CASE REPORT

Rehabilitation Following Bilateral Tibial Intramedullary Nail Placement in an Elite Athlete

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ABSTRACT

Background: Intramedullary (IM) nailing is the preferred method of treatment for tibial stress fractures because of lower rates of complication compared to conservative treatment, however; a high incidence of anterior knee pain has been associated with IM nailing. There is scant literature investigating post-surgical rehabilitation management of athletes who undergo IM nail placement. This case report analyzes physical therapist management of an athlete recovering from surgical placement of bilateral tibial IM nails. ***Case Description:*** This case report describes a 23-year old male collegiate football receiver who underwent bilateral tibial IM nail placement. The subject began participation in a progressive rehabilitation program one day after surgery. The subject participated in two sessions per week for twelve weeks. At the fifth week of rehabilitation, the cyclic training program was initiated and continued throughout the remainder of the patient's plan of care. ***Outcomes:*** The patient achieved a full, pain-free functional recovery at the end of the twelve-week rehabilitation program as indicated by the Lower Extremity Functional Scale. The patient in this case achieved full, sport-specific functional recovery without anterior knee pain. ***Conclusion:*** The cyclic training program allowed for a controlled, gradual progression of weight-bearing activities with rest periods to allow for soft tissue recovery and decreased bone irritation. Use of a cyclic training technique can be an effective way to strengthen the musculature at an intensity and speed that reduces the risk for anterior knee pain associated with the IM nailing procedure.

Background

Tibial stress fractures comprise up to 63% of fractures in athletes, occurring equally among male and female athletes.[1] Recent studies have shown that the use of intramedullary (IM) nailing is the preferred method of treatment for closed injuries, including stress fracture, because of the improved recovery of muscle function and lower rate of complication compared to conservative treatment. The surgical procedure involves a metal nail that is inserted into the medullary canal in order to immobilize the fracture. The IM nail can be used in situations where the fracture is either open or closed. A closed fracture involves a fracture that does not penetrate the skin; however, in the case of an open fracture, the fractured ends of the bone are driven through the skin. [2-5]

Although the IM nail is currently the favored method of treatment, complications have been reported with long-term functional recovery. Specifically, the incidence of chronic anterior knee pain is as high as 86% following IM nail placement.[6-8] Studies that examined anterior knee pain associated with IM nailing found that onset of anterior knee pain ranged from one to three years.[6-9] Pain complaints continued up to fourteen years following nail placement.[12] Furthermore, strength and function deficits were noted across studies.[6-8,910,12] Specific strength deficits have been related to pain inhibition.[2,10,11] It is important that the physical therapist have a thorough

understanding of the nail placement procedure because the technique can directly impact the patient's recovery process. For example, nail placement through the patellar tendon results in a greater incidence of anterior knee pain compared to paratendinous nail placement.[10,11]

The primary goal for an athlete is to return to sport, fully recovered and pain-free. When one takes into consideration the high incidence of anterior knee pain status post IM nailing, there is a paucity of literature that investigates the rehabilitation management of athletes who undergo tibial IM nailing, especially that which relates to described management and subsequent anterior knee pain. It would be beneficial to know if a specific rehabilitation protocol could reduce or prevent the occurrence of anterior knee pain. It would also be helpful to have more consistency with use of functional outcome and quality of life measures. Currently, the Short Form 36 Health Survey (SF-36), Short Musculoskeletal Functional Assessment (SMFA) and Lower Extremity Functional Scale (LEFS) have been used with this patient population; however, considering the activity level that these individuals will return to, these outcome tools may not be the best indicator of functional recovery.[12] There is no outcome measure that specifically addresses anterior knee pain as it relates to sport-specific functional recovery. The LEFS was used in the current case study because it was deemed the most valid and appropriate for the patient case. There is little evidence of interventional guidelines for optimal recovery and return to competitive sport after tibial IM nailing. Nyland and colleagues proposed a "cyclic training" program for these patients[9] based on research by Scully and colleagues.[13] This research found that active rest helped prevent tibial stress fractures by as much as three times compared to a traditionally trained control group. In the active rest phase group, training sessions were separated by a week of active rest, consisting of low impact, general conditioning or neuromuscular re-education activities.[13] Cyclic training in three to four week intervals was suggested to enhance stress remodeling.[10] Overall, there is lack of post-operative protocol for individuals recovering from bilateral tibial nail placement. When one takes into consideration that this patient population is more vulnerable to long-term anterior knee pain, more research needs to be devoted to development of a rehabilitation protocol. Also, reports on this population lack functional outcomes and quality of life measures.[1]

