilizations (**ONLINE VIDEO 2**)	3	2-3 × 12-15	2-3 times weekly
Foam rolling*	2 through 3	Until report of decreased soreness	4-5 times weekly

Abbreviations: ER, external rotation; PROM, passive range of motion.
**Target regions for foam rolling: adductor group, tensor fascia latae/lateral quadriceps, posterior hip (gluteal group/hip rotators).*

TABLE 3 Wearable Technology Load Monitoring During Reconditioning

Load Variable	M	T	W	TH	F	SAT	SUN
Duration, min	45	35	35	44	45	47	Rest
Mechanical load, BA	113	157	177	114	127	98	Rest
Physiological load, average HR/min	145	149	155	140	134	136	Rest
Average intensity, unitless	4.7	5.6	6.3	6	5.1	4.8	Rest

Abbreviations: BA, body accelerations; F, Friday; HR, heart rate; M, Monday; SAT, Saturday; SUN, Sunday; T, Tuesday; TH, Thursday; W, Wednesday.

the incision was closed (minimum of once postworkout); massage; and pneumatic compression devices (2 to 3 times weekly).[19,46,51]

Postoperative Phase 2: Subacute Additional manual therapy techniques were introduced on day 10 and included soft tissue mobilization, static stretching as tolerated, and increased rigor of hip joint mobilization. Once the patient could tolerate tissue mobilization with no residual soreness, foam rolling of the proximal hip and thigh was incorporated to increase mobility and decrease muscle soreness.[22,36,37] On days of exceptional soreness (7/10 on the NPRS for worst pain), areas of increased tone and palpable tender spots within the adductor longus, rectus abdominis, and related regional musculature were treated with dry needling.[15,30] Upon test-retest, this intervention resulted in a clinically significant decrease in pain score (greater than 2 on the NPRS) and a decrease in the concordant soreness during ROM.[18,45] Although not directly measured, ROM appeared to improve on visual observation.

Eccentric exercise was introduced in phase 2, coinciding with a progression of phase 1 core exercises. The benefits of eccentric training, which consists of loaded lengthening muscle contractions, are defined in greater detail by Lorenz and Reiman.[34] Adductor strengthening was a focus of rehabilitation due to its involvement in the case and importance in dynamic sports movements (**FIGURES 5** and **7**).[9,10,57,58] Isometric exercises, often with demands similar to those of the squeeze test[61] and with concurrent core resistance, were progressed as appropriate to the stages of healing. The Core X System (Alex McKechnie) was utilized in multiple positions, movements, and planes to engage both the core and adductors while stabilizing in functional, sport-specific positions (**FIGURES 8** through **10**, **ONLINE VIDEO 1**).

Phase 2 placed an increased emphasis on single-leg strength and multiplanar motor control, with exercises such as single-leg deadlifts (**FIGURE 3**), step-up variations (**FIGURE 6**), split squats, single-leg squats (**FIGURE 2**), and lunge variations (**FIGURE 4**).[7,38] Monitoring of all movements, particularly the squat, single-leg squat, and lunge, required special emphasis on depth modifications and reduction of excessive anterior pelvic tilt to avoid compromising stress to the adductor group, rectus abdominis, and hip joint.[42,59,64]

Return-to-run criteria achieved in phase 2 included consideration of healing stage, increased treadmill walking speed, tolerance of advanced functional exercise, and physician recommendation. Running was reintroduced in gravity-reduced conditions by first utilizing hydrotherapy. Hydrotherapy running was performed with the water at waist level, while plyometric progressions were introduced with water levels between the umbilicus and the chest plate due to laterally performed exercises. Levels were lowered once activity was performed with no residual soreness the next morning. With no residual soreness from hydrotherapy jogging, the athlete progressed to jogging as tolerated on the basketball court. Gravity-reduced conditions continued to be prescribed on days of significantly increased reported

