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CLINICAL COMMENTARY

REHABILITATION FOR PATIENTS FOLLOWING ACL RECONSTRUCTION: A KNEE SYMMETRY MODEL

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ABSTRACT

This clinical commentary outlines a new clinical model for anterior cruciate ligament (ACL) rehabilitation, the Knee Symmetry Model. This model has been developed by clinical observation, patient interaction, and by analyzing outcome measures derived from prospective follow-up of patients. More specifically, the best outcome scores occurred in patients with symmetric range of motion and strength. A thorough discussion of the details involved in the development and implementation of this rehabilitation program for this patient following ACL reconstruction is described. Included in this description is the supporting evidence and clinical rationale behind pre-operative and post-operative ACL rehabilitation. Preliminary results from a recent group of patients are presented. When using the Knee Symmetry Model 100% of patients achieved normal knee extension and 97% of patients achieved normal knee flexion.

Key Words: ACL rehabilitation, pre-operative rehabilitation, post-operative rehabilitation

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INTRODUCTION

Rehabilitation of patients following anterior cruciate ligament (ACL) surgery has evolved dramatically over the last several decades. During this time, clinicians have gradually changed their approach from absolute immobilization and no muscle activity to minimal range of motion (ROM) restrictions with immediate muscle activation following surgery.[1-8] Although ACL post-operative rehabilitation has continued to evolve, relatively minimal literature is available outlining the precise nature of ACL rehabilitation. The authors of this report have focused their clinical practice entirely on knee injuries and, through this focus, have developed a new model for ACL rehabilitation, the Knee Symmetry Model.

Current articles on ACL rehabilitation are few or lack the proper detail necessary for a practicing clinician to fully implement the rehabilitation program. Even those articles where rehabilitation is the primary focus of the study do not give full descriptions of the details involved with ACL rehabilitation.[1,3,4,6,7] Therefore, clinicians are left with insufficient detail when attempting to implement a rehabilitation program outlined in the literature. More specifically, most articles in the current literature focus on the details involved with strength training while ROM is not focused upon.[1,7] Through research and data collection, ROM appears to be the primary issue involved in excellent outcomes following ACL reconstruction. To date, other articles within the literature are infrequent that specifically focus on the ROM part of the rehabilitation process.

The authors have been able to develop the Knee Symmetry Model for ACL rehabilitation in part due to the utilization of the same graft with the same surgical approach and the same graft fixation for the past 25 years. Therefore, because the surgical procedure has been constant, the primary variable observed in patient outcomes is the rehabilitation. The surgical procedure used in this center is an ACL autograft with bone-patellar tendon-bone. While most surgeons have changed their surgical procedure, this center has maintained the same graft source, the same graft fixation, and the same surgical approach, thus, allowing changes in patient outcomes to be observed as a result of changing the rehabilitation program. Given that the graft source, fixation, and surgical approach have not changed, the focus has been on refining the rehabilitation program.

Outcomes have helped identify that patients who achieve symmetrical ROM and strength have better subjective and objective outcomes, regardless of meniscal or articular cartilage damage found at the time of surgery.[9] Physical therapists do not have control over the surgeon or patient's choice of graft selection, but do play an important role in the patient's ability to achieve symmetrical ROM. Understanding the importance of symmetrical ROM makes it the most important factor in the rehabilitation process, regardless of graft choice or the surgical procedure. The Knee Symmetry Model provides an outline to achieve this goal of full ROM. The goal of the rehabilitation program should be symmetrical ROM and the surgical procedure performed should allow the physical therapist the best opportunity to restore the patient's knee to symmetrical ROM and strength. Although the basic principles of rehabilitation outlined in this report apply to all grafts, the specific details of rehabilitation along with the outcomes reported are based on the knee symmetry model following an ACL reconstruction performed with a patellar tendon graft.

SURGICAL APPROACH

Both contralateral (CBPTB) and ipsilateral (IBPTB) bone patellar bone ACL autografts are utilized in this center. The CBPTB and IBPTB surgical procedures have been described in depth elsewhere.[10,11] The CBPTB can be used as a primary procedure or to revise a previous ipsilateral reconstruction. Critical elements of the CBPTB and IBPTB surgical procedures include proper graft placement in the tibial and femoral tunnels, full knee ROM (hyperextension and flexion) after the graft has been placed and tensioned in the tibial and femoral tunnels, and accommodative fixation (sutures tied over buttons) of the graft in the tibial and femoral bone tunnels. The graft needs to be tight enough to provide stability but loose enough to allow for full knee ROM in the operating room. If the knee is not able to go through a full ROM once the graft is tensioned, post-operative rehabilitation programs designed to restore symmetric ROM may result in decreased knee stability or leave the patient with the inability to achieve symmetrical ROM. Therefore, the authors recommend a thorough discussion with the referring surgeon when implementing this program.

REHABILITATION PHILOSOPHY

As our knowledge of the patient's response to this surgery has grown, an increased emphasis has been placed on restoring the surgical knee to the pre-injury status.[8,10] To fully accomplish this goal, the clinician is asked to restore bilateral knee symmetry. Most clinicians believe that early elimination of pain and inflammation in the injured knee is critical to achievement of knee symmetry in patients. However, the rehabilitation approach should also include bilateral knee symmetry in terms of ROM, strength, stability, and function as soon as symptoms allow. Principles of treatment begin pre-operatively and continue until complete knee symmetry is achieved post-operatively. Once knee symmetry is achieved post-operatively, the patient is discharged from formal rehabilitation; however, each patient is followed closely after discharge from formal rehabilitation. It is only through patient follow-up that the long-term results of surgery and rehabilitation have been observed and rated. Failure to perform follow-up evaluations on patients leads to an inaccurate understanding or a misinterpretation of results.

Therefore, our rehabilitation philosophy has been shaped by frequently analyzing the patient's post-operative status. Each and every patient is strongly advised to follow up on regular intervals including 1, 2, 4, and 6 months and at the first, second, fifth, tenth, and twentieth year post-operatively. This information is entered into the center's database so that all patient outcomes can be analyzed together. The understanding gained from the long-term follow up of patients has guided the establishing principles of rehabilitation within this program. This program has developed based on long-term research and data collection that recognizes the importance of obtaining knee symmetry, most importantly symmetrical ROM, as a means to provide the patient with optimal short and long-term outcomes.

PRE-OPERATIVE REHABILITATION

Patients are evaluated by the physician and physical therapist at the time of their initial appointment. The physician makes the medical diagnosis, and the physical therapist performs an initial examination by observing and measuring all elements of knee symmetry. Patients are taught a home rehabilitation program for each component of the knee symmetry model. Although an emphasis on a home program requires fewer visits to physical therapy, each visit is quite comprehensive. Emphasis is placed on educating patients and their families about the goals of rehabilitation. The primary goal, knee symmetry, is stressed repeatedly during the pre-operative period. Once the patient has achieved the specified goals and is able to demonstrate the ability to perform the exercises, they are approved for surgery.

Patients are required to reduce the inflammation and swelling in the involved limb prior to surgery. They are instructed to utilize ice, compression, and elevation 3-4 times per day until the inflammation and swelling are eliminated. During the pre-operative period patients are instructed to refrain from competitive sports; however, they are not specifically restricted from their normal daily activities.

Restoring complete passive ROM pre-operatively is a key to the entire rehabilitation program. Included in the knee ROM is bilaterally symmetric motion, which, in most patients, includes a component of hyperextension and knee flexion. Passive knee extension is measured with the patient lying supine with the heel propped on a bolster to allow the knee to fall into hyperextension *(Figure 1)*. Passive knee flexion is also measured in supine *(Figure 2)*. Both a quantitative (measurement) and qualitative (end

Figure 1. *Knee hyperextension measurement*

Figure 2. *Knee flexion measurement*

feel) approach is utilized for assessment of motion. Measurement is performed and recorded in a hyperextension/extension/flexion format.[11] If a patient has 5 degrees of hyperextension and 135 degrees of flexion their measurement is recorded as 5/0/135. If a patient has lost 5 degrees of extension from 0 degrees neutral, the measurement is recorded as 0/5/135. Likewise, the end feel for hyperextension is observed quite meticulously by the physical therapist *(Figure 3)*. It is not until both the end feel and the measurement of hyperextension are symmetrical that surgery is an option. Each physical therapist has performed a reliability test for both knee extension (hyperextension) and knee flexion. Previously the authors reported interrater intra-class correlation (ICC) values for knee extension (.88) and flexion (.99) and intrarater reliability for knee extension (.95) and flexion (.99).[12]

Figure 3. *Knee hyperextension (end feel)*

As the inflammation, swelling, and knee ROM are improved, neuromuscular re-training is initiated pre-operatively. Patients are taught leg control activities like quad sets and leg raises, and instructed how to walk with a normal gait pattern. Patients may resume low impact activities and weight training if they desire, but these activities are not required pre-operatively. Before surgery, each patient is tested for quadriceps and hamstring muscle strength isokinetically at 60° and 180° per second. Both single leg hop and unilateral leg press are measured pre-operatively and used as post-operative strength goals as well. The strength measures obtained on the uninjured knee are utilized as a post-operative goal for both knees.

Knee function is measured with both the modified Noyes and International Knee Documentation Committee (IKDC) subjective outcome instruments.[13] Each patient is given these instruments pre-operatively and at regular intervals post-operatively.

IMMEDIATE POST-OPERATIVE REHABILITATION

When CBPTB surgery is performed, both knees of the patient must be addressed in the rehabilitation process. Although a rehabilitation program must be applied to each patient's knee, the goals for each knee are somewhat different. On the graft-donor knee (contralateral knee), ROM is easily achieved and allows the clinician to focus on strength within the first 1-2 days post-operative. While on the ACL-reconstructed knee (ACL injured knee) the focus is on ROM, not strength. By performing surgery in this manner, the rehabilitation clinician is able to concentrate on the most important goals for each knee and minimize the post-operative complications. It is only through the process of performing surgery and rehabilitation on BOTH knees that the importance of goals and expectations for the two types of surgery (the ACL reconstruction and the graft-donor site) have been more completely understood. The rehabilitation program for each knee will now be outlined in detail.

ACL-Reconstructed Knee (ACL Injured Knee) – CBPTB or IBPTB

General Guidelines

During the immediate post-operative period, patients are hospitalized overnight to assure proper pain and swelling control is obtained. Patients are given ketoralac intravenously, placed on a continuous passive motion (CPM) machine, and provided with a cold/compression device (Cryocuff TM , DJ Orthopaedics, Vista, CA).

