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Diagnosis, Rehabilitation & Training Load Monitoring Following Hematogenous Calcaneal Osteomyelitis in a Competitive Adolescent Soccer Player: A Level 4 Case Report

Erik A Wikstrom, PhD, ATC. Associate Professor and Katherine Smith Gunter Scholar. Department of Exercise & Sport Science, University of North Carolina at Chapel Hill; wikstrom@unc.edu. X: @ea_wikstrom

Stuart L Mitchell, MD. Assistant Professor. Department of Orthopaedics, University of North Carolina at Chapel Hill School of Medicine; stuart_mitchell@med.unc.edu

Joshua N Tennant, MD. Associate Professor. Department of Orthopaedics, University of North Carolina at Chapel Hill School of Medicine; josh_tennant@med.unc.edu

Heather Carroll, FNP. Department of Orthopaedics, University of North Carolina at Chapel Hill School of Medicine; heather.carroll@unchealth.unc.edu

April M Wikstrom, PA-C. Department of Orthopaedics, University of North Carolina at Chapel Hill School of Medicine; April.wikstrom@unchealth.unc.edu

Correspondence

Erik Wikstrom

Fetzer Hall, 210 South Rd, Chapel Hill, NC 27514

P: 919-962-2260

E: wikstrom@unc.edu

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Abstract

A 13-year-old male competitive club soccer player with a history of bilateral Osgood-Schlatter's over the past 6-months reported unusually high fatigue and right heel pain after a match. Over the next 4 days, fever developed and persisted despite anti-pyretics. Right heel pain, warmth, and redness increased until weight bearing was not tolerated. Subsequent imaging and blood work eventually lead to a calcaneal osteomyelitis diagnosis. A bone biopsy procedure and a six-week course of antibiotics were completed. The rehabilitation and conditioning plan, which was successful, was based on assessment findings and targeted a return to sport 12 weeks post-surgery. Interprofessional collaboration was key for the diagnosis and effective medical treatment. Rehabilitation and conditioning protocol development was challenging as i) no post-surgical rehabilitation protocol for a calcaneal osteomyelitis patient wishing to return to sport has been described and ii) the impact of post-injury rehabilitation on training load is poorly documented.

Key Words

Infection, Conditioning, Pediatric

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Key Points

The initial presentation of calcaneal osteomyelitis in adolescents is similar to common growth-related heel pain in this age group.

Rehabilitation and conditioning for calcaneal osteomyelitis in an adolescent male athlete was completed successfully using an assess-treat-assess model.

Overall training load metrics resembled pre-injury metrics but the training elements driving overall training loads changed throughout the rehabilitation and conditioning timeline.

Calcaneal osteomyelitis accounts for <10% of all acute bone infections in children[1,2] and is more commonly caused by foreign body penetration relative to hematologic spread.[1] Regardless of the cause, there is often a delay in the diagnosis of calcaneal osteomyelitis because symptoms are typically less pronounced than those observed in long bone osteomyelitis.[2,3] Furthermore, the process of differential diagnosis for heel pain, particularly in children and adolescents, can be complicated and time-consuming.[4,5] Diagnostic and treatment delays can result in significant complications, such as growth disturbances, spread of infection to surrounding joints, and/or additional surgical interventions.[6,7]

Multiple case reports and series on calcaneal osteomyelitis in children and adolescents provide medical outcomes (e.g. 'healed') at various follow-up time points.[1,6–8] However, details regarding common rehabilitation milestones (e.g. weight bearing status) are minimal and vary significantly.[7,8] To date, there is no evidence to guide rehabilitation or a return to activities of daily life in adolescent patients with calcaneal osteomyelitis, let alone guide the return to high level physical activity, and/or competitive sport. Additionally, the impact of any post-injury rehabilitation and conditioning on a patient's training load (i.e. physical stress placed on the body)[9] is poorly documented. The goals of this case report are to highlight: i) the challenges of diagnosing calcaneal osteomyelitis, ii) a successful rehabilitation program for calcaneal osteomyelitis in an adolescent athlete, and iii) how this rehabilitation and conditioning program influenced the patient's internal training load.

