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Lower Extremity Strengthening, Neuromuscular Re-Education And Graded Activity For A Runner With Distal Hamstring Tendinopathy: A Case Report

Tara Oyasato

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Tara Oyasato, BS, is a Doctor of Physical Therapy student at the University of New England, 716 Stevens Ave. Portland, ME 04103. Address all correspondence to Tara Oyasato at: toyasato@une.edu

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The patient signed an informed consent acknowledging the participation in this case report and allowing the use of their personal health information and recorded images. The patient received information on the university's policies regarding the Health Insurance Portability and Accountability Act.

Key Words: Hamstring Tendinopathy, Quadriceps Dis-Use, Hamstring Overuse, Running

Abstract

Background and Purpose: Hamstring injuries are common injuries athletes face with high recurrence rates. Many hamstring injuries, including hamstring tendinopathy are caused by non-contact mechanisms like running due to its role in eccentrically controlling rapid knee extension and hip flexion. Despite its prevalence, there is controversy surrounding the optimal treatment of a hamstring strain. The purpose of this case study was to document the physical therapy (PT) interventions for a runner with an acute distal hamstring injury and tendinopathy.

Case Description: The patient was a 23-year-old active male referred to outpatient PT with a diagnosis of patellar tendinitis. The procedural interventions included patient education and activity modification, progressive lower extremity (LE) resistance training, neuromuscular re-education, soft tissue mobilizations, stretching, and running assessments. The patient received PT twice a week for 12 weeks.

Outcomes: The patient's score on the Lower Extremity Functional Scale improved from 41/80 to 70/80. His right (R) knee flexion and extension strength improved bilaterally from 3+/5 to 4/5 and his running cadence improved from 158 to 170 steps/minute. The patient no longer experienced hamstring tenderness with palpation. When performing a step up on a 4-inch platform, the patient's functional testing improved from having no ability to feel his R quadriceps contract with posterior knee pain to gaining the ability to feeling his quadriceps recruit with no pain.

Discussion: This case report demonstrated the purpose of how LE strengthening, graded activity, and neuromuscular reeducation could be beneficial to help a runner return back to full activity. Future research should focus on cadence assessment and rehabilitation for long-distance runners in addition to running cadence education for patients with hamstring injuries.

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Introduction/Background and Purpose

Hamstring injuries are one of the most common injuries that recreational and elite athletes face.[1-4] The prevalence of hamstring strains are high in sports that are associated with running and quick acceleration.[1] A descriptive epidemiology study conducted by Dalton et al[3] showed that the majority of the hamstring strains reported were in soccer, indoor and outdoor track, and football. This injury also had a high reoccurrence rate which may be attributed to premature return to sport and/or insufficient rehabilitation.[2] The inability to restore full strength and the patient's prior level of activity could lead to persistent weakness in the injured muscle.[5] This could also cause the patient to change their biomechanics and motor patterns of sporting movements.[4]

Pankaj et al[6] reported that the combination of symptoms including pain, swelling and impaired performance should be labeled as tendinopathy. Tendinopathies are typically due to overuse and although the etiology remains unclear, hypotheses have been made to explain its cause.[6] Many hamstring injuries, including hamstring tendinopathy are due to non-contact mechanisms.[3] The semitendinosus and semimembranosus make up the medial hamstring and the long head and the short head of the biceps femoris make up the lateral aspect of the hamstring. They all play an important role in eccentrically contracting to decelerate hip flexion and the rapid extension of the knee during the terminal swing phase of running.[4,5,7] The accumulation of this repetitive eccentric contraction could lead to muscle damage and put the hamstring musculature at a higher risk of injury.[8] Higashihara et al[7] suggested that the distal and middle aspect of the hamstring are more susceptible to damage in marathon runners.