Ketoralac, a prostaglandin inhibitor, is used both pre-operatively and post-operatively. Patients are given 30mg intravenously pre-operatively and started on a continuous drip post-operatively. The continuous drip consists of 90 mg of ketoralac in 1L of normal saline solution over a 23-hour period. Ketoralac is combined with a local injection of .25% Marcaine and, when combined with the ketoralac, provides patients with excellent post-operative pain relief.[14] A thin waterproof dressing is applied over the incision sites and drains are placed in bilateral knees for the first 23 hours to help minimize a hemarthrosis. Thromboembolitic compression stocking are placed on both legs and worn during the first week of bedrest. A cold/compression device is also immediately initiated in the operating room and utilized continually for the first week post-operatively.

The patient's ACL-reconstructed knee is placed in a CPM machine immediately after surgery. The primary purpose of the CPM machine is to elevate the knee above the level of the heart to help minimize post-operative swelling. Secondarily, the CPM machine provides gentle passive ROM to the ACL-reconstructed knee and is set to move from 0-30 degrees of knee flexion continuously throughout the first week after surgery. The patient is instructed to remain supine with the leg elevated and placed in the CPM continuously during the first week after surgery.

Throughout the first week after surgery the patient is placed on bed rest with bathroom privileges in order to minimize swelling and maximize ROM. The avoidance of activity is an important, but a misunderstood concept developed after the initial "Accelerated Rehabilitation after ACL Reconstruction" article in 1990.[8] The authors believe that bed rest during the first week post-operatively allows the patient to more readily achieve the post-operative goals for each knee. More specifically, bed rest decreases swelling in the patient's ACL-reconstructed knee allowing for a much quicker return of ROM. Patients are instructed to have a caregiver in place to reduce their overall activity level and permit the patient to focus on their rehabilitation during the first week post-operatively. This plan, when strictly adhered to, greatly diminishes the amount of inflammation and swelling in either knee, which facilitates an earlier restoration of knee symmetry.

Range of Motion

Immediately after surgery and while in the hospital, the patient is asked to initiate ROM activities for hyperextension and flexion four times per day. Knee hyperextension is obtained via heel prop exercises *(Figure 4)*, towel stretch exercises *(Figure 5)*, and active hyperextension *(Figure 6)* while knee flexion activities during this period include active and active-assisted heel slide exercises *(Figure 7)*. Goals for discharge from the hospital include symmetrical knee hyperextension and 125 degrees of knee flexion. It is important to emphasize that ROM is unlimited during the initial phase of rehabilitation post-operatively. The only limit on obtaining symmetric ROM is patient tolerance. Most patients lose some of their initial ROM after they are

Figure 4. *Heel props*

Figure 5. *Towel stretches*

Figure 6. *Active hyperextension*

Figure 7. *Heel slides*

discharged. However, the psychological effect of knowing near full ROM has been achieved immediately post-operatively is helpful in obtaining full ROM.

Strength

Following surgery, strength training for the ACL-reconstructed knee is not formally emphasized. Too frequently, an aggressive strengthening program for the patient's ACL-reconstructed knee leads to increased inflammation and loss of ROM, which is counter productive. However, proper quadricep muscle activation is emphasized in order to have good leg control for ambulation. This quadriceps muscle activation is achieved through quad set exercises and active hyperextension. The same program is followed for both the CBPTB and IBPTB surgical procedures.

Graft-Donor Knee (Contralateral Knee)

Range of Motion

When a CBPTB procedure is performed, both of the patient's knees must be rehabilitated. During the initial post-operative period ROM in the graft-donor knee is addressed by the same methods utilized on the patient's ACL-reconstructed knee. Knee hyperextension activities (heel prop, towel stretch, active hyperextension) are performed along with heel slide exercises for knee flexion several times per day.

Strength

The patient's graft-donor knee easily achieves normal ROM. Due to the nature of the graft harvest procedure, no effusion occurs in the graft-donor knee which allows for an easier restoration of ROM. Once normal ROM has been achieved on the graft-donor knee, focus is placed on tendon regeneration during the immediate post-operative period. Beginning on the day after surgery each patient performs resisted leg press activities on the graft-donor knee. A unilateral leg press machine (SHUTTLE, Contemporary Design Company, Glacier, WA) adapted for in-bed resisted activity is utilized for the first two weeks post-op *(Figure 8)*. Patients are taught to perform up to 100 repetitions with 7 pounds before increasing resistance on the leg press machine. Leg press activities are performed four times per day during this period. Patellar tendon discomfort is expected due to the active work performed by the patellar tendon. However, patients are cautioned to avoid ROM loss at the expense of patellar tendon strengthening. Early patellar tendon hypertrophy can be observed and is encouraged with these patients.

Figure 8. *Unilateral leg press*

Both Knees – Function

Patients are instructed to remain supine with the ACL reconstructed leg elevated in order to minimize swelling. The patient may shower and have restroom privileges. Gait is evaluated on the second day and patients are instructed to ambulate full weight bearing with proper weight shift and heel strike. It is rare for a patient to be unable to perform this, however, if the patient is having difficulty with quadriceps activation and is unable to safely bear his/her weight, he/she is given an appropriate assistive device. However, most all patients are able to begin ambulating without an assistive device day two post-operatively. Bathroom privileges are available to the patient for the first week after surgery, but ambulation or standing for long period is strongly discouraged.

INTERMEDIATE POST-OPERATIVE REHABILITATION

Following the immediate post-operative phase of rehabilitation, an intermediate phase is implemented. During this phase the goals are to rehabilitate both knees of the patient symmetrically to their pre-operative values. No time lines are used for achievement of these goals. Each patient is progressed according to his or her own healing progression. Once inflammation and swelling have been eliminated and full symmetrical ROM is achieved, strength training is increased to tolerance, and functional training for returning to sports can occur. Single-leg strengthening is emphasized during this period secondary to the strength differences between limbs. Double leg activities are discouraged because they reinforce the stronger limb. It must be emphasized that no time constraints exist on rehabilitation. When a patient has achieved symmetrical knee ROM and leg strength, and is ready to resume a given activity, he or she is encouraged to participate. Initial participation includes drills and skill development. As the patient progresses, a complete functional progression adapted for the patient's sport is incorporated into the rehabilitation program. No pre-set time frame is used for return to any activity. Typically, patients can return to sport anywhere from 2 – 6 months post-operatively depending on their functional progression.

Specifics of the Intermediate Phase

After the first week post surgery, patients are allowed to resume normal activities of daily living. If a CBPTB procedure is performed, patients are instructed to continue with an exercise program that focuses on ROM in the ACL-reconstructed knee and strengthening (or graft stimulation) in the graft-donor knee. Patients who undergo IBPTB procedures must maintain full knee ROM while emphasizing strength training on the surgical knee.

ACL-Reconstructed Knee

Patients are instructed to continue with exercises that focus on increasing both passive and active ROM. Theses include towel stretches, heel props, heels slides, and wall slides. All exercises are performed approximately three times per day. Patients are asked to monitor knee ROM during the second week post-operatively. As long as his/her knee ROM continues to improve, no limitations or restrictions in activities of daily living (ADL) are implemented. By restoring early ROM and encouraging normal use of the patient's ACL reconstructed knee, proprioceptive and neuromuscular control is quickly restored and obtained through normal ADL's. Obtaining symmetrical knee ROM (including hyperextension and flexion equal to the opposite knee) is the primary goal for the patient's ACL-reconstructed knee during the remainder of the rehabilitation process.

When an IBPTB procedure is utilized, the patient must also focus on strength training as outlined in the next paragraph. However, it must be emphasized that strength development is secondary to gaining and maintaining symmetrical knee ROM. If decreases in ROM or increases in pain or swelling are observed in the patient's knee, he or she is instructed to decrease the strength training portion of rehabilitation until ROM and swelling are normalized.

Graft-Donor Knee

The graft-donor knee should have full ROM after the first week. This allows the patient and clinician to focus on graft stimulation and strengthening until normal strength has returned. Strengthening is accomplished with low load, high repetition exercises including step down exercises, single leg press, and unilateral knee extension exercises. During this phase, it is common and normal for the patient to experience tendon soreness and discomfort until the tendon has regenerated. Continued stretching and cryotherapy help control the soreness until the tendon is regenerated and knee strength is restored.

Beginning at one month after surgery, patients will continue to undergo strength and functional testing every month until their goals are achieved. Both isokinetic testing (strength testing) and hop testing (functional testing) are performed during this time frame. When patients achieve appropriate knee ROM, they are encouraged to participate in low impact activities such as the bike or elliptical trainer. Both of these exercises assist in increasing strength and cardiovascular endurance. Patients are also allowed to begin light agility activities (shooting baskets, dribbling the soccer ball, foot work, etc.). As long as ROM continues to improve and minimal knee swelling occurs, patients can continue to participate in drills and agilities. Regardless of what time after surgery the patient achieves knee symmetry (symmetrical ROM and strength), he or she is released to begin participating in practice drills and competition. During this time period, it is normal for patients to experience soreness and swelling. Patients need to be educated on how to manage the soreness and swelling without losing ROM because ROM is an important factor in providing the best short- and long-term outcome. Activity modification or days of rest when first returning to full practice or competition may be required if ROM shows signs of decreasing.

OUTCOME MEASURES

Each patient is evaluated in several ways. Objective measures for ROM, strength, and stability, and subjective questionnaires are utilized. Range of motion is measured and recorded at each physical therapy visit. Beginning at one month after surgery, isokinetic testing of quadriceps and hamstring muscle strength at 60 degrees and 180 degrees per second is performed bilaterally through a full ROM (0 degrees to 95 degrees). The single leg press test and single leg hop test are also used as outcomes measures during the intermediate phase of rehabilitation.[14] The KT-2000 is utilized to measure the amount of anterior excursion of the tibia with 68N, 89N, 133N, and manual maximum force. Each of these measures (ROM, strength, KT-2000) is recorded at the month 1, 2, 4, and 6 evaluation, and at 1, 2, 5, 10, and 20 years post-operatively, when possible. Not all patients are able to return for each of these long-term follow up visits. However, even when patients are not able to return for a clinic visit, they are asked to fill out the subjective questionnaires in an online or paper format.