Case Report

<u>Background, Diagnosis, & Surgery</u>

A 13-year-old male competitive club soccer player (1.59m, 51.8kg) reported unusually high fatigue and right heel pain several hours after a fall season match to his parents, an athletic trainer (ATC) and orthopaedic physician assistant (PA-C). The patient had a history of significant bilateral Osgood-Schlatter's over the past 6-months. Twenty-four hours after the onset of heel pain, the patient developed a fever. Sever's disease with a concurrent viral infection was assumed. Over the next 4 days, fever persisted despite anti-pyretics, and pain, warmth, and redness of the right heel increased until weight bearing was not tolerated. Orthopaedic evaluation, sought the next day, noted unremarkable radiographs (Figure 1A) but an elevated Erythrocyte Sedimentation Rate (ERS) of 46mm/h (normal range: 0-13mm/h) and C-Reactive Protein (CRP) of 16.0 (normal range ≤10 ml/l) resulting in hospital admission for STAT MRI and blood cultures. Upon review of the MRI by the attending physician, the patient was diagnosed with Sever's disease, casted in a plantarflexed position, and discharged.

Hospital readmission and a formal diagnosis of Calcaneal Osteomyelitis (via hematogenous spread) occurred 72 hours later when blood cultures returned positive for Staphylococcus Aureus with no known foreign body puncture. Repeat MRI showed a rim-enhancing fluid collection superior to the calcaneus concerning for possible abscess and increased heterogenous signal on fluid-sensitive sequences in the calcaneus (Figure 1B). Given concern for possible abscess, the patient underwent a debridement and bone biopsy procedure via a curvilinear incision behind the medial malleolus and was on IV antibiotics (cephazolin: 50mg/kg every 8 hours) until discharge. The patient was discharged 4-days post-surgery and prescribed 5-weeks of oral antibiotics (cephalexin: 1500mg every 8 hours). Upon discharge the patient was NWB in a post-op splint positioned to maintain plantarflexion.

<u>Rehabilitation: Goals & Assessments</u>

The long-term goal of the patient was to return to competitive club soccer. The patient, in consultation with his parents, determined that the start of the spring club season, 12 weeks from surgery was an appropriate goal. Because of their respective credentials (ATC and PA-C), the patient's parents functioned as both parents and medical providers in all aspects of this case. The post-op splint was removed 1-week post-surgery. At that time, the patient was cleared by the orthopaedic surgeon with no further planned orthopaedic follow-up visits and the patient was allowed to begin partial weight-bearing as tolerated. Additionally, bilateral assessments for swelling, atrophy, ROM, strength, and self-reported function via the Foot & Ankle Disability Index subscales, and the Psychological Readiness- Return to Sport questionnaire were conducted by the ATC (Table 1). No protocols for calcaneal osteomyelitis were available to guide exercise prescription or progression. As such, physician guidance was to progress 'as tolerated'. The initial rehabilitation plan, developed by the ATC in consultation with the PA-C, was broken into 3 phases based on the initial assessment findings. All activities were completed at the patient's home under the supervision of the ATC and/or PA-C. Upon completion of each phase, the baseline bilateral assessment described above was repeated to determine the appropriateness of moving into the next phase, inform exercise prescription of the subsequent phase and adjust the overall timeline, if needed (Table 1). The session rate of perceived exertion (sRPE) was also recorded to quantify the patient's internal training load for all rehabilitation and conditioning sessions and compared to pre-injury data (Figure 2 and 3). The sRPE is the product of the session duration (minutes) and patient's perceived intensity of the session measured via a modified Borg scale (1-10).[9] Both absolute and relative internal training loads were calculated[9] and used to guide rehabilitation and conditioning volume.