The primary goal for rehabilitation of a hamstring strain is to return the athlete back to their prior level of performance and minimize the risk of re-injury. There are both modifiable and non-modifiable risk factors related to hamstring injuries. The modifiable factors include hamstring weakness, fatigue, lack of flexibility, strength imbalance between the hamstring and quadriceps and lack of warm-up.[1,9] The un-modifiable risk factors are age and previous history of a hamstring strain.[1,9] This injury has gained a considerable amount of attention in the literature due to its prevalence, high reoccurrence rate and lengthy recovery time.[1,5,10] Despite its prevalence, no specific protocol has been established to be more effective than others.[1] Askling et al[2] recommended that neuromuscular control and eccentric strengthening exercises including kneeling Nordic hamstring curl exercises are appropriate interventions for individuals with HS injuries. According to a prospective randomized comparison of two rehabilitation programs by Sherry et al,[10] a program utilizing progressive agility and trunk stabilizing exercises may be effective at treating athletes who sustained an acute hamstring strain and preventing re-injury compared to more traditional and isolated stretching and strengthening programs. A review article by Erickson et al[5] also stated that there is an increasing amount of evidence that supports the implementation of neuromuscular control, progressive agility, trunk stabilization, and eccentric strength training for the treatment and prevention of reinjury to the hamstring.

Due to the controversy surrounding the optimal treatment of a hamstring strain, the research regarding the efficacy and success of specific interventions can be strengthened. The purpose of this case study was to document the physical therapy (PT) interventions for a runner with an acute distal hamstring injury and tendinopathy.

Patient History and Systems Review

The patient verbalized and signed a consent form allowing the use of his medical information for this case report. The patient was a 23-year-old Caucasian male who was referred to outpatient PT by an orthopedic surgeon with a diagnosis of patellar tendinitis. At that time, the patient was a college student studying remotely from home. This was beneficial as he would have had difficulty getting to and from his classes on a large college campus in a timely manner. The patient's normal activities included running, using the elliptical, biking, skateboarding, and training for a triathlon, however these had to be modified once he developed knee pain.

On initial evaluation (IE), the patient had been experiencing intermittent right (R) knee pain for two months causing him to limit his activities. The patient stated that he had been running 20 miles/week when he first noticed pain along the front of his R knee, which led him to change the way he moved. Although his R knee pain first began anteriorly, his primary complaint was posterior R knee pain and slight anterior knee pain with deep pressure upon IE.

The results of the patient's systems review can be found in Table 1. He reported that his R knee pain increased when he walked greater than one mile or walked too fast, pivoted too quickly, and when going up and downstairs. He described his pain as a burning sensation and stated that he was unable to make his "quad work like how it used to." The patient denied any symptoms of numbness and tingling. Although the patient did not have any past knee injuries, he demonstrated a squat and stated that he had a history of feeling his left (L) distal hamstring 'snap' when descending. It was sometimes irritated with repetitive squatting; therefore, he did not implement squats into his regular exercise regimen. The patient stated that he was not taking any medications and his past medical history was unremarkable.

The patient expressed that his goal was to "have the problem go away and to get stronger." Potential differential diagnoses included patellar femoral pain syndrome, osteochondritis dissecans and bursitis. An x-ray showed no fracture, dislocation, or joint effusion and bone mineralization were within normal limits. The plan for examination included the Lower Extremity Functional Scale (LEFS), a gross range of motion (ROM) assessment, lower extremity (LE) strength testing, special knee testing, palpation, and functional testing. The patient was an excellent candidate for a case report due to his high level of motivation to return to his prior activity level.

Examination – Tests and Measures

Refer to Table 2 to view the results of the patient's physical examination performed at IE. The patient completed the LEFS, which was a patient-reported outcome measure assessment tool. The LEFS can be utilized to determine the patient's functional limitations to formulate goals and the appropriate plan of care (POC), as well as check if interventions are effective. Binkley et al[11] conducted a study and concluded that the LEFS was a valid and reliable tool for patients with LE injuries. Although the study did not include patients with patellar tendinopathy, it can be used to measure patient's functional change over time. A lower score shows a greater disability where a higher score demonstrates no disability.

A gross ROM assessment was done using the methods described by Norkin and White.[12] The patient was asked to perform active knee flexion and knee extension while seated. He was able to achieve both ranges of motion within normal limits. The patient's strength was assessed using the MMT techniques described by Kendall et al.[13] Cuthbert and Goodheart[14] concluded that MMT used by physical therapists was a clinically useful, valid and reliable tool.

A series of special tests were performed to rule out other knee pathologies. The varus and valgus stress test was used to assess if the medial and lateral collateral ligaments were intact. The techniques of performing these special tests are described by Brookbush.[15] Harilainen found that the sensitivity for the varus and valgus stress test was 86% and 25% respectively.[16] As reported by Malanga et al,[16] the McMurray test was used to assess the patient's medial and lateral meniscus and the Lachman's test was used to detect an anterior cruciate ligament (ACL) tear. Both of these tests are reported to have a high sensitivity and specificity. The posterior drawer was performed to detect a posterior cruciate ligament (PCL) tear. This test also had a high sensitivity and increased in specificity when coupled with other tests and measures.[17]

Palpation was performed along the joint line and the origin and insertions of the ligaments, musculature and tendons around the knee region. For the functional assessment, the patient performed a step up onto the four-inch step platform from 'The Step Original Aerobic Platform for Total Body Fitness' (TheStep, Marietta, GA) to see if he could perform this task with quadriceps recruitment.