This case report describes a 23-year old male collegiate football receiver who underwent bilateral tibial IM nail placement. The framework for the design of the cyclic training rehabilitation utilized a technique proposed by Nyland et al.[10] The purpose of this case report is to: (1) to describe and analyze the physical therapist management of an athlete recovering from surgical placement of bilateral tibial IM nails and discuss the presence of anterior knee pain at an outpatient orthopedic clinic, (2) to apply a rehabilitation protocol using cyclic training principles and (3) to apply the LEFS to measure the patient's functional progress.

Case Description

Patient History and Systems Review

The patient was a 23-year old African American male collegiate football receiver who had a complex past medical history related to tibial stress fractures. The patient's previous medical history was significant for a stress fracture of the right tibial shaft that failed conservative bone stimulator treatment and rest. The patient required plate fixation of the right tibial shaft. A month later, the patient reported that his left tibia began to bother him, with

pain localized over the middle third of the tibial shaft. The next year, the patient reported that he had right middle-third tibial shaft pain as well. Upon radiograph and examination by an orthopedic surgeon, the patient was diagnosed with bilateral tibial stress fractures. After consultation with the orthopedic surgeon, the patient elected to proceed with removal of the right tibial plate hardware and placement of bilateral tibial IM nail via a transtendinous approach. The patient's post-operative weight-bearing status was weight-bearing as tolerated. A system's review was performed and found decreased bilateral knee and ankle range motion and sensation intact to light touch. Manual muscle test was initially deferred due to pain and post-surgical status. The patient was without cardiopulmonary complaint or symptoms. The therapist monitored the patient's integument throughout the rehabilitation program and found no signs of infection and incisions appeared healthy.

Current research supports the use of reamed IM nailing as a means to protect the tibia from repetitive stress.[4] The initial clinical impression was that this patient might be at a higher risk for bone healing complications given his past medical history and the technique of placement. A Cochrane review of IM nailing for tibial shaft fractures in adults found that reamed IM nailing has a lower incidence of implant failure, but no sufficient evidence to support that this technique decreases the incidence of knee pain when compared to other techniques.[1] Since the patient underwent nail placement in both tibias, the therapist was concerned that the patient would be at an increased risk of developing anterior knee pain.[6] The patient's psychological state was also considered, given failed previous treatment. Psychological state was assessed through therapist observation of change in the patient's attitude and behavior throughout the recovery process. Special attention was given to the design of the rehabilitation program to ensure that the patient healed appropriately.

Examination

The initial physical therapy examination was performed one day after the surgical procedure. The patient presented to physical therapy with two axillary crutches, a moderately antalgic gait, decreased step and stride length bilaterally as well as impaired heel strike and weight-acceptance bilaterally. Circumferential measurements were taken 20 centimeters (cm) inferior to the patella and were recorded as 28.5 cm on the left and 28.0 cm on the right to assess for swelling. Pain was assessed using a 0 to 10 numeric pain rating scale, with "0" representing "no pain" and "10" representing "worst possible pain". The patient rated his pain as a four of ten bilaterally. The LEFS was deferred at the initial examination until the patient's pain subsided.

The patient exhibited gross tenderness to palpation at bilateral tibial crests secondary to the surgical intervention. No sign of infection was noted and the incisions appeared healthy. Ankle and knee range of motion were measured using a universal goniometer. Measurements revealed limited active and passive range of motion in all planes at bilateral ankles and knees (Table 1). Manual muscle testing was deferred due to pain and post-operative status. Patellofemoral and talocrural joints were hypomobile.