<u>Rehabilitation: Phase 1</u>

The initial assessment (Table 1) illustrated limitations in all measured outcomes and the patient's relative internal training load (i.e. acute to chronic workload ratio) was almost zero at this time (Figures 2 & 3). Therefore, phase 1 (2-week duration) focused on improving ROM and weight acceptance as well as controlling residual pain and swelling. Pain and swelling were addressed with ice, elevation, compression after each bout of rehabilitation. Additionally, OTC NSAIDs were used as needed. Therapeutic exercises were completed in 3, 10-minute daily bouts (e.g. before school, after school, and before bed). ROM exercises consisted of single (e.g. ankle pumps) and multi-plane (e.g. ABCs) exercises. Multiple 30-second bouts of grade 3 posterior mobilizations (Maitland's) were performed with careful consideration of hand placement to avoid incision site pain. ROM was slower to return than anticipated, likely due to the patient being positioned in plantar flexion for 2 weeks prior to the initiation of rehabilitation and because the incision site caused pain with dorsiflexion and eversion.

Due to pain with any weight acceptance, therapeutic exercises began with seated activities such as shifting positions to transfer body weight onto the legs bilaterally. Weight acceptance activities progressed to stationary bike riding once adequate ROM was achieved (day 12 of 14). Achieving full weight bearing in phase 1 was not achieved due to pain and fear of pain. Isometric strengthening exercises and foot shortening exercises were also introduced but appropriate motor control hindered foot shorting task completion. This exercise was removed from the protocol in favor of marble pickups and towel crunches.

Concurrent resistance training sessions were completed daily for fitness and psychological well-being (Table 2). Internal training load (Figures 2 & 3) increased significantly as expected. However, no concerns were identified as the metrics were deemed 'normal' and closely associated with patient self-reports of feeling energic and positive.

Rehabilitation: Phase 2

At this time some ROM deficits persisted while strength, muscle volume, and self-reported ankle function were still significantly reduced (Table 1). Therefore phase 2 (3-week duration) was designed to improve: ROM (continuation of phase 1 activities), foot and ankle strengthening (e.g. marble pickups, towel crunches, 4-way TheraBand), weight acceptance, and a return to walking. These exercises were completed via 3, 10-minute bouts daily (e.g. before and after school, before bed). The patient regained full weight bearing immediately in phase 2 as a crutch slip forced him to use the involved limb to prevent a fall. The event did not result in significant pain and erased the patient's apprehension to bear weight on the involved ankle. As a result, eyes closed static postural control trials, progressing from 10 to 30 seconds in duration were added to the rehabilitation bouts and closed kinetic chain activities were added to the concurrent resistance training sessions (Table 2).

Upon returning to walk without crutches, the patient failed to pronate throughout stance phase. This could suggest an arthrokinematic restriction due to prolonged plantarflexion but no restriction was noted. We hypothesized that this adaptation was the result of the of incision site pain with pronation/eversion while walking that ultimately manifested in a subconscious avoidance gait pattern. This adaptation resolved over time with time dedicated to gait retraining. The patient also reported dorsal right foot pain at the talonavicular joint during longer duration activities of daily living. However, no obvious cause was identified as the patient was not point tender and was structurally stable (i.e. negative glide tests). The patient had brief pool access (three days) in the 2nd week of Phase 2, so aquatic activities (e.g. running, pogo jumps, squat jumps) were incorporated to psychologically prepare the patient for the introduction of dynamic movements under a reduced body weight (i.e. chest high water). Following the aquatic sessions, the patient wanted to add light semi-static soccer drills (e.g. ball manipulation, 1:1 passing) to his rehabilitation plan over the final week of Phase 2. While the patient was walking at this time, these initial soccer drills generally required zero to two steps to complete. Scar sensitivity while kicking the ball was a small challenge at the start of soccer specific activities.

Concurrent aerobic cycling and resistance training sessions were completed (Table 2). During phase 2, the patient's relative internal training load spiked to almost 1.5 (Figure 3). To mitigate the workload spike, some conditioning sessions were removed or lightened over the subsequent week.