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TABLE 4 OUTCOME MEASURES

Outcome Measure	Baseline	Entering Phase 3	Return to Play
NPRS (0-10)			
Now	6	5	0
Usual	9	2	0
Best	3	0	0
Worst	10	5	0
HAGOS (0-100)			
Pain	42.5	92.5	100
Symptoms	57	86	100
PF in daily living	35	100	100
PF in sport and recreation	12.5	71	100
Physical activities	0	62.5	87.5
Quality of life	19	40	75
Hip ROM, deg			
Internal rotation	18*	14	18
External rotation	38*	28	32
Total ROM: affected	56*	...	50
Total ROM: unaffected	53*	42	53
Abduction	Limited to 75%	Limited to 15%	Symmetrical
Hip strength			
Hip abduction	122.3*	...	121.4
Hip extension	76.4*	...	90
Functional Movement Screen			
Overhead squat	1*	1	1
Lunge	1*	1	1
Hurdle step	2*	2	2
Rotary stability	1*	2	2
Active straight leg raise	2*	2	2
Shoulder mobility	3*	Not tested	3
Push-up	2*	2	2
Total	12*	Incomplete	13

Table continues on page 703.

soreness (increase greater than 2 on the NPRS from prior day).

Graded conditioning was emphasized at this time, with the stair stepper, elliptical, VersaClimber (Heart Rate Inc, Santa Ana, CA), and anti-gravity treadmills used as adjunct modalities. Cardiovascular conditioning sessions were attended a minimum of 5 days a week for 20 to 60 minutes per session and performed prior to therapeutic exercise. The duration of conditioning was determined based on current pain level, perceived and objective intensity levels, demands of daily concurrent training, and allocation of time devoted to basketball-skill training. Interval training and basketball-specific work-to-rest ratios were primarily utilized beginning in phase 2, progressing from 1:2 to 2:1.[11,31,48]

Postoperative Phase 3: Return-to-Sport Reconditioning Utilization of manual therapy and dry needling was reduced during this phase. It was prescribed if daily assessment revealed impairments potentially relating to the presence of mobility restrictions and/or increased pain. Active mobility drills implemented into the dynamic warm-up and within the performance staff's programming replaced passive intervention when possible (**TABLE 2**, **ONLINE VIDEO 2**).

Therapeutic exercise duties were shared with the sports performance staff at this time, with the goal of changing the athlete's mindset from rehabilitation to competition. Single-leg training and pelvic stabilization remained a key focus of the intervention.[1,25,65] Exercise dose schematics varied at this point, often implementing heavier resistance that required high-intensity, short-duration workloads and power production.[35,41]

The athlete was progressed to advanced plyometric and agility exercises at week 3. Activities, such as rebounding drills, were initially performed only in the sagittal plane. Agility activities allowing free motion in the frontal and transverse planes, such as pivoting and defensive sliding, were added later in week 3 and performed unrestricted by week 4. Reactive multiplanar motor control drills such as shuffling, sprinting, jumping, and change-of-direction tasks were used to simulate game-related demands.[1] Increased dosage of basketball-skill reconditioning was based on movement impairments and presence of residual soreness, understanding that baseline ROM, strength, and subjective outcome measure goals had already been attained.

The controlled full-court activities implemented at week 4 focused on restoring cardiovascular and anaerobic threshold capabilities by imposing competition-based work-to-rest ratios.[14,41,48] Similar drills are described in detail by Waters[63] (**ONLINE VIDEO 3**). Wearable technology was utilized to monitor internal load (average heart rate) and external load (body accelerations) (**TABLE 3**). Baseline values for internal and external loads were established via preseason conditioning protocols. Prior level of conditioning was achieved by matching established intensities and workloads.[3,55] Collaborative work between the sports medicine staff and coaching staff allowed basketball-skill training to be combined with therapeutic and reconditioning goals.