The examination revealed limitations in bilateral knee and ankle active and passive range of motion, as well as impaired gait and balance, decreased strength, decreased joint integrity and mobility, swelling, pain and impaired functioning ability. Based on the examination, it was evident that the patient was progressing as expected following bilateral tibial nail placement with

Table 1: Significant details from systems review screening

Systems Review	Tests and Measures	Clinical Decisions
Musculoskeletal	• 0-10 Numeric Pain Rating Scale: 4/10 in both lower extremities • Goniometric measurements: bilateral knee and ankle. Refer to Table 2 for baseline measurements.	• Measure ROM, gross strength testing of surrounding muscles, functional testing • Monitor pain with exercise
Neuromuscular	• Light touch sensory testing	• Intact, no further testing • MMT: initially deferred due to pain and post-surgical status
Cardiopulmonary	• Patient was without cardiopulmonary complaint or symptoms.	• Able to proceed with evaluation and treatment
Integumentary	• No sign of infection • Incisions appear healthy	• Continue to monitor

limitations and impairments that were consistent with the surgery. The patient's overall demeanor was positive and motivated to begin physical therapy, including his home program.

Interventions

The interventions (Appendix A) included two sessions per week to provide verbal instruction, teach home program exercises, and perform therapeutic exercises and interventions for sixty to ninety minutes at each session for twelve weeks. The patient's primary goal was to be able to return to football. The first four weeks of interventions addressed hip, knee and ankle range of motion, light strengthening with isometrics and gradual introduction of light isotonics, stretching, joint mobility, and cryotherapy. Together these interventions were intended to reduce pain, swelling, muscle atrophy and improve range of motion.

During the first month, special attention was placed on progressive weight-bearing activities and tasks performed in non-cardinal movement planes to encourage tissue healing in functional directions.[10] Multiple studies support early weight-bearing in this population because it stimulates bone healing.[4,10,14-16] One study looked at the effects of weight- bearing on healing femoral osteotomies stabilized by IM pins in rats. It concluded that increased weight-bearing promotes normal function of surrounding structures and improved bone healing.[14] Based on this evidence and his weight-bearing status, the patient was encouraged to place as much weight as he could comfortably tolerate through both lower extremities and crutches when walking throughout the day. By the end of the fourth week of rehabilitation, the patient reported no lower extremity pain and ambulated without crutches with improved gait including better bilateral heel-toe pattern and an equal and increased stride length. The patient's pain decreased from a 4/10 to a 0/10 by the end of the fourth week of rehabilitation.

Along with weight-bearing activities, the first four weeks of the rehabilitation program were devoted to muscle re-education, restoring range of motion, normalizing gait and eliminating pain. Given his risk for muscle atrophy and decreased bone mineral density (BMD) secondary to self-immobilization,[3,6,10] muscle re-education was initiated with neuromuscular electrical stimulation and the use of biofeedback. These were selected based on their ability to increase muscle girth and bone density.[17]At the end of the first four weeks of rehabilitation the patient made significant improvements in active and passive range of motion, pain, and gait. Significant improvements were also noted with bilateral quadriceps control, but the patient continued to have impaired eccentric control and tightness of the quadriceps, which was evident when the patient negotiated stairs.

Early objectives were met at the fifth week of rehabilitation so the cyclic training program was initiated and continued throughout the remainder of the patient's plan of care (Table 2). Consistent with previously proposed cyclic training, every third week the patient performed low impact general conditioning activities as part of the rehabilitation program to promote rest and recovery.[10] The cyclic training protocol was applied to this patient with a work to active rest ratio of two to one. This ratio was selected to ensure adequate recovery for tissue healing because the patient was recovering from a more complex bilateral tibial nail placement. The therapist also thought that allowing two weeks of training

Table 2: Range of motion (ROM) measurements at baseline

Joint	**Left: Active /Passive**	**Right: Active/Passive**
Ankle		
Dorsiflexion	Lacking 12° from neutral/lacking 8° from neutral dorsiflexion	Lacking 15° from neutral/lacking 12° from neutral dorsiflexion
Plantarflexion	40°/45°	45°/48°
Eversion	12°/15°	10°/13°
Inversion	21°/25°	23°/30°
Knee		
Flexion	115°/120°	118°/122°
Extension	Lacking 5° from neutral extension/lacking 2° from neutral extension	Lacking 3° from neutral extension/0°

Table 3: Cyclic training program*

Week	**Effort- Word Rating**	**Effort- Numeric Rating**
5	Moderate-Maximum (Max)	5 to 10
6	Moderate-Max	5 to 10
7	Minimal	1 to 4
8	Moderate-Max	5 to 10
9	Moderate-Max	5 to 10
10	Minimal	1 to 4
11	Moderate-Max	5 to 10
12	Moderate-Max	5 to 10