Tables 1 to 4 outline the objective measures and outcome instruments for a recent group of patients. These tables represent the one year or more post-operative outcomes for patients who underwent a contralateral bone-patellar tendon-bone autograft ACL reconstruction from 2003 to 2006. The mean subjective scores on the IKDC outcome measure are within the established age-specific norms for this instrument.[15]

Table 1 represents the passive ROM measurements. The outcome instrument used is the IKDC objective survey. This outcome instrument defines normal ROM as a side to side difference of less than 2 degrees of knee extension and less than 5 degrees of knee flexion when compared to the uninvolved knee. The results indicate that equal side to side measurements provide the best long term outcome. In Table 1 the authors have outlined that the vast majority of patients achieve "normal" ROM as defined by the IKDC criteria.

Table 2 reports that the subjective and objective knee scores from two outcome instruments (IKDC and modified Noyes). Although a cohort group does not exist to compare the results, the scores reported are within the age-adjusted "normal" scores.[13]

Strength is reported in Tables 3 and 4 for each knee separately. Secondary to the type of surgery performed (CBPTB and IBPTB) both knees were compared to the pre-operative values of the uninjured knee. The patient's ACL reconstructed knee was compared to the patient's graft-donor knee. Additionally, information was reported as a frequency distribution to allow the reader to observe the percentage of scores within a given range. This table further outlines the principle of specific rehabilitation for the ACL reconstructed knee and graft-donor knee discussed earlier. A majority of the ACL reconstructed knees were able to achieve 80-100% strength when compared to the graft knee and when compared to the pre-operative value at both 60 degrees and 180 degrees/sec.

Table 1. Passive Range of Motion Reported as Side to Side Differences

Total Subjects	Normal Extension (< 2° diff)	Normal Flexion (< 5° diff)	Normal ROM (< 2° diff in ext & < 5° diff in flex)
228	228 (100%)	221 (97%)	221 (97%)

* Based on criteria set forth by the International Knee Documentation Committee

Table 2. Mean Subjective and Objective Scores (n=228)

Mean IKDC[a] subjective score	87.0 ± 11.1
Mean modified Noyes subjective score – ACL-reconstructed Knee (100 points possible)	91.7 ± 8.9
Mean modified Noyes subjective score – graft-donor Knee (100 points possible)	93.5 ± 7.5
Mean KT 2000 at 30 lbs.	1.0 ± 1.5 mm
Mean KT 2000 Manual Max	1.8 ± 1.4 mm

[a]**International Knee Documentation Committee**

DISCUSSION

Rehabilitation of the patient following ACL reconstruction has continued to change over the last decade from the "Accelerated Rehabilitation after ACL Reconstruction" program outlined in 1990 to the more current Knee Symmetry Model.[8] The Knee Symmetry Model, which was developed in response to outcome research, emphasizes the return of two normal knees. When compared to the 1990 paper, specific differences that should be emphasized include the symmetric knee concept, the elimination of time frames as post-operative guidelines, unrestricted knee ROM immediately, strict bed rest for the first five days post-operatively, and specialized rehabilitation for the graft-donor knee and the ACL-reconstructed knee. The Knee Symmetry Model has evolved after observing long-term outcomes. Patients who achieved symmetrical knee ROM had better subjective and objective outcomes as compared to those patients who did not achieve symmetrical ROM. With further analysis, the complication rate for patients with ACL reconstructions was less frequent and less severe in patients who

Table 3. Frequency Distribution for Quadriceps Muscle Strength at 60°/second (n=228)

Percentile	ACLR vs. Graft	ACLR vs. Pre-op	Graft vs. Pre-op
00-59%	0	0	3
60-79%	5	12	18
80-100%	95	88	79

*Percentile = Side to Side Difference
*ACLR = ACL-reconstructed knee
*Graft = Graft-donor knee
*Pre-op = Pre-operative value for the uninjured knee

Table 4. Frequency Distribution for Quadriceps Muscle Strength at 180°/second (n=228)

Percentile	ACLR vs. Graft	ACLR vs. Pre-op	Graft vs. Pre-op
00-59%	0	0	0
60-79%	4	7	9
80-100%	96	93	91

*Percentile = Side to Side Difference
*ACLR = ACL-reconstructed knee
*Graft = Graft-donor knee
*Pre-op = Pre-operative value for the uninjured knee

obtained knee symmetry sooner post-operatively. The CBPTB surgery further assisted in this process by identifying the different emphases needed for the ACL knee and the graft-donor knee. Understanding the necessary goals for each knee helped in establishing a rehabilitation program directed in restoring knee symmetry as quickly and as safely as possible.

Speculation exists in the literature that ACL reconstruction may lead to a long-term outcome of knee osteoarthritis. Through 26 years of research, patients who achieve symmetrical knee ROM have less chance of developing arthritic changes.(Shelbourne KD, unpublished data 2007) Therefore, the Knee Symmetry Model along with the use of the contralateral graft provides the patient with the best opportunity to restore normal knee ROM with predictable stability. Given that many patients who undergo ACL reconstruction are in their teens and early 20's, it remains an important factor to provide these patients with not only the return to their current sport but to also provide them with a good outcome 20 years after surgery.

Although other authors present and discuss ROM deficits in their papers, the interpretation of their results in a comparison with this paper is difficult secondary to a lack of specific methods of measurement provided by other authors. Additionally, the authors are not aware of other articles citing reliability of the extension (hyperextension) and flexion measures in their studies. Given that ROM measurements are a central issue in the rehabilitation of a patient after ACL surgery described in this report, the authors have attempted to address both of these issues in order to capture their ROM measures in a repeatable fashion. Other investigators may use the same or similar methods of measurement for extension (hyperextension) and flexion, but their methods are not described and verified with a reliability study. Secondary to a lack of uniformity within ROM measurement following knee surgery, it is difficult to compare ROM results of one study with another.

The IKDC information *(Table 2)* presented in this paper is in keeping with published age-specific normative data.[13] Although the results of this paper are early (1-3 years), the results are quite promising, and intermediate and long-term results will be published as they become available. Early results also show that ROM *(Table 1)* is very acceptable. When using the IKDC format for reporting ROM, patients do not have difficulty maintaining their ROM in either knee. While the strength results reported in Table 3 and 4 shows a decrease in strength at the 60 degrees/second testing speed with the graft-donor knee, the 180 degrees/second speed is very acceptable for both knees. We believe that the 60 degrees/second strength deficit in the graft-donor knee further outlines the belief that the primary goal for the graft-donor knee is to improve strength. Interestingly the patient's ACL reconstructed knee did not have any problems maintaining their strength long-term. This result further outlines that the primary goal for the patient's ACL reconstructed knee is to achieve full ROM.

Some clinicians appear to be fearful of gaining knee symmetry following knee surgery, but, to restore any joint to equilibrium, the clinician should strive for normal ROM and strength. Previous data from this center demonstrated that patients who failed to achieve symmetrical ROM were unable to achieve symmetrical strength. Additionally, those patients who did achieve symmetrical ROM had better strength scores. Therefore, obtaining symmetrical ROM allows the patient to restore normal strength and ultimately normal function. A stiff knee can be strengthened but never achieves symmetrical and normal strength, leaving the patient with a less than optimal outcome. Knee stability and symmetric ROM can be restored post-operatively without compromising either of these goals. The vast majority of patients who have had ACL reconstructions, contralateral and ipsilateral grafts, have symmetric ROM and a stable knee. In the patient sample of 228 patients (mean age 22.8 years), 221 (97%) obtained full knee ROM and had a mean manual maximum KT-2000 value of 1.8 mm. Therefore, the goals of symmetric ROM and knee stability are not conflicting, and represent what the goal should be for patients following ACL reconstructive surgery.

The understanding of rehabilitation following ACL reconstruction has been enhanced by the large number of patients who receive a contralateral graft. The observation of patients following an ACL reconstruction with a contralateral graft has allowed the analysis of the two elements of surgery individually. Instead of the patient's ACL reconstruction and the graft-donor being on the same knee, these components of the surgical procedure are on different knees. Thus, each knee has one component of the procedure. The problem-solving gained from observing the patient's graft-donor knee and the ACL-reconstructed knee in large volumes of patients has led to the understanding of varying goals for each surgical component.

CONCLUSIONS

This clinical commentary outlines a philosophy of care and a new rehabilitation program following ACL reconstructive surgery. Data collected shows that patients who achieve symmetrical knee ROM have better subjective and objective outcomes. The knee symmetry model provides a means and description to achieve these results. Specific principles of the program that facilitate achieving knee symmetry include the following: elimination of time frames as post-operative guidelines, unrestricted ROM immediately, bed rest for the first week post-operatively, and specialized rehabilitation for the patient's graft-donor knee and the ACL-reconstructed knee. The knee symmetry model produces results that provide patients with the best short- and long-term outcomes while minimizing post-operative complications following ACL reconstruction.

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CASE REPORT

COMPREHENSIVE SPORTS MEDICINE TREATMENT OF AN ATHLETE WHO RUNS CROSS-COUNTRY AND IS IRON DEFICIENT

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ABSTRACT

Background. Optimal athletic performance may be dependent upon an athlete maintaining adequate iron levels through the consumption of dietary forms of iron and subsequent metabolism. Endurance athletes, especially female distance runners, have been identified as being at risk for developing iron deficiency. While iron deficiency is treatable, early diagnosis may be delayed if an adequate medical history and evaluation is not conducted.

Objective. To describe the evaluation, diagnosis, and comprehensive sports medicine treatment of a collegiate cross-country athlete with a medical diagnosis of iron deficiency with anemia and sports-related musculoskeletal pain.

Case Description. A 21-year-old female collegiate cross-country athlete experienced a decline in her running performance beginning her freshman year of school. She continued to experience degradation in sports performance despite medical intervention. Two-and-a-half years after initially seeking medical attention she was diagnosed with iron deficiency with anemia by a primary care medical doctor. Additionally, the subject required rehabilitation due to the onset of sports-related musculoskeletal symptoms.

Outcomes. Comprehensive treatment for this patient consisted of iron supplementation, therapeutic exercises, manual therapy, and modalities. The athlete was able to compete during her entire cross-country season and earn All-American status at the Division-III level.

Discussion. Sports medicine professionals must consider iron deficiency as a possible differential diagnosis when evaluating endurance athletes. Subtle signs of iron deficiency may, unfortunately, be overlooked ultimately delaying treatment.