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OUTCOMES

The patient returned to in-season competition at 5 weeks postoperation. The athlete regained his starting position in his first contest and played 11 minutes, with coaching game plan being the limiting factor of time played. The prior average of minutes played was regained after 10 games. At 2-year follow-up, the individual remains an active professional basketball player with no complication or reinjury.

Both the Copenhagen Hip and Groin Outcome Score and NPRS outcome measures were improved beyond the minimal important difference (17.7 to 33.8[52] per subscale and 2,[18,45] respectively) before the athlete advanced from phase 2. Additional outcome measures included hip mobility and strength, power output, the Functional Movement Screen,[29] the Y Balance Test,[50] internal and external workload,[6] and sport performance metrics. With the exception of basketball metrics, all measures were incorporated into the return-to-play decision (**TABLE 4**).

TABLE 4 OUTCOME MEASURES (CONTINUED)

Outcome Measure	Baseline	Entering Phase 3	Return to Play
Step-down test	Poor	Fair	Good
Y Balance Test difference, cm			
Anterior	8.00*	...	2.50
Posteromedial	2.00*	...	9.50
Posterolateral	5.00*	...	7.00
Single-leg squat power	...	...	95%-105%†
Soreness present			
During activity	Yes	Occasional	No
Day following activity	Yes	Occasional	No
Basketball-drill load monitoring	Fitness monitoring*		
Physiological (internal load)	45‡	...	45§
Mechanical (external load)	180	...	177
Basketball performance			
Starting position	Yes	...	Yes
Minutes per game	20.92	...	18.90
Points per game	3.46	...	3.25
Rebounds per game	5.56	...	5.00

Abbreviations: HAGOS, Copenhagen Hip and Groin Outcome Score; NPRS, numeric pain-rating scale; PF, physical function; ROM, range of motion.
**Preseason.*
†Contralateral.
‡At 70% of maximum heart rate (average).
§At 73% of maximum heart rate (average).

DISCUSSION

Elite athletes involved in sports that require high-intensity, multidirectional movement are often exposed to hip and groin pathology. Differential diagnosis of pathology in this region is challenging due to the number of structures potentially impacted and limited ability of diagnostics,[24] but it is necessary to determine proper intervention. Whether the injury is chronic or acute, surgical management is often indicated. Following surgery, rehabilitation recommendations and outcomes have shown significant variability.[13,17,56]

The prescription of rehabilitation interventions in this case relied on an understanding of anatomy, biomechanics, and the consideration of regional interdependence.[62] Muscles that attach specifically to the pubis are essential in stabilizing the entire lumbopelvic complex, as the pelvis is exposed to a large degree of multidirectional forces.[40,59] Limitations in motor control and recruitment[1,26] may predispose an individual to kinetic-chain dysfunction[25,33,65] or injury.[12,44,60,64] Posture and mobility restrictions may contribute to uneven force attenuation, as excessive anterior pelvic tilt has been shown to have a relationship with decreased hip ROM and femoroacetabular impingement,[44] while concomitant hip mobility deficits have been frequently noted in cases of athletic groin pain.[16,60,64] Identification and comprehensive treatment of these impairments via manual therapy and therapeutic exercise may benefit a subgroup demonstrating these characteristics following surgical intervention.[17]

The prescription of therapeutic exercises should be based on these noted biomechanical factors, while considering current evidence and demands of sport. In similar clinical situations, strengthening of the adductor, gluteal, and core complexes has been recommended.[1,27,54,65] Adductor strength has been shown to reduce injury rates in hockey athletes, but has not shown functional carryover to dynamic testing (ie, hop testing), indicating the potential need for movement assessment and intervention before a return to sport.[28,57,58] An adductor-abductor strength ratio of at least 90% is desired, combined with 100% side-to-side isometric adductor strength, when returning from injury in soccer athletes.[54] Different sport-specific demands may have an impact on this ratio and the functional training prescribed. Sport-specific movement requires repeated bouts of multiplanar single-leg actions. Movement patterns and muscle firing patterns have been shown to differ when comparing single- and double-leg exercises.[38] Select single-leg exercises have been shown to have greater muscle activity compared to alternative exercises, potentially improving exercise effectiveness.[7,54] An emphasis

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on single-leg training was believed to be of benefit during phases 2 and 3 of this case.