<u>Rehabilitation: Phase 3</u>

Phase 3a was considered the patient's return to participation[10] and was 4 weeks in duration. The follow up assessment (Table 1) indicated some atrophy and weakness were still present but the largest deficits were noted in self-reported ankle function. Therefore, activities were designed to stress dynamic balance, weight shifting, and light changes of direction via individual soccer specific activities (e.g. 1:1 passing patterns, dribbling drills, etc) as these activities would strengthen the leg muscles, improve overall function of the ankle, and incorporate a return to jogging and running. Based on patient feedback, sessions progressed to integrate more dynamic soccer activities to enhance neuromuscular control, jogging/running, and higher intensity changes of direction. Over phase 3a, sessions were completed 3-4 days per week with durations ranging from 60-120 minutes based on session intensity. The patient continued to note dorsal foot pain during and after some sessions. Upon report, the session was terminated, and the pain would resolve. While physical evaluations remained unremarkable, it was noted that this pain was most likely to occur when planting hard on the involved foot. Concurrent resistance training sessions were completed 4 days per week (Table 2). During this phase, total training loads reached values comparable, albeit lower, to preinjury values. Additionally, the relative training load (i.e. acute to chronic workload ratio) was maintained close to 1 indicating that the steady increases in workload were appropriate for the patient.

As the orthopaedic surgeon previously discharged the patient, the ATC in consultation with the PA-C cleared the patient for unrestricted return to sport at end of the 10th post-surgery week in consultation with the patient. While earlier than the target goal, the patient's ability to complete individual training sessions comparable to team training sessions (i.e. sRPE ≥6, duration ≥90 minutes) without pain, foot/ankle/lower leg fatigue, and without visual gait compensation demonstrated a readiness to return to team activities. No traditional functional tests were used in the decision making process. The final two weeks prior to the start of the competitive soccer season (phase 3b) leveraged small sided pick-up and futsol (i.e. indoor soccer on a court) games to continue to emphasize functional and soccer specific movement patterns. These soccer specific sessions were completed 4 days per week with sessions lasting 60-90 minutes. Concurrent, weight training as well as speed and agility training sessions were initiated at the patient's request, supervised by the ATC and/or PA-C, and completed 4 days per week (Table 2). Total internal training load continued to be comparable to preinjury levels (Figure 2) and relative training load continued to be greater than 1, again suggesting that the overall workload was appropriate.

The patient successfully began their competitive soccer season at 12-weeks post-surgery. Some minor atrophy and self-reported limitations in sport related ankle function reamined present (Table 1). Right heel pain returned at 16-weeks post-surgery. Minor atrophy was still present despite increased calf girth bilateral as were minimal deficits in self-reported ankle function. An evaluation by the Orthopaedic surgeon and radiographs were unremarkable for calcaneal osteomyelitis. The patient was diagnosed with Sever's disease and treated conservatively as needed by the ATC and PA-C. The patient continues to play competitive club and secondary school soccer with no lingering impairments.

DISCUSSION

Initial presentation and progression of symptoms, the underlying cause (Staphylococcus aureus), and delay in the formal diagnosis of the current case were all consistent with previously reported calcaneal osteomyelitis cases in children and adolescents.[2,6–8] Differentiation from Sever's disease in this age group is particularly challenging[7] given the prevalence of the condition and the similar clinical examination findings (e.g positive squeeze test, warmth, pain).[4,5] The patient's history of bilateral Osgood-Schlatter's further made the diagnosis of Sever's disease more likely and thus complicated the diagnostic process prior to the blood culture results.

There is no meaningful data against which to contextualize the appropriateness of the current timeline or the effectiveness of the deployed protocol. Previously, a 12-year-old girl was reported to have full pain free weight bearing without gait abnormalities at a 9-month follow-up following multiple debridement procedures.[8] However, a 9-year-old boy, was reported to be able to fully weight bear without pain at 6 weeks[7] and was playing soccer at a 12-month follow-up. These cases had similar initial presentations, diagnostic delays, and the boy's medical treatment was comparable to the current case. However, we are unable to determine what, if any, rehabilitation was done to facilitate or hinder the return of weight bearing status and/or sport.