**0 represents "no effort" and 10 represents "maximal effort"*

Table 4: Treadmill progression

Week	Session	Treadmill	Time	Speed	Incline	Body Weight
5	Session 1	AG Treadmill	5 min	5.0 mph	None	40%
	Session 2	AG Treadmill	5 min	5.0-5.5 mph	None	50%
6	Session 1	AG Treadmill	8 min	5.0-5.5 mph	None	60%
	Session 2	AG Treadmill	8 min	5.0-5.5 mph	None	70%
7	Session 1	Active Rest on Elliptical	15 min	5.0 mph	None	100%
	Session 2	Active Rest on Elliptical	15 min	5.0 mph	None	100%
8	Session 1	AG Treadmill	10 min	5.2-5.5 mph	None	85%
	Session 2	Standard Treadmill	6 min	5.0 mph	None	100%
9	Session 1	Standard Treadmill	6 min	5.0 mph	3%	100%
	Session 2	Standard Treadmill	8 min	5.0 mph	3%	100%
10	Session 1	Active Rest on Elliptical	15 min	5.0 mph	None	100%
	Session 2	Active Rest on Elliptical	15 min	5.0 mph	None	100%
11	Session 1	Standard Treadmill	10 min	5.5-6.5 mph	None	100%
	Session 2	Standard Treadmill	10 min	6.0 mph	3-6%	100%
12	Session 1	Standard Treadmill	10 min	7.0 mph	None	100%
	Session 2	Standard Treadmill	12 min	6.0-6.5 mph	3-6%	100%

moderately hard and one week of active rest would yield greater benefits for the patient's psychological outlook, motivation and confidence. The general conditioning exercises performed during the active rest phase also allowed for improved cardiovascular endurance, muscular endurance and strength, and an increase in overall BMD.[17]

At weeks five through eight, greater weight-bearing and progressive resistive exercise were initiated. During this phase of recovery the fracture is strong and stable and return of strength is highest.[14] Therefore, the patient began running on an *Anti-Gravity* (AG) *Treadmill®M320/F320 AlterG (Fremont, California)*. The AG treadmill has been used to transition a patient to full body weight running or walking on a standard treadmill.[18] Patil et al. found the AG treadmill to be effective for allowing a controlled decrease in knee joint forces during early rehabilitation in patients who underwent lower limb surgery.[18] Another study investigated the effects of the AG treadmill in runners and found that the subjects were able to run at moderate to high running speeds while maintaining a normal running pattern and lower vertical ground reaction force.[19] A lower vertical ground reaction force translates into lower impact and decreased knee joint forces while running.[19] These findings suggest that the AG treadmill is highly relevant and can be an integral part of the rehabilitation process for an individual recovering from bilateral tibial nail placement because it allows for more control when introducing higher impact activities to the patient's rehabilitation program. Over a span of seven weeks the therapist gradually progressed the patient from running on the AG treadmill to running on a standard treadmill with his full body weight. The treadmill progression was based on current evidence, the patient's response, and the therapist's clinical judgment (Table 3). If the patient displayed antalgic running gait or subjectively reported pain, the percentage of body weight and running speed were altered until running gait normalized and pain was no longer reported. During week five, the patient began running on the AG treadmill at 50% of his body weight at five miles per hour (mph). At these settings, the patient displayed an antalgic running pattern. The patient's body weight was decreased to 40% and the running gait normalized at this point. After initial adjustments were made to the treadmill settings, the patient did not elicit pain or an antalgic running pattern throughout the remainder of the progression of the rehabilitation program.

At weeks five through eight of recovery the patient's most evident limitations were decreased quadriceps strength, decreased ankle stabilization, moderate muscle fatigue, quadriceps tightness and difficulty negotiating stairs secondary to impaired eccentric quadriceps control. In response to the recovery week of cyclic training, the patient reported improved rest, readiness for exercise and confidence when performing weight-bearing exercises. By the end of week eight, the therapist noted moderate improvements in eccentric quadriceps control and overall muscle endurance. These improvements were evident with the patient's ability to increase exercise intensity and repetitions without signs of muscle fatigue or pain while maintaining appropriate form.