While the focus of phases 1 and 2 was to achieve an appropriate physiological foundation, phase 3 placed a greater emphasis on dynamic ability and reconditioning. It has been reported that if the acute workload of the rehabilitating athlete is significantly greater than the chronic workload, there is increased risk for reinjury.[6] Workload monitoring during rehabilitation is not often documented; however, there may be value in assessing both physiological and mechanical loads.[47] Monitoring creates a physiological conditioning profile while assisting in setting workout intensity and progression, serving as both a training tool and outcome measure.[3,5]

In addition to workload monitoring, this case employed numerous objective measures to assist in progression and return-to-play decision making. An optimal battery of measures may assist in desired return-to-sport outcomes but has yet to be identified.[26] Outcome questionnaires exhibit limitations that include interpretation, few sport-related questions, questionable reliability of answers due to athlete pressures, and ceiling effects. For example, Copenhagen Hip and Groin Outcome Score[52] results in this case showed significant improvement within 2 weeks, while healing time and current presentation indicated that the athlete was not yet at the indicated level of performance. Further objective measures were of benefit to complement questionnaire deficiencies by further detailing the response to rehabilitation. Baseline ROM, strength, and movement data, combined with consistent objective reassessment during rehabilitation, may help demonstrate progress, identify current asymmetry and impairment, and assist in setting evidence-informed goals[54,58] (**TABLE 4**). Movement[29] and motor control[50] measures may be valuable in injury risk assessment, while potentially bridging the gap between static[56] and performance measures.[6] Despite the deliberate detail utilized for intervention and the usefulness of objective measures identified in this case, it is not clear which methods or measures specifically improved the outcome. There appears to be a need for clinical trials addressing specific interventions, outcome measures, and objective batteries unique to this population to address these concerns.

CONCLUSION

Return-to-sport situations are challenging, particularity in clinical situations such as this case, where the pressures of returning to professional competition were combined with an uncommon injury involving complex anatomy. This report emphasizes evidence-informed intervention and comprehensive care in a case that resulted in the successful in-season return to sport ahead of previously established timelines. There is a paucity of evidence to guide the clinician in terminal phases of rehabilitation, where advanced resistance training, sport reconditioning, and functional outcome measures are required. An integrated rehabilitation system that is comprehensive in its approach, informed by current evidence, and objectively measured may allow athletes to recover earlier with optimal outcomes. ◉

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APPENDIX

POSTOPERATIVE EXERCISE PROTOCOL FOR RETURN TO SPORT PARTICIPATION

Phase 1

Resistance Exercises

Day 1

- Prone core draw-in plus hip extension, 3 × 10
- Supine core draw-in plus adductor squeeze, 3 × 10 plus 10 s of isometrics
- Clam shell, 3 × 12
- Transversus abdominis marches, 3 × 10
- Seated hip external/internal rotation plus band, 3 × 10
- Bridges plus adductor squeeze, 3 × 10

Day 2

- Supine core draw-in plus adductor squeeze, 3 × 10 plus isometric
- Seated hip external/internal rotation plus band, 3 × 10
- Prone transversus abdominis draw plus opposite-arm leg raise, 3 × 10
- Transversus abdominis march plus upper extremity band resistance, 3 × 10
- Sidelying hip abduction, 3 × 10
- Lateral/monster slides plus band, 2 × 20 ft

Day 3

- Transversus abdominis marches, 3 × 10
- Lateral/monster slides plus band, 3 × 25 ft plus perturbations
- Sidelying hip external rotation, 3 × 10
- Bird dog, 3 × 10
- Cable standing antirotational press, 3 × 10
- Single-leg glute bridge plus adductor manual resistance, 3 × 10
- Hip hinge, 3 × 10
- Supine adductor isometrics (modified squeeze test), 2 × 10 plus 10 s of isometrics