Clinical Impression: Evaluation, Diagnosis, Prognosis

Following the IE, the patient's presentation was consistent with quadriceps dis-use secondary to patellar tendinitis, which caused R sided hamstring tendinopathy. The patient continued to be appropriate for this case report due to his biomechanical dysfunction, willingness to participate in PT, and functional impairments. The decision was to proceed with PT in order to increase the patient's LE strength, improve gait and running mechanics and overall functional status to return back to his prior level of activity. The patient's medical diagnosis was acute pain of R knee [M25.561] and his PT diagnosis was strain of muscle, fascia and tendon of the posterior muscle group at thigh level, R thigh, initial encounter [S76.311A].

Erickson et al[5] reported that the more proximal the site of maximal pain, the longer the recovery period to return to prior level of function. Heiderscheit et al[9] reported injuries involving the intramuscular tendon or aponeurosis and adjacent muscle fibers (typically the biceps femoris) generally require a shorter recovery period than hamstring strains involving a proximal, free tendon (semitendinosus and/or semimembranosus). Due to the patient having pain more distal and closer to the hamstring's insertion site along the biceps femoris, semitendinosus and semimembranosus, the patient's rehabilitation recovery was variable. Despite the severity in presentation of a patient with greater tenderness during palpation along with weakness, the convalescent period could still be typically less than those with tenderness along the proximal free tendon.[9] The patient's age and motivation to return to his prior level of activity were both contributing factors to a positive prognosis. Although the patient did not have a magnetic resonance image (MRI), Chu et al[4] concluded that image results did not correlate with the prognosis of return to sport. Based on his prognosis, it was determined that he would benefit from outpatient PT twice a week for eight weeks.

There was no plan for referral or consultation with other providers besides his referring physician. The patient had a scheduled follow-up appointment with the orthopedic surgeon three weeks from his IE. The plan was to assess the patient's running cadence at a later date when the patient's knee was less irritable as it was not done during the IE. This would again be collected at discharge, as well as all other measures performed on IE.

The procedural interventions included patient education and activity modification, progressive LE resistance training, neuromuscular re-education, soft tissue mobilizations (STM), stretching, and running assessments. The short and long-term goals that were developed after the IE are in Table 3.

Intervention and Plan of Care

Coordination and constant communication occurred between the primary therapist, PT student, and personal trainer about the patient's POC. The first nine weeks of PT were facilitated by the student physical therapist with supervision of the primary therapist. Weeks 10-12 therapy sessions were administered and witnessed by the primary physical therapist. A daily note was handwritten after every session. Although there was no direct communication with the referring physician at week three, the patient reported his physician was pleased with his progress and to continue with the current treatment plan.

After every PT session, the physical therapist reviewed the individualized home exercise program (HEP) with the patient and progressed the HEP when the patient was able to complete the previous week's running plan without issues. The HEP included LE strengthening exercises, stretches and running mileage/time for that week. The patient was present for all scheduled appointments (25 total), was compliant during the sessions, and reported doing his HEP one to three times a week.

The volume and progression of interventions are located in Table 4 and Appendix 1 shows the patient's warm-up done at the beginning of each visit. PT sessions focused on helping the patient achieve greater muscle activation of his quadriceps rather than the involuntary contraction of his hamstring. These included open kinetic chain (OKC) movements and then progressed to closed kinetic chain (CKC) movements which allowed the load to be increased. Anderson et al[23] concluded that rehabilitation programs should include heavy resistance exercises in order to encourage neuromuscular activation to stimulate muscle growth and strength. Exercises were appropriately progressed by increasing repetitions, sets, or increasing weighted resistance based on observation and patient feedback. In order to optimally stimulate maximal muscle strength and intermuscular coordination, a combination of both simple and complex exercises should be prescribed.[23]