The sRPE has become a valuable and common metric for monitoring and managing the internal training loads experienced by athletes.[11,12] However, minimal internal training load data has been reported while athletes are rehabilitating following an injury.[13,14] The steady increase of the current absolute internal training load (i.e. weekly sum) was consistent with trends reported in a case study of a 28-year-old professional skier following an ACL rupture.[14] However, the training elements (e.g. resistance training vs sport specific) contributing to the overall internal training load were not provided in the previous case. Reporting training element contributions is important as evidence suggests that injured athletes, prior to their return to sport, can achieve similar internal training loads relative to their uninjured counterparts despite different training elements driving the overall load in different phases of the rehabilitation process.[13] Similarly, the absolute internal training load of the current patient became comparable to pre-injury training loads starting at ~4-weeks post-surgery (Figure 2). However, the training element driving the internal training load of the current patient changed throughout the rehabilitation phases (Figure 2).[13]

Relative training load, also known as an acute:chronic workload ratio (ACWR), has been used to suggest an increased risk of injury due to an unhealthy spike in acute (e.g. past week) activity relative to chronic activity (e.g. past month).[9] As expected, the patient did have an ACWR spike upon the initiation of active rehabilitation activities in phase 2 (Figure 3). The spike is not surprising given that the total training load magnitude at this time was comparable to preinjury workload values (Figure 2). However, it was surprising that active rehabilitation exercises (e.g. strength, balance, and gait exercises) were considered so intense (i.e. sRPE values ranging from 7 to 9) by the patient, particularly as he had already begun resistance training. This increased intensity drove the training load spike as all phase 1 rehabilitation bout had an sRPE value of 1 given that they were relatively passive (e.g. NWB ROM). Overall, the rehabilitation and conditioning program maintained ACWR ratios close to but typically above 1 following the initial spike. Highlighting that the inclusion of training load metrics can facilitate the goal of a steady increase in workload throughout the process to prepare the patient for the physical demands of a return to competitive athletics.

It is important to note the unique circumstances created by the dual role of the parents. Specifically, it allowed for constant interaction with the patient which provided insights leading immediate program modifications without the need to connect with a 3rd party rehabilitation specialist. There was an established trust amongst the patient and his parents/providers which was helpful in dealing with frustrations and fear. This trust may have also contributed to the patient consistently reporting high psychological readiness to return to sport, despite significantly limitations at each assessment (Table 1). Youthful naivete may have also contributed to this pattern. Further, despite the parents greater knowledge and professional networks, relative to the general public, delays in diagnosis persisted.

CLINICAL BOTTOM LINE

Calcaneal osteomyelitis is a rare but serious medical condition. Understanding the symptom presentation relative to common heel conditions in an adolescent age group is important to expedite a diagnosis and medical treatment. While all rehabilitation protocols should be tailored to the needs of the patient, this case provides an exemplar rehabilitation and conditioning program for youth, and potentially adult, patients with calcaneal osteomyelitis that wish to return to physical activity and sport. However, this program has to be further explored in more patients to guage generalizability. This case also outlines the benefits of including internal training load data across all elements of a rehabilitation and conditioning program as it can help guide progression and decision making.