Key Words: iron deficiency with anemia, cross-country, iron supplementation

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INTRODUCTION

Consumption of dietary iron is necessary for optimal human cellular metabolism and growth.[1] An individual who consumes a diet that is deficient of iron rich foods or who experiences depletion of iron stores may experience symptoms ranging from fatigue to degradation in physical performance.[1-3] Iron deficiency is the number one nutritional deficiency affecting billions worldwide.[4,5] Iron deficiency with anemia affects between 1% to 2% of all adults in the United States and is estimated to globally affect 0.5 to 0.6 billion people.[1,5,6] In addition, up to 20% of Americans may suffer from iron deficiency without anemia with an estimated 1 to 1.8 billion suffering this condition worldwide.[1,6]

Optimal athletic performance is also dependent upon maintaining iron levels through the consumption of dietary forms of iron and subsequent metabolism.[2,5,7,8] The formation of hemoglobin and the body's subsequent ability to transport oxygen from the lungs to the tissues will be impaired in the athlete who is iron defficient. Additionally, athletes who are iron deficient may experience the following symptoms: nausea, frequent infections, shortness of breath during exercise, respiratory illness, fatigue, weakness, pale appearance, lack of energy, and exhaustion.[3, 9]

Endurance athletes, especially female distance runners, have been identified as being at risk for developing iron deficiency.[10-13] One epidemiological study of endurance runners identified 82% of the female athletes as iron deficient.[14,15] While iron deficiency is treatable, early diagnosis may be delayed if an adequate medical history and evaluation is not conducted.

The purpose of this report is to highlight a unique case of a collegiate female cross-country athlete who experienced a chronic degradation in her performance due to becoming iron deficient and anemic. Initial medical and allied healthcare evaluations and interventions failed to identify and appropriately treat her iron deficiency with anemia. The athlete continued to train and compete in distance running for both her collegiate cross-country and track teams, despite suffering fatigue and exhaustion. She considered quitting competitive running due to her inability to compete at a high level. Two-and-a-half years after initially seeking medical attention she was diagnosed with iron deficiency anemia by a primary care medical doctor. This case is unique as it details the medical intervention and sports rehabilitation management in the comprehensive treatment of a female collegiate cross-country athlete with a diagnosis of iron deficiency with anemia.

CASE DESCRIPTION

A 21-year-old female cross-country athlete presented at the start of the cross-country season to the athletic training team with a sports-related injury to the left hip and left knee. Her primary musculoskeletal complaint was her inability to complete her training runs without experiencing either left hip or left knee pain. The patient was concurrently receiving medical management for iron deficiency anemia by her primary care physician.

Previous History

The patient ran competitively on both her high school cross-country and track teams. She denied any history of sports-related running injuries during her high school career. Her best recorded time in high school for the 5,000-meter run was 19:36 (minutes:seconds). During her freshman collegiate cross-country season she experienced a decline in her running performance that she initially attributed to the intensity of the collegiate training program (Division I) and a "slow" acclimation to her new training environment (school situated at an elevation of 6910 feet or 2106 meters). The subject had previously attended a high school that was situated at sea level.

She described "feeling sluggish throughout the day" and that she required long naps during the day despite sleeping for 8 to 10 hours each night. When running she felt that she was racing "flat," that she lacked energy during workouts, and that she experienced an increase (a slowing) of her race-pace. Her 5000-meter race time had slowed to 19:58.

In fall of 2006, she sought medical attention to identify a cause for her fatigue related symptoms after the completion of her freshman cross-country season. She also sought medical attention at this time for a new onset of allergies. During the course of several medical consults she was diagnosed by her medical doctor with asthma and hypoglycemia. Initial treatments failed to provide symptom relief and did not affect her athletic performance. She continued to seek medical attention for her sports-related symptoms. She reported that she was tested over the next year-and-a-half three times for mononucleosis and one time for anemia. According to the patient each test was negative. A "nutritionist" offered an unsolicited recommendation to her to increase her protein consumption, but the athlete was not provided any dietary guidance (note: the patient was unaware as to the educational or professional background of the "nutritionist").

The patient transferred from the Division-I school after two years to a Division-III university in Oregon. Despite the change in training environments (school situated at an elevation of 210 ft or 64 m), she continued to experience her fatigue related symptoms and poor athletic performance. Not long after transferring schools, she began to experience back and left hip musculoskeletal pain. The patient sought chiropractic treatment in order to address her new musculoskeletal complaints. She received several treatments including manipulation of the spine, deep tissue massage, ultrasound, moist heat, and cryotherapy. She continued chiropractic treatment for 6 months despite a lack of improvement.

Differential Diagnosis

Medical Management

Previous medical evaluations and interventions by allopathic and chiropractic physicians failed to successfully decrease the subject's symptoms. The subject again sought medical attention in Spring of 2007 after terminating chiropractic treatment. A complete blood count demonstrated low levels of hemoglobin (HGB), hematocrit (HCT), mean corpuscular volume (MCV), and mean corpuscular hemoglobin (MCH) *(Table 1, column 1)*. Based upon these values, additional labs were performed 10 days later in order to assess serum iron levels, total iron binding capacity (TIBC), transferrin saturation, and serum ferritin levels *(Table 1, column 2)*. Only one lab value, the TIBC, was within the standard reference values. Based upon these results, she was diagnosed with iron deficiency with anemia. The patient was instructed by her medical doctor to begin immediate iron supplementation (see treatment section).

Musculoskeletal Differential Diagnosis

At the start of the cross-country season the patient was referred by her coach to the university's athletic training department for treatment of her sports-related musculoskeletal injuries. Despite receiving the medical diagnosis of iron deficiency with anemia (and the initiation of iron supplementation), the patient continued to experience

Table 1. Complete Blood Count Lab Values for the Athlete Running Cross-Country. Standard Reference Values are presented in the Far Right Column.

	03/24/07	04/03/07	05/17/07	07/11/2007	09/13/07	10/23/07	12/10/07	Reference Values
Hemoglobin (HGB) (g/dL)	10.4	n/a	14.2	n/a	14.7	14.9	n/a	(12.0 – 16.0)
Hematocrit (HCT) (%)	32.5	n/a	43.7	n/a	42.3	43.0	n/a	(37.0 – 47.0)
Mean Corpuscular Volume (MCV) (fL)	75.4	n/a	80.9	n/a	92.8	94.1	n/a	(80.0 - 100.0)
Mean Corpuscular Hemoglobin (MCH) (pg)	24.2	n/a	26.3	n/a	32.2	32.5	n/a	(27.0 – 34.0)
Iron (ug/dL)	n/a	19	70	127	63	n/a	153	(26 – 170)
Total Iron Binding Capacity (TIBC) (ug/dL)	n/a	393	424	307	333	n/a	310	(262 – 474)
% Saturation	n/a	5	17	41	19	n/a	49	(10 – 40)
Ferritin (ng/mL)	n/a	2	8	18	14	n/a	22	(10 – 200)

n/a: values not available or not tested

recurrent left hip pain as well as an acute episode of left knee pain (onset 1-2 weeks prior to physical examination in the athletic training department). The patient's primary musculoskeletal complaints were chronic left hip pain and the new onset of non-traumatic anterior-lateral left knee pain both which were affecting her ability to complete her training runs pain free.

Musculoskeletal Assessment of the Injured Runner

Standing Examination

Static and dynamic posture and alignment were first assessed in standing. Static posture and alignment appeared unremarkable when viewed anteriorly, laterally, and posteriorly. Active lumbar spine range of motion was also assessed to be within normal limits. Gait observation was unremarkable.

Several functional tests were conducted to assess the subject for dysfunctional biomechanical movement patterns. Functional tests may be useful in providing qualitative information relating to an individual's ability to perform basic and complex movement patterns.[16] When performing a lunge, the patient demonstrated contralateral hip drop, femoral adduction, and knee valgum with each lead leg. When performing a squat, the patient was unable to maintain proper trunk alignment (demonstrating excessive lumbar flexion) during the descent phase. She also was unable to eccentrically control the descent with her hip musculature, instead relying on her quadriceps (as demonstrated by her knees flexing over her feet). The single-legged squat test (SLST) further highlighted her inability to maintain core stability and lower extremity alignment. A Trendelenburg sign, femoral adduction and internal rotation, and knee valgum were demonstrated bilaterally during each SLST with the left lower extremity malalignment qualitatively assessed to be worse than that on the right.

Seated Examination

The patient assumed a sitting posture on the evaluation table. In this position dermatomes, reflexes, and selected muscle tests were conducted *(Table 2)*. Dermatomes and reflexes (L3 and S1) were determined to be intact bilaterally. Manual muscle tests for hip internal rotation, hip external rotation, hip flexion, and knee extension were conducted bilaterally revealing gross hip weakness bilaterally (*Table 2*). A hand held dynamometer (MicroFet 2, Hoggan Health Industries, West Jordan, Utah) was utilized to quantify hip strength. Hip flexion, hip internal rotation, and hip external rotation strength were measured in sitting as recommended by the manufacturer *(Table 2)*.

Supine Examination

Active range of motion (AROM) was assessed in supine. Hip, knee, and ankle AROM was deemed symmetrical and within normal limits bilaterally. Provocation tests (special tests) failed to reproduce hip or knee symptoms. Hamstring flexibility was measured bilaterally using the 90-90 test.[17] To quantify hamstring flexibility, the knee was passively extended from the 90-90 position until resistance prevented further extension of the joint.[17] Hamstring flexibility was measured to be 70º bilaterally. Additional manual muscle tests and dynamometry was conducted *(Table 2)*. Palpation revealed tenderness on the left side at the posterior superior iliac spine, piriformis, gluteus maximus and medius, and hamstring muscles (common origin), as well as the greater tubercle of the hip, distal iliotibial tract, and the antero-lateral knee.

Table 2. Selected Hip Strength Measures Recorded during the Initial Evaluation and after the End of the Subject's Cross-Country Season

	Initial Evaluation Dynamometry (foot/pounds)		Initial Evaluation Traditional Manual Muscle Test (scale 1 – 5)		Post-Rehabilitation Measures Dynamometry (foot/pounds)	
	Right	Left	Right	Left	Right	Left
Flexion	28.8	29.6	3+	3+	44	41
Abduction	32	30	3+	3+	40	42
Extension	28	29	4-	4-	33	35
External Rotation	19	19	3+	3+	23	22
Internal Rotation	16	20	4	4	19.3	19.5

Exam Summary

To summarize, the primary physical examination findings were poor hip and core strength. Based upon these findings, the primary author hypothesized that the patient likely experienced pain while running as a result of her weak hip and core musculature failing to maintain optimal lower extremity biomechanics, especially as she fatigued at or near the end of a run. Altered running mechanics in response to dysfunctional core strength may increase the stress on various tissues in response to repetitive submaximal loads. It was also hypothesized that due to the fact that she was running in an iron deficient (with anemia) state, she was unable to adequately recover between each bout of running. Despite her deficient physiological status, she attempted to train and compete at her perceived optimal level. Continuing to train in this state set the stage for developing a running related overuse injury. Her previous unsuccessful attempt to rehabilitate her injured hip was likely impaired by her iron deficient state and the particular treatments utilized. For example, throughout her course of chiropractic treatment, she was not prescribed any form of stretching or strengthening therapeutic exercises.