Erickson et al[5] proposed that rehabilitation program should address modifiable risk factors such as imbalances between hamstring eccentric and quadriceps concentric strength. Neuromuscular control was also an important component of rehabilitation.[5] Research conducted by Sole et al[18] suggested that there was a change in LE proprioception and neuromuscular control post hamstring injury. Changes in neuromuscular control associated with increased hamstring muscle activation could lead to an overall increase in the loading of those muscles and increase their risk for injury.[18]

A foam wedge (OPTP, Minneapolis, MN) was placed under the patient's foot during certain CKC exercises (Appendix 2) and was used as an adaptive tool to achieve greater quadriceps muscle activation in the first two weeks of PT. The wedge altered the joint position angle of his ankle into a more plantarflexed position. Kongsgaard et al[19] reported that knee extensor muscle activity was significantly greater during eccentric squats when performed on a declined surface when compared to a regular squat.

STM with active and passive ROM was performed when the patient had complaints of either R or L-sided hamstring tightness. Despite conflicting evidence, STM can be used as a conservative management tool for athletes with hamstring pain in conjunction with other interventions.[4]

Addressing the patient's running form was critical to his rehabilitation. The magnitude and rate of one's landing force during the stance phase may be associated with running injuries.[20] A systematic review by Schubert et al[20] concluded that running stride rate (*cadence*) could be a mechanism that influences injury risk and recovery of a runner due to the effects on impact peak, kinematics and kinetics. Although there was limited evidence on the optimal running cadence, Daniels[21] reported that almost all elite distance runners run at the same rate of 180 or more steps per minute (min), while competitive distance runners preferred a cadence of between 170-180 steps per min.[22] Running efficiency could also be improved by adopting a faster cadence.[21]

At six weeks, the patient felt minimal symptoms in his R hamstring and started to develop the same symptoms in his L hamstring. The POC was kept the same and the interventions were focused on treating his L hamstring. Some of the LE strengthening exercises increased the patient's L HS pain and treatment sessions involved identifying different LE CKC exercises that did not exacerbate his symptoms.

Outcomes

Tests and measures taken at the IE were repeated at week nine (Table 2). The patient showed an improvement of 36% in the LEFS assessment which was considered significant because the minimum clinically important difference was nine points (about 11%). At week nine, his MMT scores improved and his hamstrings were no longer tender to palpate.

During weeks one to three, the patient had difficulty feeling his quadriceps contract with the functional test of the step up but by week nine, he was able to do step ups bilaterally onto a 12” platform (Perform Better, West Warwick, RI). He reported no hamstring pain bilaterally and he could feel the contraction of his quadriceps bilaterally. The patient’s running cadence increased from 158 to 168-170 steps/min and each week his running mileage and time for his HEP were increased.

Although the mechanism of his L hamstring tightness and pain developed at week six was unknown, it could be due to compensating for his R hamstring and over-reliance of his L leg. Due to the similar presentation as his R side at the IE, the same interventions were continued and applied to the L leg. Despite this setback, the patient was able to progress through the LE strengthening exercises every week. He was able to achieve all of his goals as well as return back to some of his normal recreational activities including hiking by the end of week nine.

The patient verbally reported his compliance with completing his HEP one to three times a week throughout the course of PT and tolerated the majority of the interventions prescribed at each session. During week seven, the patient was unable to complete exercises due to either fatigue, L hamstring tightness, and/or pain. Exercises were then adjusted or skipped in a particular session with the discretion of the therapist if the patient was not performing the movement with proper form, had noticeable compensations, or due to time constraints. See Table 4.

During weeks 10-12, the patient's strengthening exercises continued, avoiding movements (split squats, box squats and single leg Romanian deadlifts) that exacerbated his pain. He was able to complete a step up onto an 18" box (Perform Better, West Warwick, RI) with no pain or compensation. The patient was discharged at week 12 with the ability to run three and a half miles pain-free, three times a week, however this was less than his baseline of five to eight miles before the onset of his R hamstring pain. He was educated to continue running and to progress his distance by ten percent each week.