Day 4

- Bridges plus adductor squeeze, 2 × 10
- Sidelying hip abduction, 3 × 12
- Bird dog, 3 × 10
- Single-leg glute bridge plus adductor manual resistance, 3 × 10
- Monster walks, 3 × 20 ft
- Kneeling chops plus medicine ball, 3 × 10
- Modified side plank, 3 × 10
- Supine adductor isometrics (modified squeeze test), 2 × 10 plus 10 s of isometrics
- Return to upper extremity weightlifting, 2 to 3 times per week

Day 5

- Single-leg glute bridge plus adductor manual resistance, 3 × 15
- Monster walks, 3 × 20 ft
- Sidelying hip adduction, 3 × 10
- Bird dog plus band, 3 × 10
- Lay-up step-ups plus medicine-ball overhead press, 3 × 10
- Romanian deadlift, 2 × 10
- Cable antirotation walkouts, 3 × 10
- Prone hip internal/external rotation plus band, 3 × 10

Reconditioning Exercises

Day 1

- Forward/back/lateral ambulation, 1 mi

Day 2

- Forward/back/lateral ambulation, 1 mi on court

Day 3

- Forward/back/lateral ambulation, 1 mi on court
- Treadmill walking, 0.5 mi at 2.4 mph

Day 4

- Forward/back/lateral ambulation, 0.5 mi
- Stadium stair walking, 3 × 4 (35 steps each)

Day 5

- Treadmill walking, 15 min at 2.6 mph

Phase 2

Resistance Exercises (**FIGURES 2** through **10**)

Day 6

- Adductor band slides, 3 × 10
- Single-leg glute bridge plus Core X, 3 × 10
- Core X squat, 3 × 10
- Standing hip internal/external rotation, 3 × 10
- Stability-ball hamstring curls, 3 × 10
- Tall kneeling chops plus adductor ball squeeze, 3 × 10

Day 7

- Core X standing plus stability-ball upper extremity press, 3 × 10 plus manual hold
- Single-leg deadlift, 3 × 10
- Bird dog plus band resistance, 3 × 10 plus manual hold
- Core X hip internal rotation pivot, 3 × 10 plus manual hold
- Lateral lunge, 3 × 10
- Side plank, 3 × 10 plus manual hold

Day 8

- Single-leg glute bridge plus Core X, 3 × 12 plus holds
- Tall kneeling chops plus adductor ball squeeze, 3 × 10
- Adduction reaction lateral stepping, 3 × 10
- Core X pivots, 3 × 12 plus manual hold
- Front plank, 3 × 45 s
- Lateral step-up plus band, 3 × 10
- Romanian deadlift, 3 × 10

Day 9

- Adductor band slides, 3 × 10
- Bird dog plus band resistance, 3 × 10
- Core X stability-ball press, 3 × 10
- Core X cross-leg thrust, 3 × 10
- Lateral lunge plus medicine-ball chop, 3 × 10
- Half-kneeling cable lift, 3 × 10
- Monster band walks plus dribble reaction, 3 × 30 s multi

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Day 10
- Single-leg deadlift, 3 × 10
- Core X stability-ball press, 3 × 20
- Core X walking lunge, 3 × 20
- Slide-board hamstring curl, 3 × 10
- Cable antirotational press, 3 × 10
- Single-leg squat, 3 × 10

Day 11
- Rest

Day 12
- Lateral lunge plus medicine-ball chop, 3 × 10
- Single-leg squat, 3 × 10
- Core X single-leg glute bridge, 3 × 10
- 2-way steamboat, 3 × 12
- Standing hip internal/external rotation, 3 × 10
- Slide-board reverse lunge, 3 × 10
- Front/side plank circuit plus medicine-ball adductor squeeze, 3 × 30 s