Eight weeks after bilateral tibial nail placement, radiographs of the patient's tibias revealed no change in the position of the IM nails and resorption of the stress fractures. The surgeon cleared the patient for unrestricted rehabilitation at this time. During this stage of recovery, the primary goal was to restore normal running gait and improve dynamic quadriceps strength. Focus was placed on increased eccentric loading of the quadriceps, improving neuromuscular

responses, plyometric and agility training, running gait and functional sport activities. The quadriceps remained the focus of intervention because research linked quadriceps weakness and decreased functional knee scores to anterior knee pain.[8,11]

Plyometric training was implemented at this phase of recovery as well. Plyometric training creates one of the greatest osteogenic responses because it requires a large amount of loading in weight-bearing, causing high strain for a short duration in varying patterns.[17] This has been shown to help facilitate bone healing.[10] Balance and proprioception activities were also incorporated into most exercises in order to improve the patient's neuromuscular responses and improve reactive ability.

During weeks nine through twelve, the patient continued to respond positively to the cyclic training program. At this phase, focus was placed on continued eccentric loading of the quadriceps, improving neuromuscular responses, enhancing dynamic stability with plyometric and agility training, running gait, and functional athletic activity. At the initiation of more intense loading exercises, the patient exhibited slight hesitancy with performing activity on the left leg stating that, "it just feels a little different." The rehabilitation program was carefully progressed at this point and the patient was closely monitored for any signs of pain, significant instability, or antalgic gait during activities. At the next session, it was noted that the patient was more fearful of performing box jumps because his left lower extremity still felt "different" than the right when landing, but never felt painful. At this point, the therapist decided to focus on weight acceptance activities with the left lower extremity starting from basic, level surfaces and progressing to higher surfaces in order to help the patient regain confidence when loading the left lower extremity. After a week of placing more emphasis on the left lower extremity, the patient no longer exhibited hesitancy with jumping activities.

Outcomes

The patient was discharged from physical therapy after twelve weeks and was able to return to training with his football team. The patient met his ultimate goal of returning to full competition for the football season. The patient achieved a full functional recovery indicated by his scores on the LEFS. The LEFS is a valid and reliable outcome measure tool that can be used with a broad-spectrum of lower extremity problems. The minimal clinically important difference (MCID) is ten scale points.[20] At the initial measurement during the third week of the rehabilitation program, the patient recorded a LEFS score of 42/80. The LEFS was administered again at twelve weeks into physical therapy and a score of 80/80 was recorded. These scores indicate that the patient went from being functionally limited in 50% of lower extremity activities to no longer being limited with functional activities of the lower extremities by the end of his rehabilitation. Based upon the MCID, the patient made a significant change in functional recovery. On follow-up communication six weeks after discharge, the patient stated he was able to continue making progress during preseason training to achieve his prior level of function as was evidenced by running and agility measurements that were comparable to his measurements taken in the previous season.

Discussion

This case report discusses the evidence and clinical reasoning behind the physical therapy plan of care implemented with a patient who underwent bilateral reamed tibial IM nailing. The patient in this study had a previously complicated past medical

history related to prior bilateral tibial stress fractures. The case was made more complex because the patient elected to have both tibias repaired simultaneously. The therapist was concerned that this patient might be at a higher risk for anterior knee pain during or after the rehabilitation process based on the latest research that suggests IM nails can lead to anterior knee pain.[1,6-8,10,12] One of the primary objectives throughout the patient's treatment was to implement a rehabilitation program that would decrease the likelihood of anterior knee pain both in the short-term and the long-term. A good base of quadriceps strength was built with the initial interventions consisting of quadriceps neuromuscular re-education and biofeedback, manual resistance to simulate an open-chain eccentric load and gradual progression of eccentric loads with closed-kinetic chain exercises. Exercises were only progressed if the patient was able to perform them without pain and with appropriate form. Interventions were consistent with the literature regarding knee pain.[6-10]

A cyclic training program, originally proposed by Nyland and colleagues, was implemented at week five and continued to discharge. The basic principle of the protocol from the Nyland et al. study was applied and alterations were made based on the therapist's clinical judgment and application of evidence-based research. Overall, the patient responded positively to the cyclic training program and had no complaints of anterior knee pain throughout the rehabilitation process. Pain was assessed at the beginning and end of each session. The protocol allowed for a controlled, gradual progression of weight-bearing activities with rest periods to allow for soft tissue recovery and decreased bone irritation.[12,14]