Discussion

This case report demonstrated the purpose of how LE strengthening, graded activity and neuromuscular reeducation could be beneficial for a runner to aide them back to their sport or activity after a hamstring injury. The current literature suggested that hamstring rehabilitation programs should focus on the patient's modifiable risk factors which include hamstring weakness, fatigue, lack of flexibility, strength imbalances between the hamstring and quadriceps, and lack of warm-up.[1,9] Based on the IE, the patient demonstrated strength deficits in his quadriceps and hamstrings bilaterally. LE strengthening interventions were implemented to focus on these deficits. The foam wedge was used as an assistance tool to help the patient feel the contraction of his quadriceps muscles during squat patterns. The patient's fatiguability was addressed by gradually increasing his HEP every week, as well as applying the superset training method to exercises like the reverse sled drag (Elitefts, London, OH) and the plank. Cadence was another important modifiable risk factor that was appropriate to address in PT due to the patient's wish to return to running.

One limitation of this case report was that the patient did not have an MRI that could have supplemented the clinical presentation of a hamstring tendinopathy. Another limitation was the change in symptoms the patient reported in week six. Although his R hamstring pain and tightness had subsided, he developed a similar presentation of pain and tightness in his L hamstring. The patient was educated that due to the similar presentation, his L hamstring tightness would most likely improve if he applied the same interventions used for his R leg. This caused his POC to be modified and lengthened his time in PT.

The length of the patient's PT participation was advantageous to the case report to see the improvement in both R and L hamstring and quadriceps strength. Another benefit was his compliance with his HEP through adherence to the graded activity progression that was determined by the therapist of the mileage or total running time for that week.

Based on this case report, clinicians should note that despite the presentation of a patient at their IE, compensatory movements like changing one's gait mechanics and movement patterns could evoke musculoskeletal issues on the contralateral side. Although the patient was not running the same mileage as he was prior to his injury, by the end of week nine he was able to go on hikes, short runs and mitigate the feeling of hamstring tightness with appropriate stretching. By discharge at week 12 he was able to run three and a half miles, three times a week with no hamstring pain. LE strengthening, neuromuscular reeducation, graded activity, STM, and running education were all implemented into this patient's POC and may have helped to reduce his hamstring pain and tightness.

Future research should focus on cadence assessment and rehabilitation for long-distance runners in addition to running cadence education for patients with hamstring injuries. Specific parameters regarding running characteristics and cadence would be very beneficial for physical therapists when developing rehabilitation programs for active individuals wishing to return to long distance running after a hamstring injury.

Timeline

IE
- IE at outpatient orthopedic PT clinic
- PT diagnosis: strain of muscle, fascia and tendon of the posterior muscle group at thigh level, R thigh, initial encounter

Week One
- STM on R HS provided pain relief and decreased feeling of HS tightness
- Able to decrease HS pain with use of foam wedge during squatting exercises

Week Two
- Treadmill assessment at patient's self-selected pace; Cadence:158 steps/min
- Strengthening exercises progressed
- HEP: 5 to 6 rounds of 30s running intervals

Week Three - Four
- Strengthening exercises progressed
- HS tightness exacerbated due to going on a weekend hike
- Attempted to run at his normal running pace but stopped after experiencing pain in R HS
- Follow up appointment with referring physician
- HEP: 2 min running, 2 min walking and repeat until a total time of 10 min is achieved. Step ups

Week Five
- Strengthening exercises progressed
- HEP: 3 min running intervals with 30s rest breaks in between until a total time of 15 min is achieved

Week Six
- Patient reported feeling weaker in his L leg during strengthening interventions
- Patient experienced L knee pain and L HS tightness during his eight mile hike over the weekend
- Treadmill assessment at patient's self-selected pace; Cadence:168-170 steps/min
- HEP: Run 5 min intervals for 4 rounds, world's greatest stretch before running (Appendix 3)

Week Seven
- Discontinued and regressed certain exercises due to L HS tightness and pain (box sq, SL RDL, split sq, step up)
- Attempted different squat variations to ilicit active quadricep contraction on L leg
- HEP: running for 5 min, resting for 1 min and repeat until total time of 20 min is achieved, couch stretch after run (Appendix 3)

Week Eight
- Went on a 3 mile hike over the weekend and was able to mitigate HS tightness with stretching
- Strengthening exercises progressed
- HEP: run 5 to 6 min, rest for 1 minute and repeat 4 times, forward lunges

Week Nine
- Able to go on 2 mile trail run without aggravating his symptoms
- Strengthening exercises progressed
- HEP: Run 3 miles

Week Ten - Twelve
- Able to run 3.5 mile runs, 3x/week pain free
- Strengthening exercises progressed

D/C
- Continue with running plan and increase distance by 10% each week
- Continue HS self STM and stretching as needed