Treatment

Medical Treatment

Once a diagnosis of iron deficiency with anemia was established, the patient was instructed to begin iron supplementation. She reported purchasing an over the counter ferrous sulfate supplement with each 134 mg pill containing 27 mg of elemental iron. She would consume between 2 to 6 pills per day. Her supplementation schedule would change in response to recommendations she would receive from medical providers. One provider recommended she consume as few as 2 pills 3 times a week whereas at a different point in time she was consuming 4 to 6 pills daily. The patient reported that the variability of the supplementation schedule "was a challenge to follow" and concerned her as to the effectiveness of the treatment program. Supplementation did improve the athlete's lab values *(Table 1)*. Her iron, % saturation, and ferritin levels had all increased by the start of the cross-country season *(Table 1, column 4)*.

Rehabilitation Intervention

The athlete's primary goal was to be able to compete in each scheduled conference cross-country meet. Her secondary goals included decreasing her musculoskeletal pain while running and increasing her overall hip and core strength. The subject was treated by the primary author in the university's athletic training room facility two days a week throughout the span of the cross-country season *(Table 3)*. Evidence based therapeutic interventions were selected based upon the physical examination findings and patient preferences. Table 3 details the therapeutic exercise, manual therapy, and modality interventions utilized with this athlete. During the initial session, the subject received instruction in exercises designed to increase core strength. Four stretching exercises were added to the home exercise program during the

Table 3. Rehabilitation Program. The Athlete was Treated Two Times a Week throughout the Course of the Cross-Country Season

Session	Modalities	Manual Therapy	Therapeutic Exercises
1	None	None	1. Instruct for daily HEP: clamshells, straight leg raise hip abduction, side plank, front plank
2	None	1. Effluerage and petrissage massage techniques: left posterior hip and gluteals in sidelying. 2. Grade V sacro-iliac region manipulation performed two times to each side.	1. Review and technique correction of previous HEP. 2. Instruct for daily HEP: hamstring stretch (supine), piriformis stretch (supine), prayer stretch, supine trunk rotations
3-4	None	1. Effluerage and petrissage massage: left posterior-lateral hip, gluteals. 2. Grade V sacro-iliac manipulation performed two times to each side.	1. HEP review 2. Review/ educate proper spine posture 3. Add to HEP: squats and lunges (1-3 sets x10 reps)
5-17	1. Interferential electrical stimulation 15 min to left hip and left gluteal region 2. Moist heat 15' left hip and left gluteal region	1. Effluerage and petrissage massage: left gluteal, left hip, lumbar spine (side-lying or prone). 2. Grade III-V mobilization as indicated to thoracic spine, lumbar spine, and sacro-iliac joint.	

second visit. Manual therapy techniques were also initiated during the second session. Massage techniques (effleurage and petrissage strokes) were performed based upon subject request. She felt that previous massage treatments had helped to "manage her symptoms." She was also complaining of lower back pain during this session. Utilizing the clinical prediction rule developed by Flynn et al[18] (she had four predictive factors: acute symptoms less than 16 days, hip internal rotation greater than 35 degrees, lumbar hypomobility, and no symptoms distal to the knee), it was determined that the patient might benefit from a general sacroiliac manipulative technique.[18, 19] The patient experienced cavitations on each side during the manipulation and reported a reduction in low back pain.

After the end of the second week of treatment the patient competed in her first conference run of the season *(Table 4)*. She ran a personal best in the 5,000 meter run dropping 15 seconds off of her all-time best performance.

Manual therapy techniques, as previously discussed, were continued to address soft tissue symptoms (massage) and pain in the lumbar region (manipulation) during sessions 3 and 4. The patient was also instructed to add squats and lunges to her home exercise program. The patient was instructed to perform the squats and lunges facing a mirror in order to reduce the medial collapse of the lower extremities that was observed during the initial evaluation.

She continued to run personal bests and experience improvements from her 2006 race times during each subsequent race *(Table 4)*. To highlight this fact, at the end of week 3 she improved over 3 minutes during a 6,000 meter race.

Despite her improved race times, she continued to experience sport related hip pain. Additional modalities (moist hot packs, interferential electrical stimulation) were utilized in combination with the other manual treatments *(Table 3)*. As the season progressed it became apparent that she would probably continue to experience sports-related pain throughout the remainder of the season. The sports medicine team held the belief that for the athlete to experience a significant reduction in pain, she would need to abstain from running. The treatment focus at the end of the season was to address her musculoskeletal pain with manual therapy, therapeutic exercises, and modalities.

DISCUSSION

This case highlights the comprehensive management of a female cross-country athlete who had been diagnosed with iron deficiency with anemia. Successful medical intervention and rehabilitation strategies helped the athlete to achieve her primary goal to compete in each race. The subject was able to achieve personal bests (her time during the 5th race of the season ranks as the 2nd fastest time recorded in school history for the 6000-meter run) *(Table 4)*. She qualified for the NCAA Division III National Championships finishing 34th overall earning her an All-American status.

Failure to Identify the Iron Deficient State

The failure to identify the iron deficient state in this endurance athlete affected her ability to compete for both her cross-country and track teams during previous seasons. Despite the successful outcome of this case, additional measures may have helped the sports medicine team recognize her iron deficient state sooner.

It is plausible that the subject had been experiencing symptoms related to iron deficiency, with or without anemia, dating back to her freshman cross-country season. Iron deficiency progresses over three stages.[5, 20] The first stage is marked by a decrease in serum ferritin levels, but no change in HGB levels.[5] Physicians who evaluate only the HGB and HCT levels, failing to evaluate other markers such as serum ferritin,

Table 4. Change in Times between 2006 and 2007 Cross-Country Season

Event	Distance (m)	2006 Time (min/sec)	2007 Time (min/sec)
1	5,000 m	did not compete	19:21.13
2	6,000 m	25:46	22:45.80
3	5,000 m	20:59.85	18:13.65
4	6,000 m	26:53.00	22.27
5	6,000 m	24:44.60	21:52.40
6	6,000 m	did not compete	22:03.80
7	6,000 m	did not compete	22.09

may misdiagnose an athlete as iron sufficient.[9, 21] The second stage of iron deficiency is marked by decreasing iron stores, decreasing serum iron, decreasing transferrin saturation, and an increase in TIBC.[5] In the final stage of iron deficiency, the individual becomes anemic.[5] Sports medicine physicians recommend conducting a complete blood count to evaluate HGB, HCT, serum iron, TIBC, serum ferritin, and transferrin saturation with athletes who are suspected of iron deficiency (with or without anemia).[2,5]

The gold standard measure for identifying iron deficiency is a bone marrow biopsy with Prussian blue staining.[5] In lieu of a bone marrow biopsy, serum ferritin levels are considered to be an appropriate clinical measure for iron deficiency.[5,21,22] An athlete is considered iron deficient with serum ferritin levels less than 10-12 ng/mL.[1,5,7,22] When the subject received her diagnosis of iron deficiency with anemia, her serum ferritin levels were 2 ng/mL *(Table 1)*. According to the subject, her ferritin levels had not been tested until April 2007 *(Table 1, column 2)*.

Diet and Iron Supplementation

Iron deficiency in athletes may be the result of one or more of the following factors: gastrointenstinal blood loss,[5,13, 23-26] hemolysis,[27,28] hematuria,[29] sweat loss,[30] intense activity or exercise,[5,11,12,23,31,32] and a lack of intake or absorption of dietary iron.[3,5,33] Consumption of drinks containing caffeine may also inhibit absorption of iron.[3] The subject in this case possessed several of the risk factors, including a diet poor in dietary iron consumption. When interviewing the subject, the primary author found that the athlete avoided certain foods (red meats, eggs) that may have provided a source of dietary iron. The primary author also referred the athlete to a registered dietician in order to develop an appropriate diet for sport and to rule out the presence of an eating disorder.[34]

Once a diagnosis of iron deficiency with anemia was established, the subject initiated iron supplementation. According to the patient, she was not provided clear instruction as to the recommended daily dosage. Supplementation, as expected, did positively influence her lab values *(Table 1)*, but it can be argued that her ferritin levels were sub-optimal throughout the majority of the season.[35] Shaskey and Green[2] suggest that once an athlete begins iron supplementation, 12 months may be needed for iron stores to be completely restored.

Rehabilitation Interventions

The subject did present with weakness in her core musculature as demonstrated by biomechanical faults with functional movement patterns. A growing body of evidence exists suggesting a relationship between core weakness in endurance runners and the onset of injury.[36-38] The subject did experience improvements in hip strength *(Table 2)*, but these gains did not appear to correlate with a decrease in pain. At the end of the season, the primary author reviewed the home exercise program with the athlete, encouraging her to continue the strengthening exercises. Continued strength gains may ultimately decrease the subject's pain experience or help to reduce the risk of future lower extremity injuries.

CONCLUSION

Iron deficiency (with or without anemia) may severely affect an athlete's ability to perform at an optimal level. Sports medicine professionals must consider iron deficiency as a possible differential diagnosis when evaluating endurance athletes. Subtle signs of iron deficiency may be overlooked delaying treatment. In this case, proper treatment allowed the athlete to compete at a high level throughout her cross-country season.

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NAJSPT

CASE REPORT

TREATMENT OF LATERAL KNEE PAIN BY ADDRESSING TIBIOFIBULAR HYPOMOBILITY IN A RECREATIONAL RUNNER

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ABSTRACT

Background. Altered joint arthrokinematics can affect structures distal and proximal to the site of dysfunction. Hypomobility of the proximal tibiofibular joint may limit ankle dorsiflexion and indirectly alter stresses about the knee.

Objectives. To examine the effect of addressing hypomobility of the proximal tibiofibular joint in an individual with lateral knee pain.

Case Description. A 24 year old female recreational runner presented with a three month history of right lateral knee pain. Limited right ankle dorsiflexion was noted and determined to be related to decreased mobility of the proximal tibiofibular joint, as well as, the talocrural and distal tibiofibular joints. Functional movement deficits were noted during the squat test and step down test. Treatment was performed three times over the course of two weeks which included proximal tibiofibular joint manipulation and an exercise program consisting of hip strengthening, balance, and gastrocnemius/soleus muscle complex stretching.