Reconditioning for Return to Play

Day 6
- Treadmill, 1 mi at 3.5 mph

Day 7
- Treadmill, 1 mi at 3.5 mph
- Elliptical, 20 min level and 10 min flat

Day 8
- Treadmill, 10 min at 3.8 mph
- Stair climber, 10 min
- Elliptical, 20 min level and 10 min flat

Day 9
- Treadmill, 10 min at 3.8 mph
- Stair climber, 10 min at 1:2 intervals (work-rest)
- Elliptical, 10 min at 1:2 intervals (work-rest)

Day 10
- Stair climber, 10 min at 1:2 intervals (work-rest)
- Elliptical, 10 min at 1:2 intervals (work-rest)
- Hydroworks, 20-s walk and 20-s jog

Day 11
- Elliptical, 45 min at 1:2 intervals (work-rest)
- Hydroworks, 20-s walk and 20-s jog
- Full-court jog, 1 × 6 forward and 1 × 6 backward

Day 12
- Elliptical, 45 min at 1:2 intervals (work-rest)
- Alter-G, 6 mph at 75% of rate of perceived exertion
- Full-court jog, 1 × 6 forward and 1 × 6 backward

Day 13
- StairMaster/VersaClimber, 20 min at 1:2 (work-rest) intervals

Day 14
- StairMaster/VersaClimber, 45 min at 75% of rate of perceived exertion
- Basketball-skill conditioning, 15 min at low intensity

Day 15
- StairMaster/VersaClimber, 20 min at 1:1 (work-rest) intervals
- Basketball-skill conditioning, 15 min at low intensity

Day 16
- StairMaster/VersaClimber, 45 min at 75% of rate of perceived exertion
- Basketball-skill conditioning, 15 min at low intensity

Day 17
- StairMaster/VersaClimber, 20 min at 2:1 (work-rest) intervals
- Basketball-skill conditioning, 15 min at low intensity

Day 18
- Basketball-skill conditioning, 30 min at low/moderate intensity
- Full-court strides, 1 × 5 at 80% of rate of perceived exertion
- Stadium stair run, 1 × 6 at 60% of rate of perceived exertion

Day 19
- Basketball-skill conditioning, 30 min at low/moderate intensity
- Full-court strides, 1 × 5 at 80% of rate of perceived exertion
- Stadium stair run, 1 × 6 at 60% of rate of perceived exertion

Phase 3

Resistance Exercises (**ONLINE VIDEO 1**)

Day 20
- Lateral lunge plus medicine-ball chop, 3 × 10
- Half Turkish get-up plus kettlebell resistance, 3 × 5
- Half-kneeling cable chop, 3 × 10
- Single-leg glute bridge plus band perturbation, 3 × 15

Day 21
- Bird dog plus band, 3 × 12
- Stability-ball hamstring curls, 3 × 12
- Double- and single-leg squat, 3 × 10
- Half-kneeling hip flexion stretch, 3 × 45 s

Day 22
- Core X single-arm circles in single-leg stance, 3 × 30 s
- Core X walking pivot plus perturbations, 3 × 40 steps
- Core X stability-ball adductor squeeze plus rotation, 3 × 20
- Rearfoot elevated split squat, 3 × 8
- Adduction walks plus arm and leg band resistance, 3 × 30 steps
- Single-leg deadlift, 3 × 8
- Core X squat, 3 × 10

Day 23
- Hydrotherapy squat, 3 × 30 s at 1:1 (work-rest) intervals
- Hydro side slide/shuffle, 3 × 30 s at 1:1 (work-rest) intervals
- Hydro skip/bound/tuck jump, 3 × 30 s at 1:1 (work-rest) intervals
- Hydro multidirection hop circuit, 3 × 30 s at 1:1 (work-rest) intervals
- Hydro sprint intervals, 6 × 15 s at 1:1 (work-rest) intervals
- Bird dog plus isometric holds, 3 × 6 (7 s)
- Half-kneeling hip flexion stretch, 3 × 45 s