This case study report addresses the importance of implementing an appropriate rehabilitation program for individuals who undergo insertion of bilateral tibial IM nails because of the high risk of developing anterior knee pain and long-term decreased functional ability.[811,12] For this reason, special attention was placed on pain management throughout the rehabilitation process to gauge if there were specific activities that elicited anterior knee pain. The patient in this case was able to achieve full, sport-specific functional recovery, regaining muscular strength and endurance without anterior knee pain. After the fourth week of rehabilitation, the patient had no subjective complaints of knee pain throughout the remainder of his recovery which could have been the result of appropriate gradual implementation and progression of strengthening and weight-bearing activities. Although the patient had no complaints of knee pain at the end of the clinical program, long-term follow-up should be conducted on this patient to see if he develops anterior knee pain over the next five to twenty years.

Previous research indicates that this patient population is at risk for long-term functional deficits, anterior knee pain and decreased thigh muscle strength.[7,8,10-12] The patient in this case report had no complaints of anterior knee pain during the rehabilitation process. The patient reported bilateral surgical incision site pain during the first four weeks of rehabilitation and none thereafter. Periodic follow-up at five, fifteen and twenty years would be valuable information to gauge whether or not the cyclic training protocol decreased the likelihood of developing anterior knee pain in the long term. It should also be noted that there are many factors that contribute to anterior knee pain in this population. Therefore, it would be difficult to make a definitive conclusion that the cyclic rehabilitation program was the reason for not developing anterior knee pain. There are a few studies that look at the long-term effects of IM nail placement. Studies have

reported knee pain between 45% and 57% within the first two years following surgery,[21,22] with the younger population complaining of more knee pain.[20] Incidence of pain at a fourteen year follow-up was 28.6%.[12] Based on these findings, it seems that the incidence of anterior knee pain decreases over time. Most of the individuals in these studies followed a traditional rehabilitation protocol for twelve to fifteen weeks. The current case study is the first to stray from the traditional rehabilitation protocol and follow a cyclic rehabilitation protocol. More research needs to be devoted to investigating a cyclic training protocol and its short and long-term effects in a larger population when compared to a traditional rehabilitation protocol.

More research is needed to investigate the type of surgical technique of IM nail placement used and the complications that might arise during the recovery process. Long-term effects, ten to fifteen years down the road, should also be investigated. Future research should investigate the likelihood of an athlete returning to sport after full recovery from an IM nail procedure when following a progressive, cyclic, sport-specific rehabilitation program compared to a traditional rehabilitation program.

This case study had several limitations. No consistent objective means for measuring mild, moderate and maximal effort were used when gauging the patient's effort during active rest phase activities and during activities on the weeks when the patient should have been working at a moderate to maximal effort. Effort was determined by the therapist informally asking the patient to rate the degree of effort on a zero to ten scale. Zero was defined as "no effort" and ten was "maximal effort". In the future, more formal use of a heart rate monitor or Borg Rating of Perceived Exertion Scale would be a more objective means of quickly determining the patient's effort throughout the session in order to classify the activity as requiring minimal, moderate or maximal effort. Another limitation to this case study was a limited long-term follow-up.

Conclusion

Physical therapists should be able to use clinical judgment and reasoning to design and implement a progressive rehabilitation program for a patient status-post IM nail placement; however, this case report gives a suggested adapted protocol for implementing a program for a more complex patient with bilateral tibial shaft nails and a prior history of failed treatment for tibial stress fractures. Use of a cyclic training technique may be a more effective way to strengthen the musculature at an intensity and speed that reduces the risk for anterior knee pain associated with the IM nailing procedure.