Outcomes. Immediately following intervention, improvements were noted for ankle dorsiflexion, squat test, and step down test. One week following the initial intervention the patient reported she was able to run pain free.

Discussion. Addressing impairments distant to the site of dysfunction, such as the proximal tibiofibular joint, may be indicated in individuals with lateral knee pain.

Key Words: ankle sprain, arthrokinematics, manipulation

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INTRODUCTION

The knee joint is the most commonly injured joint for runners and typical injuries include patellofemoral pain, iliotibial band syndrome, meniscus lesions, and patellar tendinopathy.[1] Knee pain about the lateral aspect of the knee is less commonly described and primarily thought to be related to iliotibial band syndrome[2] or a lateral meniscus lesion.[3] In the absence of these two conditions, other less common presentations could be lateral plica, fabella syndrome, biceps tendinosis, or popliteus tendinosis. A thorough examination of the local structures as well as distant sites may be helpful in the differential diagnosis of lateral knee pain.

An adjacent structure which may contribute to lateral knee pain is the proximal tibiofibular joint.[4-6] Previous authors[5, 6] have suggested that hypermobility of the proximal tibiofibular joint may be a source of lateral knee pain. During ankle dorsiflexion, torsional stress is placed through the proximal tibiofibular joint, via external rotation and anterior glide of the fibula.[6] Decreased mobility of the proximal tibiofibular joint may subsequently limit ankle dorsiflexion range of motion (ROM). Ankle dorsiflexion restrictions have been previously associated with anterior knee pain[7, 8] and are thought to be due to gastrocnemius/soleus tightness or talocrural joint hypomobility. No study has discussed the potential for hypomobility of the proximal tibiofibular joint and the contribution to lower extremity dysfunction. The purpose of this case report was to examine the effect of addressing hypomobility of the proximal tibiofibular joint in an individual with lateral knee pain.

CASE DESCRIPTION

The patient was a 24 year old recreational runner and reported an onset of right knee pain three months prior to initial examination. At that time she had been running 3-4 miles, 5-6 times a week, for the previous six months. After the onset of knee pain she reduced both distance and frequency to 2-3 miles, 2-3 times per week. She recalled no specific trauma or incident that precipitated the pain and reported symptoms only occurred during running and not other activities such as prolonged sitting or stair climbing. Although she was not experiencing pain (0/10) at rest, she rated her worst pain during running as 5/10. She described pain on the lateral aspect of knee which extended into the region of the proximal tibiofibular joint.

Her past medical history included a right lateral ankle sprain, which occurred six years previous. The patient did not seek medical consultation for this injury. She indicated that she had difficulty with walking for 2 to 3 days following the injury and severe ecchymosis resolved within one month. Based on her recall of the injury, the injury was likely be a grade II ankle sprain.[9] This injury was not disclosed until assessment of ankle mobility during the physical examination. The rest of her medical and orthopedic history was unremarkable.

Previous intervention for lateral knee pain had included the use of a patellar tendon strap, based on physician initial recommendations, but provided minimal relief of symptoms. Prior to examination the patient completed the Activity Measure for Post-Acute Care (AM-PAC) outcomes measure and scored 76 out of a possible 81.53.[10] Clinical outcomes collected during the initial examination and follow up sessions are presented in Table 1. The initial examination consisted of observation of static posture, dynamic movement including balance, strength, range of motion (ROM), joint mobility, and special tests.

TABLE 1. Clinical Outcomes

	Initial Evaluation	Immediately post Rx	Visit 2 (1 week)	Visit 3 (2 weeks)
Visual Analog Scale Current/Best/Worst	0/0/5	N/A	0/0/0	0/0/0
Dorsiflexion (degree) (knee extended)				
Right	5	10	10	15
Left	15	15	15	15
Dorsiflexion (degree) (knee flexed 90°)				
Right	8	10	12	20
Left	15	15	15	15
Step Down Test				
Right	5/6	3/6	1/6	1/6
Left	1/6	1/6	1/6	1/6
AM-PAC Score	76.58	N/A	81.53	81.53
Right = involved				

Static Posture and Functional Movement

Static posture was assessed visually in standing, and the right knee was held in slightly more knee flexion than the left knee. Functional movement examination included the squat test,[11] single limb stance, and step down test.[12] All tests were performed using visual observation. The squat test[11] was used to qualitatively examine the movement pattern and functional ROM of the lower extremity. During the descent phase of the squat, the patient's involved (right) lower extremity demonstrated dynamic knee valgus, which has been defined as a combination of femoral adduction, knee abduction, and ankle eversion,[13] compared to the uninvolved (left) lower extremity. A left weight shift was also noted and squat depth was limited on the right side relative to the left. This limitation was thought to be associated with a decrease in right ankle dorsiflexion motion, as compared to the left, which occurred without report of associated ankle pain. After discussion of this impairment, the patient recalled a history of right ankle sprain which had occurred six years previous.

Next, single limb stance was performed with eyes open while standing on a stable surface. The patient was able to balance 10 seconds on the right and 30 seconds on the left before losing balance. The last functional test was the step down test[12] which provided a quantitative assessment of lower extremity functional movement. This test was scored using established criteria *(Table 2)*[12] with lower scores (0 or 1) indicating good quality of movement and higher scores (5 or 6) indicating poor quality of movement. The patient scored 5 points on right (involved) and 1 point on the left (uninvolved) side.

Strength, Range of Motion, and Joint Mobility

Examination of lower extremity strength, ROM, and joint mobility occurred with the patient lying on a treatment table. Manual muscle testing indicated weakness of the right hip abductors (4/5) and hip external rotators (4/5) with all other major muscle groups determined to have full strength (5/5) with no re-creation of pain. The patient's lower extremity ROM was within a functional range and equal bilaterally with the exception of limited right ankle dorsiflexion. Active ankle dorsiflexion was assessed with both the knee extended (right, 5 degrees; left 15 degrees) and flexed to 90 degrees (right, 8 degrees; left 15 degrees).

Table 2. Step Down Test (20 cm/8 in box) Scoring Criteria

Arm Strategy	1 point
If subject used an arm strategy in an attempt to recover balance	
Trunk Movement:	1 point
Trunk lean to side	
Pelvis Plane:	1 point
If pelvis rotated or elevated one side compared with the other	
Knee Position:	
Knee deviates medially and tibial tuberosity crossed an imaginary vertical line over either;	
the 2nd toe	1 point
medial border of the foot	2 points
Maintain steady unilateral stance:	
Stepped down on the non-tested side, or if test limb became unsteady (i.e. wavered from side to side on the tested side)	1 point
Movement Quality: Good: 0-1 points; Medium: 2-3 points; Poor: 4-6 points	

Mobility of the patella was assessed with the patient in supine with the knee in full extension and determined to be normal and equal bilaterally. To determine if limited right ankle dorsiflexion was due to contractile or non-contractile tissues, further assessment of joint mobility was performed at the talocrural joint as well as the distal and proximal tibiofibular joints. Talocrural joint mobility *(Figure 1)* was assessed with the patient in a supine position with the ankle over the edge of the treatment table.[14, 15] The therapist stabilized the tibia and fibula with one hand while the other hand was placed over the talus. The webspace of the movement hand made contact with the neck of the talus while the fingers and thumb grasped the medial and lateral talus. Next, an anterior to posterior directed force was applied to determine the excursion and end feel of talar glide in the ankle mortise. The right talocrural joint was noted to be hypomobile with posterior glide of the talus on the tibia/fibula relative to the left.

Joint mobility of the proximal tibiofibular joint *(Figure 2)* was assessed with the patient in a hook-lying position.[15] The proximal tibia was stabilized with one hand while the thumb and index finger grasped the proximal fibular head. The fibular head was translated posterior to anterior in the plane of the articulation with the tibia. Compared to the left, the right proximal tibiofibular joint was determined to be hypomobile with limited anterior glide of the fibula on the tibia.

Next, mobility of the distal tibiofibular joint *(Figure 3)* was assessed with the patient in supine.[16] The therapist stabilized the distal tibia by making contact with the anterior aspect of the tibia with the thenar emi-

Figure 1. *Mobility testing of the talocrural joint*

Figure 2. *Mobility testing of the proximal tibiofibular joint*

Figure 3. *Mobility testing of the distal tibiofibular joint*

nence and the posterior aspect of the tibia with a lumbrical grip. The other hand grasped the distal fibula with the anterior aspect in contact with the thenar eminence and the posterior aspect of the fibula in contact with the index finger. The distal fibula was translated in an anterior to posterior direction on the stable tibia and was determined to be hypomobile on the right relative to the left.

Based on the assessment of these three joints, the greatest restriction was determined to occur at the right proximal tibiofibular joint, which also reproduced familiar knee pain experienced by the patient. A second physical therapist, blinded to the initial examination findings, was asked to perform mobility assessment of the right proximal tibiofibular joint and pain provocation to confirm findings. The second physical therapist also noted hypomobility in the right proximal tibiofibular joint. Thus, clinical agreement with examination findings existed, but no statistical measures of intertester reliability were performed.

Palpation and Special Tests

The medial and lateral knee joint line and soft tissue structures including the patella tendon, medial and lateral retinacula, biceps tendon, and popliteus tendon were palpated without any complaint bilaterally. Palpable tenderness was reported on the right side along the distal aspect of the iliotibial band lateral to the patella and the fibular head.

Varus stress tests, McMurray's, and Apley's compression were all negative bilaterally. Isometric quadriceps contraction and patellar compression did not reproduce symptoms. Ober's Test and Thomas Test were equally limited bilaterally, per visual observation, but did not reproduce familiar pain. Noble compression test also did not reproduce pain with passive flexion and extension of the knee. Although these special tests are commonly performed in the assessment of lower extremity dysfunction, the sensitivity and specificity for iliotibial band syndrome has not been determined.

Evaluation and Differential Diagnosis

Based on evaluation of examination findings, the patellofemoral joint and iliotibial band were ruled out as sources of dysfunction. During the examination, the patient did not have pain with prolonged sitting, stairs (step down test), squatting, and palpation of the medial retinaculum. These findings indicated something other than patellofemoral joint pain was a cause of the dysfunction.[17] Iliotibial band syndrome was also ruled out as a cause due to the inability to provoke symptoms during Ober's or Thomas Tests.