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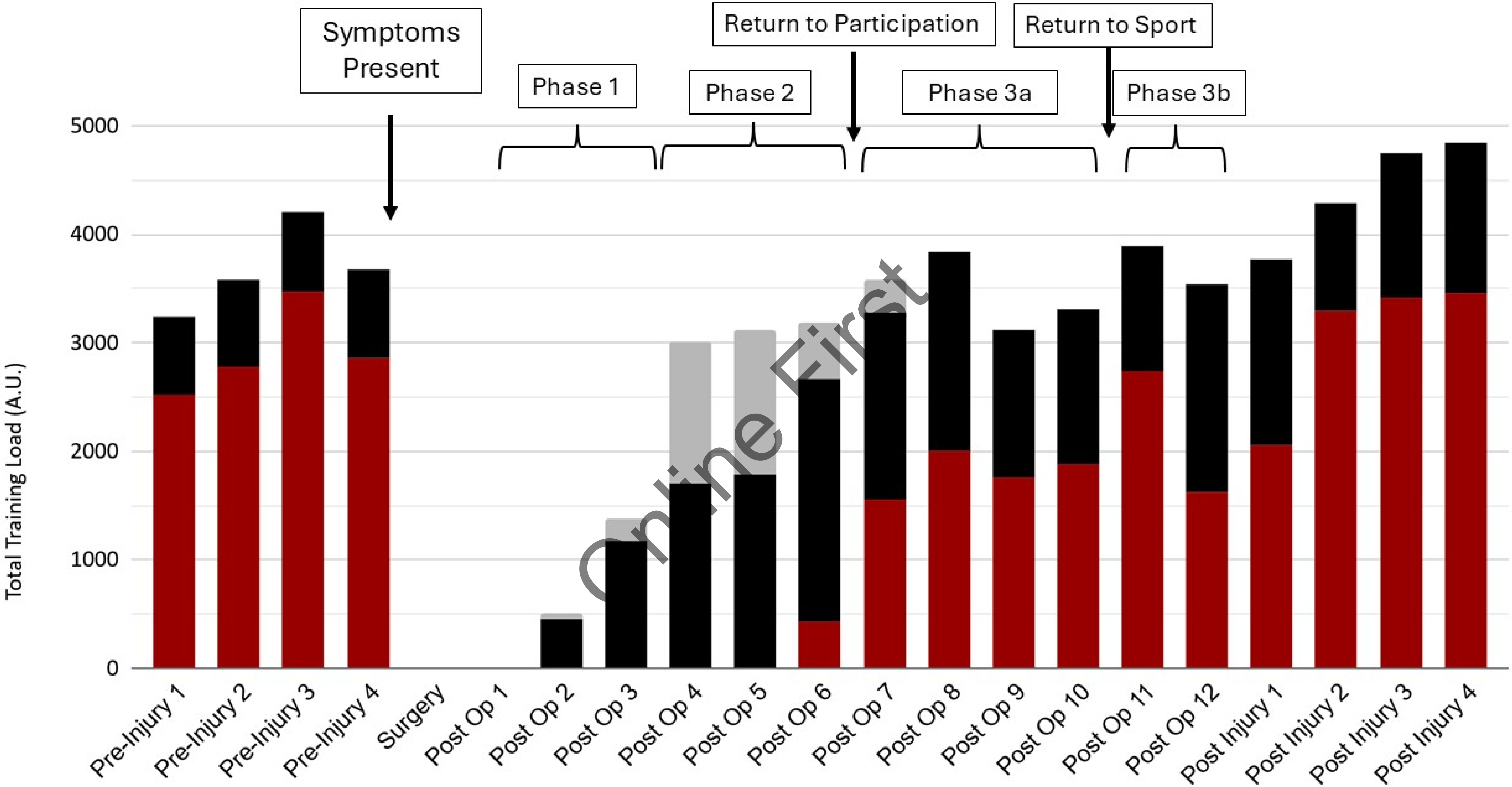
Figure Legends

Figure 1: A) Unremarkable right heel radiograph at initial evaluation and B) STIR sagittal MRI upon initial hospital admission illustrating signal abnormality and rim enhancing fluid collection in the calcaneus.

Figure 2: Overall and activity specific weekly internal training load from one month prior to the injury through one month post injury. The session Rate of Perceived Exertion (sRPE) values for each type of activity where recorded daily, multiplied by activity duration, and the products were summed to generate weekly absolute internal training load.[15,16] Red represents soccer specific activities. Black includes both aerobic conditioning and resistance training activities. Grey represents rehabilitation exercises (e.g. range of motion, balance, theraband).

Figure 3: The daily (Grey) and weekly (Black) Acute:chronic workload ratio from one month prior to the injury through one month post injury. The acute:chronic workload ratio was calculated via an exponentially weighted moving average. This calculation weights more recent activity more heavily than the chronic activity. Values >1 indicate greater recent activity relative to the weighted average over a longer period of time (i.e. a more intense training day / set of training days).[17]


A
B


Symptoms Present
Phase 1
Phase 2
Return to Participation
Phase 3a
Return to Sport
Phase 3b
Total Training Load (A.U.)
5000
4000
3000
2000
1000
0
Pre-Injury 1
Pre-Injury 2
Pre-Injury 3
Pre-Injury 4
Surgery
Post Op 1
Post Op 2
Post Op 3
Post Op 4
Post Op 5
Post Op 6
Post Op 7
Post Op 8
Post Op 9
Post Op 10
Post Op 11
Post Op 12
Post Injury 1
Post Injury 2
Post Injury 3
Post Injury 4
Online First