IE= initial evaluation, PT= physical therapy, STM= soft tissue mobilizations, R= right, HS= hamstring, min= minute, HEP= home exercise program, s= seconds, L= left, D/C= discharged, sq= squat, SL RDL= single leg Romanian dead lift,

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Tables and Figures

Table 1. Systems Review

Cardiovascular/Pulmonary	Not Impaired
Musculoskeletal	Impaired; Decreased quadriceps activity and strength
Neuromuscular	Not impaired; No antalgic gait
Integumentary	Not Impaired
Communication	Not Impaired
Affect, Cognition, **Language, Learning Style**	Not impaired Learning style: auditory & visual

Table 2. Tests and Measures

Tests & Measures	Initial Evaluation Results		Progress Note: 9 weeks	
Functional Outcome Measures				
Lower Extremity Functional Scale (LEFS)	41/80 (51% of maximal function)		70/80 (87% of maximal function)	
Active Range of Motion	**Left**	**Right**	**Left**	**Right**
Knee Flexion	WNL	WNL	WNL	WNL
Knee Extension	WNL	WNL	WNL	WNL
Manual Muscle Testing (MMT)	**Left**	**Right**	**Left**	**Right**
Knee Extension	3+/5	3+/5	4/5	5/5
Knee Flexion	3+/5	3+/5	4/5	5/5
Palpation	Tender to palpate distal medial and lateral right hamstring. Mild right patellar tenderness with deep pressure.		No tenderness with palpation to bilateral medial and lateral hamstring.	
Functional Testing	**Left**	**Right**	**Left**	**Right**

Step ups	WNL	Posterior knee pain with step up prior to verbal cues. Able to increase quadricep recruitment and eliminate hamstring pain when shifting weight anterior over forefoot.	Able to perform step up bilaterally with 0/10 knee pain and no verbal cues from the therapist. Able to feel the contraction of his quadriceps in R and L leg.

WNL = within normal limits, n/a = not applicable

Table 3. Short- & Long-Term Goals

Short-Term Goals (4 weeks)	**Long-Term Goals (6-8 weeks)**
1. The patient will be able to perform a R step up with 0/10 pain in order to ascend and descend stairs at home by the end of 4 weeks. **(Met at week 3)** 2. The patient will be able to increase his LEFS score by ≥ 25% in order to return back to participating in some of his lower	1. The patient will be able to increase his running cadence to 170+ steps/min in order to decrease the amount of force translated through his LEs and decrease his overall knee pain when running by the end of 6 weeks. 2. The patient will be able to increase his knee R extensor strength to a 5/5 bilaterally in order to go on advanced hikes without self-limiting himself with 0/10 pain by the end of 8 weeks. **(Met at week 6)**

impact activities like walking and going on easy hikes within 4 weeks. **(Met at week 9)**	

LEFS = Lower Extremity Functional Scale

Table 4. Interventions by Session

Interventions	Session 1	Session 2	Session 3	Session 4	Session 5	Session 6	Session 7	Session 8	Session 9
AA	3’	3’	3’	3’	3’	3’	3’	3’	3’
Double Set	Purple 3 x 15	Purple 3 x 15	Purple 3 x 15	Pink 3 x 15	Pink 3 x 15	Pink 3 x 15	Pink 3 x 15	Pink 3 x 15	Pink 3 x 15
HKE	20# 3 x 15	20# 3 x 15	20# 3 x 15	22.5# 3 x 15	25.5# x 15 22.5# 3 x 15	25# 3 x 15	30# 3 x 15	32.5# 3 x 10	32.5# 3 x 15
Step Up	Wedge 6” 3 x 8	Wedge 6” 3 x 8	Wedge 6” 4 x 8	Wedge 6” 4 x 8	8” x 8 6” 3 x 10	8” 3 x 10	8” 3 x 12	12” 3 x 10	12” 10# 3 x 12
Split Squat	n/a	n/a	n/a	n/a	Blue pad 3 x 8	Blue pad 3 x 8	Blue pad 3 x 10	Blue pad 4 x 10	Blue pad 3 x 10
GTS SLS	Wedge L6 3 x 10	Wedge L6 3 x 10	Wedge L6 3 x 12	Wedge L6 4 x 12	NW L6 5 x 15	NW L6 5 x 15	NW L6 5 x 15	NW L6 4 x 15 1 x 3	NW L7 5 x 15
GTS DLS	Wedge L7 3 x 10	NW L5 4 x 10	NW L6 4 x 10	NW L7 4 x 10	NW L7 + 10# 4 x 10	NW L7 +10# 4 x 15	NW L7 +10# 4 x 15	NW L7 +20# 4 x 15	n/a
FM LAQ	10# 3 x 15	10# 3 x 15	10# x 15 12.5# 2 x 15	12.5# 3 x 15	15# 3 x 15	15# 3 x 15	15# 3 x 15	17.5# 3 x 15	17.5# 3 x 15
Box Squat	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	4 x 8
Reverse Sled Drag	n/a	n/a	n/a	n/a	n/a	90# x 4	90# x 4	90# x 4	115# x 4