Pertinent examination findings included limited right ankle dorsiflexion ROM, proximal tibiofibular joint hypomobility, provocation of familiar pain with proximal tibiofibular joint mobility testing, and abnormal lower extremity biomechanics during the squat and step down tests. Hypomobility of the patient's right tibiofibular joint was most likely the underlying cause of pain and dysfunction. At this point the decision was made to direct treatment to the patient's right proximal tibiofibular joint.

INTERVENTION

Initial intervention utilized a high velocity, end range, posterior to anterior thrust, applied to the proximal tibiofibular joint *(Figure 4)* in a manner consistent with previously published methods.[15,18] Briefly, the subject was in a supine position while the physical therapist aligned his index finger with the proximal fibular head and utilized the other hand to produce passive knee flexion and external rotation of the tibia. The associated soft tissue of the popliteal region was pulled in a lateral direction until the metacarpophalangeal joint was firmly stabilized behind the fibular head. The opposite hand grasped the anterior aspect of the ankle while the knee was passively flexed and the tibia was externally rotated. When the restrictive barrier was engaged, indicating the end of physiological motion, a high velocity, low amplitude thrust was applied through the tibia with the force directed towards the subject's heel toward the ipsilateral buttock.[18] An audible joint cavitation (pop) was felt and heard by the patient and heard by both physical therapists (treating and observing) that were in the room.

OUTCOME

Initial Visit

Following initial intervention, joint mobility of the proximal tibiofibular, distal tibiofibular, and talocrural joints of the involved extremity was re-assessed, using the same methods as previously described, and noted to have improved mobility, but still hypomobile relative to the uninvolved joints. Ankle dorsiflexion was reassessed using the same methods as the initial assessment. A 5 degree increase in ankle dorsiflexion occurred with the knee extended (right, 10 degrees; left 15 degrees) and a 2 degree increase with the knee flexed to 90 degrees (right, 10 degrees; left 15 degrees). Functional movements were also re-assessed with an improvement, per visual observation, in active ankle dorsiflexion during the squat test. The step down test was repeated and the score improved to three points which indicated improvement to medium quality of movement.

Additional treatment during the first clinical visit consisted of therapeutic exercises which included hip abduction in side-lying *(Figure 5)* and hip abduction/external rotation (clam shell) in crook lying *(Figure 6)*. Both exercises were performed for three sets of 30 repetitions each, to target hip abductor and external rotator muscles. The patient was instructed to maintain the trunk in neutral and isolate the hip abductor and external rotator muscles. These exercises were also incorporated into a home exercise program. The patient was also allowed to continue her current running program (2-3 miles, 2-3 times per week) with the stipulation that lateral knee pain did not increase during the activity.

Second Visit-One Week Following Initial Visit

One week following the initial visit, the patient reported improvement in symptoms and the ability to run without reproducing knee pain. The AM-PAC was repeated and a maximum score of 81.53 was obtained.[10] The step down test was performed and a score of one point was obtained bilaterally. Joint mobility of the proximal and distal tibiofibular joints and posterior glide of the talus were re-assessed and determined to be improved compared to first visit but still hypomobile relative to the left side.

The patient's right proximal tibiofibular joint once again demonstrated the greatest amount of hypomobility, thus the treatment was directed at this joint. A proximal tibiofibular joint manipulation was performed using the

Figure 4. *Proximal tibiofibular joint manipulation*

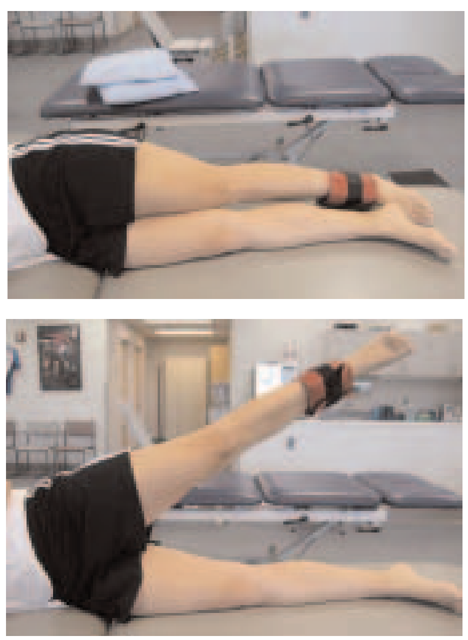

Figure 5. *Hip abduction in side-lying*

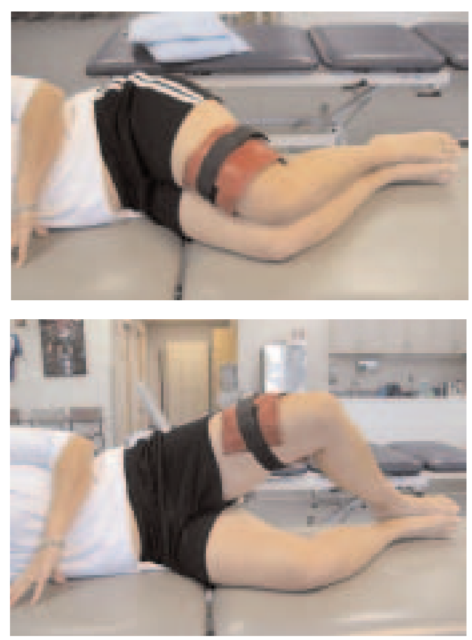

Figure 6. *Hip abduction and external rotation in crook-lying*

same technique as the first visit. Additionally, small amplitude, end of ROM (Grade IV), anterior to posterior joint mobilization[14] was performed at the talocrural joint with the subject lying in supine to improve posterior glide of the talus on the tibia/fibula. Therapeutic exercise program during the second clinical visit included the hip exercises performed during the initial visit as well as the addition of single limb stance exercises with repetitive rhythmic oscillations of the opposite limb performed with an elastic band attached to the opposite limb. This exercise was intended to increase strength and neuromuscular control of the lower extremity in a functional standing position. All exercises performed during the second clinical visit were also continued as part of the home exercise program.

Third Visit- Two Weeks Following Initial Visit

The patient returned for a third visit one week later and reported she was pain free, and still able to run without symptom exacerbation (0/10). The step down test was reassessed and the patient scored one bilaterally. Ankle ROM was also reassessed on the right side using the same methods as previously described. Compared to measurements during the initial examination, ankle dorsiflexion had improved 10 degrees with the knee extended (15 degrees) and 10 degrees with the knee flexed to 90 degrees (20 degrees). The AM-PAC score remained at a maximal obtainable score of 81.53.

Joint mobility of the proximal and distal tibiofibular joints and the talocrural joint was performed in a similar manner as previous examinations and was noted to be normal and equal bilaterally. Since the patient had no reports of pain, functional deficits, nor joint mobility restrictions the decision was made, with the consent of the patient, to discontinue physical therapy services and discharge her to her established home exercise program.

Follow-up

Ten months following discharge, the patient was contacted by phone for follow up evaluation of function. She reported that her knee and ankle had remained symptom free, and she was able to run 4-5 miles, 4-5 times per week. Another telephone follow up was conducted sixteen months following discharge, and the patient indicated she continued to remain symptom free and had increased running distance to 4-8 miles 4-5 times per week.

DISCUSSION

In this case report, restricted mobility of the joints associated with the tibia, fibula, and talus may have been a contributing factor to lateral knee pain.[7] Decreased ankle dorsiflexion ROM[7, 8] and altered mobility of the tibiofibular joints[4-6] have been shown to be associated with knee pain. It is unknown if limited ankle dorsiflexion was a precipitating, or compensatory mechanism, but stresses may have been increased about the knee joint during gait.[19]

A plausible explanation for proximal tibiofibular joint dysfunction may be indirectly related to the history of a previous ankle sprain.[5] Changes in the positional alignment of the talus, tibia, and fibula have been implicated in a subpopulation of individuals with a history of ankle sprain.[3,20-23] Two positional faults have been described to occur at either the talocrural joint[21] or the distal tibiofibular joint.[3,20,22,23] At the talocrural joint, the talus is thought to migrate anteriorly following lateral ankle sprains due to the disruption of the ligaments restraining anterior talus translation.[21] At the distal tibiofibular joint, a slight anterior displacement of the fibula relative to the tibia is thought to occur.[3,20,22,23] Based on the arthrokinematics associated with the tibiofibular joints, anterior translation of the distal fibula is associated with a concomitant posterior translation (external rotation) of the proximal fibula.[24] Clinically the positional faults are recognized as decreased posterior glide of the talus *(Figure 1)* or distal fibula *(Figure 3)* or decreased anterior glide of the proximal fibula *(Figure 2)*, all of which manifest as decreased ankle dorsiflexion ROM.[3, 20-23] If altered arthrokinematics and compensatory movement patterns are not appropriately addressed following injury, an opportunity exists for future local and distant joint pathology.[25-27] Although the ankle sprain reported by the patient had occurred approximately six years previously, only within the past year had her activity level increased to the point where this dysfunction may have become symptomatic. It is possible that her level of function prior to the initiation of her running program nine months previous may have not been enough to create symptomatic dysfunction. Repetitive stresses through the lower quarter associated with running may have provided enough stress to the joints creating a painful response.

Manual therapeutic interventions[14, 28-30] are reported clinically to offer the ability to restore normal joint arthrokinematics. By addressing hypomobility of the proximal tibiofibular joints, lower extremity arthrokinematics may be restored, ultimately altering stresses placed at the local joint. It is possible that this restoration of arthrokinematics may have contributed to the patient's decreased lateral knee pain symptoms. Due to the nature of the case report and the use of a multifaceted home exercise program, a cause and effect relationship can not be determined.

Results of this case report should be approached with caution due to the nature the single subject design and limited reliability and validity of examination methods. Examiner bias may have also been present during analysis of functional movements and joint mobility following intervention. Additional study is required to examine the contribution of the proximal tibiofibular joint in individuals with lateral knee pain and better develop examination and treatment for lateral knee pain.

SUMMARY

Consideration of the potential for ankle joint hypomobility contradicts common clinical thoughts associated with a history of lateral ankle sprain. Although the lateral ligaments of the ankle may have laxity associated with ligament disruption, recent evidence suggests that hypomobility of the adjacent talocrural and tibiofibular joints may contribute to chronic dysfunction.[20,21,31,32] Dysfunction may be asymptomatic unless tissues are stressed with activities such as running. This case presentation documents that proximal tibiofibular hypomobility may serve as a contributor to lateral knee pain. A thorough history and examination of surrounding structures will help identify underlying impairments which contribute to dysfunction. The treating clinician should be aware of specific biomechanical deficits that may contribute to lateral knee pain, as well as additional treatment options such as manual interventions for this type of condition.