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Appendix A: Goals and progression of interventions

Week	Goals	Flexibility	Strengthening	Balance/Proprioception	ROM	Manual	Modality
1-2	- Perform 15 straight leg raises on bilateral lower extremeties without lag. - Perform ¼ squat - Decreased swelling and edema to slight levels noted with comparing bilaterally and with initial measurements taken. - Decrease pain from 4/10 to a 2/10.	Gastrocnemius and hamstring towel stretch	Hip isometrics, quad sets, long arc quads, straight leg raises (abduction, adduction, flexion, extension), 4-way ankle with theraband, bridging, heel raises	Weight shifts, mini squats,	Heel slides, ankle AROM, unicam bike set at 50°, BAPS board (forward, backward, side to side, clockwise, counter clockwise)	Grades: II, III Patellofemoral glides (superior, inferior, medial, lateral), talocrural distraction, A/P, P/A and medial/lateral talar mobilization ROM: knee & ankle, all planes	Cryotherapy (15 min) post exercise Neuromuscular electrical stimulation (NMES) with quad sets and straight leg raises
3-4	- Perform a 1/2 squat without pain on a level surface. - Biomechanical improvements in joint mobility of the patellofemoral and talocrural joint with mild-mod restrictions noted. - Decrease pain from a 2/10 to a 0/10.	Gastrocnemius and hamstring towel stretch	Standing hamstring curl, 4-way straight leg raise, bridging, step-ups forward and lateral, eccentric single-leg leg press machine (135#), 4-way hip machine (60#)	Balance board (forward, lateral and diagonal), squats on foam, cone walking (forward and lateral)	Unicam bike set at 80° and progressed to standard stationary bike, heel slides	Continued from above with grades II, III, IV, ROM, PNF isotonic combination for knee extension	Cryotherapy post exercise,

5-6	- Ambulate without crutches for 500 feet with appropriate weight acceptance and heel strike on level surfaces. - Biomechanical improvements in joint mobility of the patellofemoral and talocrural joint with no restrictions noted. - Achieve full and symmetrical bilateral A/PROM for all planes of ankle and knee range of motion. - Descend 2 flights of 10 stairs (6" step) with reciprocal pattern and controlled eccentric lowering.		Ankle 4-way with silver theraband, leg press-eccentric single leg and double leg; 4-way hip machine	Single leg balance on BOSU with toss, cone walking forward & lateral with toss, balance board with squat (forward, lateral, diagonal),	Bike 10' Elliptical 8'	Continued from above with grades II, III, IV Manual resistance PNF combination isotonics D1/D2 at ankles. Manual resistance for knee extension in weak arc.	Cryotherapy post exercise,
		Agility/Plyos	**Strengthening**	**Dynamic Balance/Proprioception**	**CV Endurance and Running**	**Manual**	**Modality**
7-8	- Run on altered gravity treadmill for up to 8 minutes with normal running gait, absent of gait impairments. - Maintain wall squat at 90/90 for 1 minute - Perform 10 step downs with bilateral lower extremities from a 6 inch box on an unstable surface without hip drop and maintaining appropriate form	Light bounding with bungee cord in all directions, quick step-ups (2 inch box), bounding on bosu to foam pad, dot agility drills, ladders, box jumps (15 inch, 18 inch)	Leg press machine with increased weight, 4-way hip, sustained wall squats with weighted vest	Single leg balance with UE movement on unstable surface, wall squats at 30/60/90° depth at 2 sets of 1' each.	Elliptical 6', AG Ttreadmill running at 40% of body weight. Warmup Speed 2.5 mph X 2'; Jog: 5.0 mph X 5'	Continued from above with grades II, III, IV Manual ROM PNF combination isotonics D1/D2 at ankles	Cryotherapy post-exercise bilateral tibias

9-12	- Run on level surfaces for 20-30 minutes with appropriate running mechanics and without subjective complaints of pain in the LE's. - Perform 3 sets of 10 box jumps without pain, muscle fatigue and with appropriate muscle recruitment using a 20 inch box.	Box jumps (18, 20, 24 inch), Track starts from varying box heights with and without weighted vest, lunge jumps, ladders, box taps	Leg press machine with increased weight, 4-way hip, sustained wall squats with weighted vest	Step-downs from foam pad and therapist perturbations, Single leg balance with UE movement on unstable surface, squats on wobble board in forward, lateral, diagonal directions with UE movement.	AG Treadmill running at 80-90% of body weight at 5.0 mph, standard treadmill at 5.0 mph and 3% incline.	Continued from above with grades II, III, IV Manual resistance PNF combination isotonics D1/D2 at ankles. Manual resistance for knee extension in weak arc.	