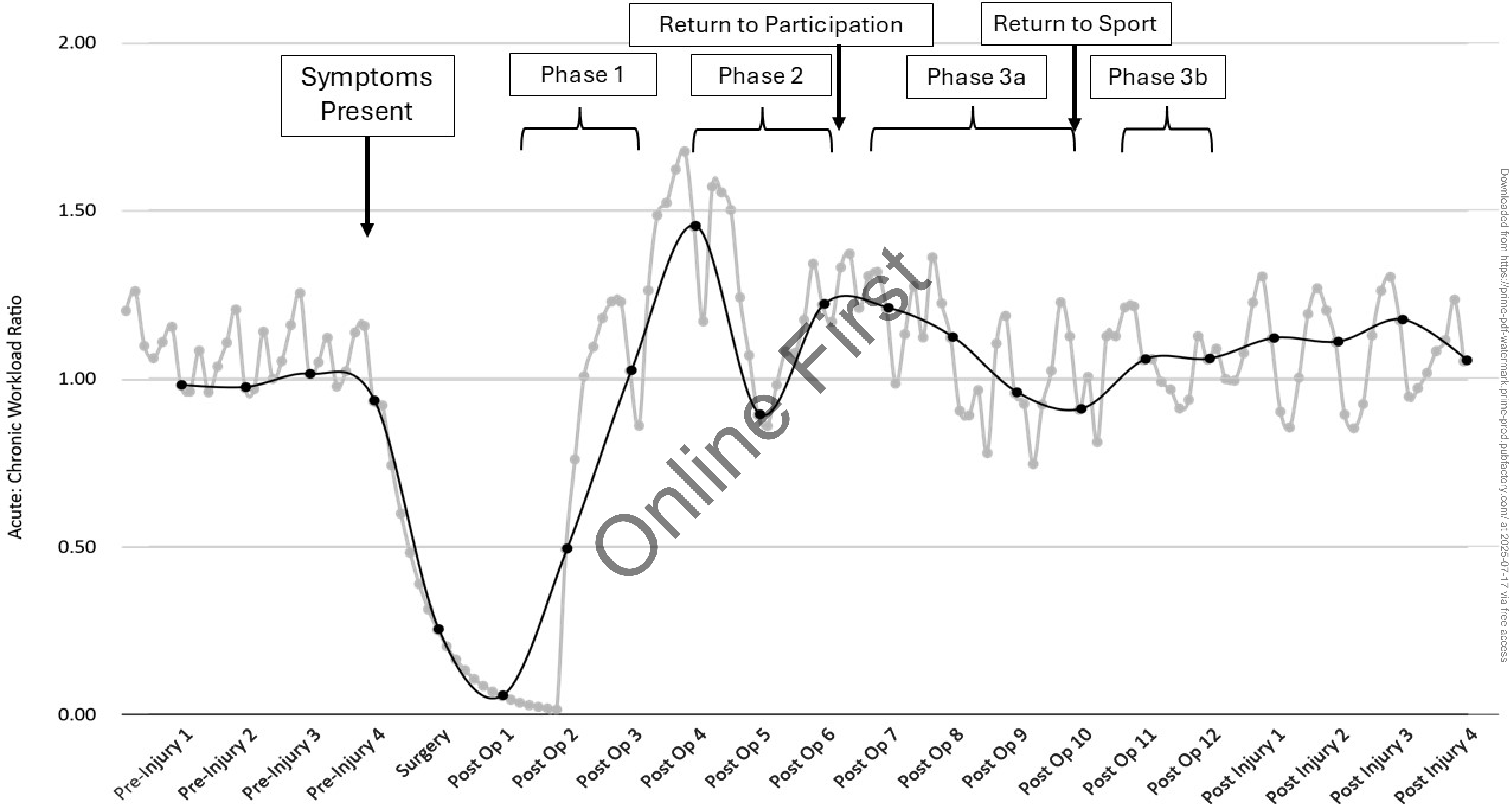

Return to Participation
Return to Sport
Symptoms Present
Phase 1
Phase 2
Phase 3a
Phase 3b
2.00
1.50
1.00
0.50
0.00
Acute: Chronic Workload Ratio
Pre-Injury 1
Pre-Injury 2
Pre-Injury 3
Pre-Injury 4
Surgery
Post Op 1
Post Op 2
Post Op 3
Post Op 4
Post Op 5
Post Op 6
Post Op 7
Post Op 8
Post Op 9
Post Op 10
Post Op 11
Post Op 12
Post Injury 1
Post Injury 2
Post Injury 3
Post Injury 4