Interventions	Session 10	Session 11	Session 12	Session 13	Session 14	Session 15	Session 16	Session 17
AA	3'	3'	3'	3'	3'	3'	3'	3'
Double Set	Pink 3 x 15	Pink 3 x 15	Pink 3 x 15	Pink 3 x 15	Pink 3 x 15	Pink 3 x 15	Pink 3 x 15	Pink 3 x 15
HKE	35# 3 x 15	37.5# 3 x 15	40# 3 x 15	42.5# 3 x 15	42.5# 3 x 15	42.5# 3 x 15	45# 3 x 15	45# 3 x 15
Step Up	12" 10# 4 x 10	12" 15# 4 x 10	12" 20# 4 x 10	12" 25# 4 x 10	→	6" x 8 8" 3 x 8	8" 4 x 8	12" 4 x 8
Split Sq	15# x 10 20# 2 x 10	20# 2 x 10 25# x 10	25# 3 x 10	30# 3 x 10	P! & Discontinued	n/a	n/a	n/a
RFE SLSQ	n/a	n/a	n/a	n/a	n/a	4 x 8	10# 4 x 8	15# 4 x 8
GTS SLS (NW)	L7 5 x 15	L7 + 10# 5 x 15	L7 + 20# 5 x 15	L7 + 20# 5 x 15	L7 + 20# 5 x 15	L7 + 20# 6 x 10	L7 + 30# 6 x 10	L7 + 40# 6 x 10
FM LAQ	20# 3 x 15	22.5# 3 x 15	R: 25# 3 x 15 L: 22.5# 3 x 15	→	→	B: 22.5# 3 x 15	B: 22.5# 3 x 15	R: 25# 3 x 15 L: 22.5# 3 x 15
Box Sq	4 x 8	15# 4 x 8	20# 4 x 8	25# 4 x 8	Discontinued	n/a	n/a	n/a
SL RDL	n/a	n/a	3 x 8	4 x 8	Discontinued	n/a	n/a	n/a
DL RDL	n/a	n/a	n/a	n/a	2 x 8 10 kg 2 x 8	12kg 2 x 8 16kg 2 x 8	16kg 2 x 8 18kg 2 x 8	18 kg 4 x 8
Dynamic Forward Lunge	n/a	n/a	n/a	n/a	3 x 5	4 x 6	4 x 8	4 x 10
*Prone Plank	4 x 30s	4 x 30s	4 x 30s	→	→	4 x 30s	4 x 30s	4 x 30s

*Reverse Sled Drag**	115# x 4	115# x 4	115# x 4	→	→	115# x 4	115# x 4	125# x 4

Interventions	**Session 18**	**Session 19**	**Session 20**	**Session 21**	**Session 22**	**Session 23**
AA	3’	3’	3’	3’	3’	3’
Double Set	Pink 3 x 15	Pink 3 x 15	Pink 3 x 15	Pink 3 x 15	Pink 3 x 15	Pink 3 x 15
HKE	47.5#	50#	50#	50#	50#	50#
Step Up	12” + 10# (2) 4 x 8	12” + 12# (2) 3 x 10	12” + 12# (2) 3 x 10	12” + 12# (2) 3 x 12	18” 3 x 8	18” 3 x 10
RFE SLSQ	20# 4 x 8	25# 4 x 8	25# 4 x 8	30# 3 x 8	30# 3 x 10	30# 3 x 10
Forward Lunge	4 x 10	5# (2) 3 x 10	5# (2) 3 x 10	10# (2) 3 x 10	12# (2) 3 x 10	15# (2) 3 x 10
DL RDL	20 kg 4 x 8	20 kg 4 x 8	20 kg 4 x 8	24 kg 3 x 8	24 kg 3 x 10	24 kg 3 x 10
GTS SLS	L7 + 25# 6 x 10	L7 + 25# 6 x 10	L7 + 25# 6 x 15	L7 + 25# 6 x 15	L7 + 25# 6 x 15	L7 + 25# 6 x 15
FM LAQ	25# 3 x 15	25# 3 x 15	27.5# 3 x 12	→	→	→
*Prone Plank	4 x 30s	4 x 30s	4 x 30s	4 x 30s	4 x 30s	4 x 30s
*Reverse Sled Drag**	125# x 4	125# x 4	125# x 4	125# x 4	125# x 4	125# x 4