Day 24
- Lateral lunge plus medicine-ball chop, 4 × 6
- Hydrotherapy squat, 3 × 30 s at 1:1 (work-rest) intervals
- Hydro side slide/shuffle, 3 × 30 s at 1:1 (work-rest) intervals
- Hydro skip/bound/tuck jump, 3 × 30 s at 1:1 (work-rest) intervals
- Hydro multidirection hop circuit, 3 × 30 s at 1:1 (work-rest) intervals
- Hydro sprint intervals, 6 × 15 s at 1:1 (work-rest) intervals
- Front squat, 4 × 6

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- Shuttle single-leg squat, 4 × 6
- Shuttle hip extension, 4 × 6

Day 25
- Core X single-arm circles in single-leg stance, 3 × 10
- Core X walking lunge with change of direction, 3 × 20
- Core X wall press, 3 × 10

Day 26
- Double- and single-leg squat, 4 × 8
- Rearfoot elevated split squat, 4 × 8
- Single-leg deadlift, 4 × 8
- Front squat, 4 × 8
- Shuttle double-leg jumps, 4 × 15
- Half-kneeling hip flexion stretch, 2 × 45 s

Reconditioning for Return to Play (**ONLINE VIDEO 3**)

Day 21
- Basketball-skill conditioning, 30 min at low/moderate (2:1) intensity

Day 22
- Basketball-skill conditioning, 30 min at low/moderate (2:1) intensity
- Pool swimming, 1 × 10 pool sprint
- Pool dynamic warm-up, 10 min

Day 23
- Basketball-skill conditioning, 20 min at low/moderate (1:1) intensity
- Pool swimming, 1 × 10 pool sprint
- Pool dynamic recovery cool-down, 10 min
- Elliptical (intervals), 15 min (2:1)
- StairMaster/VersaClimber, 15 min at 2:1 intervals
- Full-court strides, 1 × 10

Day 24
- Basketball-skill conditioning, 20 min at low/moderate (1:1) intensity
- Elliptical (intervals), 10 min (2:1)
- StairMaster/VersaClimber, 10 min at 2:1 Intervals

Day 25
- Rest

Day 26
- Basketball-skill conditioning, 35 min at moderate (2:1) intensity

Day 27
- Travel and rest

Day 28
- Basketball-skill conditioning, 45 min at moderate/high (2:1) intensity

Day 29
- Basketball-skill conditioning, 45 min at moderate/high (1:1) intensity

Day 30
- Basketball-skill conditioning, 35 min at high (2:1) intensity

Day 31
- Basketball-skill conditioning, 30 min at low/moderate/high (2:1) intensity

Day 32
- Basketball-skill conditioning, 30 min at low/moderate (1:1) intensity
- Contact practice, 45 min at moderate intensity

Day 33
- Contact practice, 45 min at moderate (2:1) intensity

Day 34
- Basketball-skill conditioning, 60 min at moderate/high (1:1) intensity

Day 35
- Full team practice, 60 min

Day 36
- Return to competition (11 min 59 s)

Day 46
- 22 min 38 s per-game average

Examples of Basketball-Specific Reconditioning Drills

Low Intensity	Moderate Intensity	High Intensity
• Dynamic warm-up	• Pick and roll	• Defensive reaction agility
• Sagittal plane ladders	• Spin and pivot with perturbations	• Full-court sprints
• Jump hook/Mikan drill	• Post battles	• Angle sprinting
• Low-post core perturbations	• Hurdle plyometrics	• Reactive agility slides
• Spot shooting	• Agility cones	• Wave drill
• Rebound taps	• Basketball paint slides and angle cuts	• Full-court position skill drills
• Sagittal plane hurdle stepping	• Run-ins/lay-up line drills/dunking	• Full-court zig-zags
• Rebounding reaction	• Full-court dribble and pass drills	• Continuous motion
• Jump rope	• Planned change of direction	• Full-court 1-on-1

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