Table 1: Rehabilitation timeline and assessment findings.

Rehabilitation Phase	Start of Phase 1	Start of Phase 2	Start of Phase 3a		Start of Phase 3b	Start of Spring Season	Follow-Up
Weeks Post Surgery	1 week	3-weeks	6-weeks		10-weeks	12 Weeks	16-Weeks
Involved Swelling: Figure 8 (cm)	51	48	-	Return to Participation (i.e. individual soccer specific drills)	Return to Sport (i.e. unrestricted team practices)	-	-
Uninvolved Swelling: Figure 8 (cm)	48	48	-			-	-
Involved Atrophy: Calf Girth (cm)	29.8	29.8	30.8			32.4	34
Uninvolved Atrophy: Calf Girth (cm)	31.1	30.5	31.4			33.0	34.6
Active dorsiflexion ROM: Involved v. uninvolved (Visual)	~20° deficit	~5° deficit	Equal			-	-
Plantar flexion: MMT (out of 5)	2+	4	4+			5	-
Dorsiflexion: MMT (out of 5)	2+	4	4+			5	
Inversion: MMT (out of 5)	3	4	4			5	
Eversion: MMT (out of 5)	2+	4	5			5	
Foot & Ankle Disability Index: ADL (%)	12.5%	37%	93%			96.5%	97.6%
Foot & Ankle Disability Index: Sport (%)	0%	3.1%	75%			84%	94%
Psychological Readiness-Return to Sport (out of 60)	50	60	58			59	60

MMT: manual muscle test, ADL: activities of daily living

Table 2: Conditioning Program		
Phase 1 (2 weeks)	Aerobic	20 minutes of steady state stationary biking. Only completed on the last two days of Phase 1.
	Resistance Training	20-30 minute dumbbell and resistance bands sessions were completed 5 days a week. Sessions included a mix of upper and lower body, as well as core exercises. Volume targets were 3 sets of 10-20 repetitions based on the exercise. One upper body exercise was completed for each major muscle group. Non-weight lower body exercises included band resisted 4-way straight leg raises, internal and external hip rotation, knee extension and knee flexion.
Phase 2 (3 weeks)	Aerobic	1st week: Steady state stationary biking that increased from 20 to 30 minutes. 2nd and 3rd week: Stationary bike interval sessions that increased from 20 to 30 minutes.
	Resistance Training	1st and 2nd week: Identical program as Phase 1. 3rd week: Two upper body and two lower body sessions. Volume targets and durations mimicked Phase 1 Identical exercises as Phase 1. Once weight bearing, body weight squats, calf raises, and dumbbell deadlifts were added .
Phase 3a (4 weeks)	Aerobic	1st and 2nd week: Three 30 minute stationary bike interval sessions per week. Soccer specific drills.
	Resistance Training	~45 minute dumbbell, weight vest, and/or resistance band sessions. Two upper body and two lower body sessions per week. Volume targets remained the same. Identical exercises as Phase 2 plus the incorporation of single limb lower body exercises (e.g. lunges, steps ups, calf raises).
Phase 3b (2 weeks)	Aerobic Conditioning	Soccer specific drills.
	Resistance Training	30-45 minute barbell and dumbbell sessions with emphasis on form. Two upper body and two lower body sessions were completed each week.
	Speed & Agility Training	15-20 minute sessions completed four days a week. Two sessions focused on power and plyometrics. One session focused on change of directions and one session focused on acceleration and linear speed.

Following return to sport, the patient continued with the resistance, speed, and agility training program outlined in Phase 3b throughout the spring season.