AA = assault bike,’ = minute, HKE = hip-knee-extension, # = pounds, “= inches, → = skipped that session, Sq = squat, P! = pain, n/a = not applicable, RFE SLSQ = rear foot elevated single leg squat, GTS SLS = gravity training system single leg squat, L = level, NW = no wedge, GTS DLS = gravity training system double leg squat, FM LAQ = Free Motion long arch quad, R = right leg, L = left leg, B = bilateral, SL RDL = single-leg Romanian deadlift, DL RDL = double-leg Romanian deadlift, kg = kilograms, s = seconds

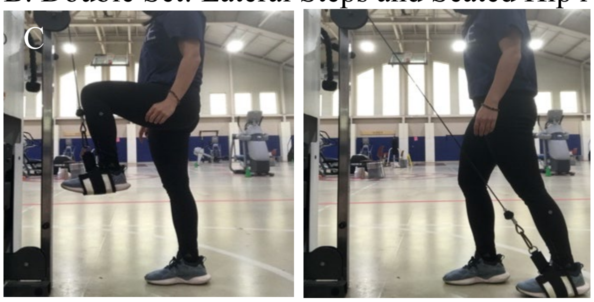
* Interventions were completed as a superset

** One repetition of the reverse sled drag was pulled 150 feet

Appendices

Appendix 1: Warm Up

A. Assault Bike (Rogue Fitness, Columbus, OH)
B. Double Set: Lateral Steps and Seated Hip Abduction (ProsourceFit, Chatsworth, CA)



C. Standing Hip-Knee-Extension (Freemotion, West Logan, UT)

Appendix 2: Foam Wedge with Closed Kinetic Chain Exercises

A. Single Leg Squat on Total Gym Gravity Training System (GTS) machine

B. Step ups

Appendix 3: Stretches for Home Exercise Program

A. World's Greatest Stretch B. Couch Stretch

CARE Checklist

CARE Content Area	Page
1. **Title** – The area of focus and "case report" should appear in the title	1
2. **Key Words** – Two to five key words that identify topics in this case report	1
3. **Abstract** – (structure or unstructured) a. Introduction – What is unique and why is it important? b. The patient's main concerns and important clinical findings. c. The main diagnoses, interventions, and outcomes. d. Conclusion—What are one or more "take-away" lessons?	2
4. **Introduction** – Briefly summarize why this case is unique with medical literature references.	3-4
5. **Patient Information** a. De-identified demographic and other patient information. b. Main concerns and symptoms of the patient. c. Medical, family, and psychosocial history including genetic information. d. Relevant past interventions and their outcomes.	4-5
6. **Clinical Findings** – Relevant physical examination (PE) and other clinical findings	7-8

7. **Timeline** – Relevant data from this episode of care organized as a timeline (figure or table).	14
8. **Diagnostic Assessment** a. Diagnostic methods (PE, laboratory testing, imaging, surveys). b. Diagnostic challenges. c. Diagnostic reasoning including differential diagnosis. d. Prognostic characteristics when applicable.	7-8
9. **Therapeutic Intervention** a. Types of intervention (pharmacologic, surgical, preventive). b. Administration of intervention (dosage, strength, duration). c. Changes in the interventions with explanations.	8-10
10. **Follow-up and Outcomes** a. Clinician and patient-assessed outcomes when appropriate. b. Important follow-up diagnostic and other test results. c. Intervention adherence and tolerability (how was this assessed)? d. Adverse and unanticipated events.	10-12
11. **Discussion** a. Strengths and limitations in your approach to this case. b. Discussion of the relevant medical literature. c. The rationale for your conclusions. d. The primary "take-away" lessons from this case report.	12-13
12. **Patient Perspective** – The patient can share their perspective on their case.	5-6
13. **Informed Consent** – The patient should give informed consent.	1