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CLINICAL COMMENTARY

EXAMINATION AND INTERVENTION FOR SINUS TARSI SYNDROME

Kevin Helgeson, PT, DHSc[1]

ABSTRACT

Athletes with persistent anterolateral ankle discomfort may have developed sinus tarsi syndrome (STS). Sinus tarsi syndrome develops from excessive motions of the subtalar joint that results in subtalar joint synovitis and infiltration of fibrotic tissue into the sinus tarsi space. Physical therapists treating athletes with ankle conditions should examine the talocrural and subtalar joints for signs of hypermobility as injuries can affect both of these important articulations of the lower extremity. Localized ankle discomfort to the sinus tarsi space and feelings of instability with pronation and supination movements of the subtalar joint will help identify STS. Intervention for this condition will focus on enhancing subtalar joint stability and function of the lower extremities. The purpose of this clinical commentary is to discuss the etiologies and signs of STS and describe the components of an intervention plan appropriate for athletes with STS.

Key Words: ankle injuries, subtalar joint, joint instability

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INTRODUCTION

Sinus tarsi syndrome (STS) is a clinical entity characterized by persistent anterolateral ankle pain secondary to traumatic injuries to the ankle. Historically, the etiology of this condition has not been well understood. Recent discussions of STS now describe this entity as primarily an instability of the subtalar joint due to ligamentous injuries that results in a synovitis and infiltration of fibrotic tissue into the sinus tarsi space.[2,3] This clinical commentary will describe the possible etiologies and examination findings of athletes with STS and treatment options for this condition for the sports physical therapist.

ANATOMICAL AND KINESIOLOGICAL CONSIDERATIONS

The subtalar joint is comprised of the articulation of the talus and calcaneus across an anterior, middle, and posterior facet. These facets may have variations in their structure and alignments that will affect the movement and stability of the subtalar joint.[4] Extrinsic and intrinsic ligaments provide static stability for the subtalar joint. Extrinsic ligaments include the calcaneofibular ligament and the deltoid ligament, which also provide stability for the talocrural joint. The talocalcaneal, interosseuous, and cervical ligaments are the intrinsic ligaments that provide a strong connection for the calcaneal and talar joint surfaces.[5] Ruptures of the intrinsic ligaments allow increased movement of the subtalar joint that may result in instability.[6-8]

The motions of the subtalar joint and the entire rearfoot are complex and have been the subject of extensive study and controversy.[4,9,10] The osteokinematics of the subtalar joint occur about a triplanar axis to create pronation and supination movements.[5] Supination motions of the subtalar joint create a bony stability through the rearfoot and midfoot that is important for propulsive movements through the foot. Pronation motions create increased mobility of the rearfoot and midfoot joints allowing the foot to accommodate to uneven surfaces.[5,11] During running activities, athletes may weight bear entirely onto the forefoot, with ground reaction forces creating supination and pronation motions that occur from the midfoot into the rearfoot. Ground reaction forces during running create movements through the subtalar joint at a higher rate of acceleration and forces than during walking activities.[12]

The sinus tarsi space is filled with many connective tissues that contribute to the stability and the overall proprioception of the ankle. The space is filled with adipose tissue that serves as a bedding for numerous mechanoreceptors and free nerve endings, which along with the ligaments and muscles provide proprioceptive information on the movement of the foot and ankle.[2,13] The vascular supply of the sinus tarsi is provided by an anastomosis of the sinus tarsi and tarsal canal arteries.[14] The extensor digitorum brevis muscle attaches to the medial and distal aspect of the sinus tarsi, running over the calcaneocuboid joint towards the toes. The inferior extensor retinaculum lies over the lateral aspect of this space and serves as a covering over the sinus tarsi.[2]

ETIOLOGY

Sinus tarsi syndrome is believed to occur following a single traumatic event or a series of ankle sprains that result in significant injuries to the talocrural interosseous and cervical ligaments.[2,5] These injuries cause instability of the subtalar joint resulting in excessive supination and pronation movements. The excessive movement of the subtalar joint imparts increased forces onto the synovium of the subtalar joint and across the sinus tarsi tissues. The excessive forces result in subtalar joint synovitis with chronic inflammation and infiltration of fibrotic tissues in the sinus tarsi that are responsible for the characteristic anterolateral ankle pain of STS.[2] These traumatic injuries may also injure ligaments of the tibiotalar and talocalcaneal joints resulting in increased mobility and instability of the rearfoot and midfoot. Athletes with increased mobility of the talocrural and subtalar joints may be at a greater risk for developing instability after an ankle injury.[4]

The incidence of STS is unknown, but has been associated with ankle sprains that may also result in talocrural joint instability. Keefe and Haddad[15] estimated that 10-25% of patients with chronic talocrural joint instability will also have subtalar joint instability. Hertel et al[16] found that 9 out of 12 patients with recurrent ankle sprains had signs of increased talocrural and subtalar joint motions upon a radiographic examination. Hubbard and Hertel[17] have advocated that a large percentage of injuries classified as an ankle sprain will include an injury to the subtalar joint ligaments.

EXAMINATION

Athletes with STS usually describe a history of a traumatic ankle injury, typically with a supination/inversion mechanism of injury. Athletes involved with jumping sports may incur an injury to the subtalar joint after coming to an abrupt stop after a jump or a fall. This mechanism is thought to create a "whiplash injury" to the rearfoot with the talus moving anteriorly over the calcaneus.[15] This mechanism may result in a sprain to the ligaments of the talocrural joint as well. Physical therapists should also be cautious with athletes who have an extended history of talocrural joint instability even after undergoing reconstruction of the lateral ankle ligaments, as these procedures are intended to improve stability of the talocrural joint and may not improve stability at the subtalar joint.[18]

An acute ankle injury will typically present with pain accompanied by swelling, ecchymosis, and tenderness in the anterolateral ankle. Because the synovitis and fibrotic tissues associated with STS will take time to develop, athletes with injuries to the subtalar joint may not initially have symptoms that can be localized to the sinus tarsi *(Figure 1)*. Athletes with STS will typically describe a feeling of instability of the foot and ankle that is provoked upon walking over uneven ground, stepping off a curb, or running or sprinting activities.[5,15,19] Athletes involved with cutting and jumping activities on firm surfaces will have the greatest difficulty with subtalar instability as these activities will cause excessive movements of the subtalar joint to the end ranges of pronation and supination.[15,20]

Assessment of standing posture in athletes with STS may demonstrate a pes planus posture or an asymmetry of the rearfoot angle with the leg, but these are not typical findings.[19] Passive range of motion of the ankle and subtalar joint may not reveal excessive motion, but pain over the sinus tarsi at the end range of ankle plantarflexion with foot supination is typical of STS. Muscles that cross the ankle joint should be assessed for any loss of strength, especially the plantarflexor muscles.

Before examining the subtalar joint, a careful assessment of the talocrural joint should be performed. Anterior and posterior glides of the talus on the tibia and a talar tilt test that produces movement of the talus in the frontal plane are recommended for assessing talocrural joint stability.[21,22] Mobility of the contralateral ankle and foot joints should be assessed to determine if the athlete has increased joint mobility that will make them susceptible to developing an instability.

Stability of the subtalar joint is assessed with medial and lateral subtalar joint glides performed by moving the calcaneus over a stabilized talus in the transverse plane and with subtalar joint distraction.[16,17] Therman et al[20] described a stability test that is thought to recreate instability of the subtalar joint *(Figure 2)*. The test is performed with the athlete in supine with the ankle in 10 degrees of dorsiflexion to keep the talocrural joint in a stable position. The forefoot is first stabilized by the examiners hand, while an inversion and internal rotational force is applied to the calcaneus. Then an inversion force is applied to the forefoot. The examiner assesses for an excessive medial shift of the calcaneus and a reproduction of the athlete's complaint of instability and symptoms.

Figure 1. *Symptoms associated with STS are usually described as deep in the ankle and can be localized by athlete pointing to the sinus tarsi space.*

Figure 2. *Clinical test for reproduction of subtalar instability. The forefoot is first stabilized by the examiners hand, while an inversion and internal rotational force is applied to the calcaneus.*

Reproduction of the athletes feeling of instability or giving way may be reproduced by having the athlete single leg stand on the affected side and perform rotating motions of the leg and foot that may reproduce their symptoms.[5] Therapists may also want to assess the athlete during functional activities of walking, running, stepping down from a step, and hopping on the affected extremity. Activities that produce feelings of instability should be assessed for the relative position of the rearfoot and leg for any compensation through the lower extremity the athletes makes when the instability is produced. The activity levels of athletes with STS can be assessed using the Ankle Disability Index, which includes the athlete's rankings of sports related activities.[23]

DIFFERENTIAL DIAGNOSIS

Athletes with recurrent ankle sprains or symptoms of ankle instability should be suspected of having instability of the talocrural and subtalar joints. Localization of pain to the sinus tarsi with the presence of ankle instability is a good indication that the athlete has developed STS. Conditions that may also produce lateral ankle discomfort include a cuboid subluxation and peroneal tendon subluxation.[24] The diagnosis of STS has typically been confirmed by the cessation of symptoms upon injection of lidocaine into the sinus tarsi.[1]

IMAGING

Athletes suspected of having subtalar joint instability and STS may be referred for diagnostic imaging. Although imaging studies have been proposed to assess the stability of the subtalar joint, most of these methods have been proven to be inconsistent in their findings with low levels of specificity for subtalar joint instability.[15,16] Radiographs of the subtalar joint are usually performed with Broden stress views which are a series of oblique-lateral views performed with the ankle and foot placed in inverted and supinated positions.[5] Stress fluoroscopy is a method of visualizing the motions of the subtalar joint in real time using low level radiation. The advantage of fluoroscopy over radiographs is that the examiner can attempt to replicate the movements that are causing the athlete's sensation of instability or discomfort from the sinus tarsi.[16]

Magnetic resonance imaging (MRI) is the best method to visualize the structure within the sinus tarsi, especially the interosseous and cervical ligaments.[2] The most distinct finding for individuals with STS is a bright signal seen on T2 weighted images found in the area for sinus tarsal adipose tissue as this represents an infiltration or replacement of this tissue with inflammatory cells and fibrotic tissue.[25,26] The MRI findings may also include alterations in the structure of the interosseous and cervical ligaments and degenerative changes in the subtalar joint.[2,25]

INTERVENTION

Recommendations for rehabilitation of STS include balance and proprioceptive training, muscle strengthening exercises, bracing, taping, and foot orthosis.[2,15,24] No random control trials for the efficacy of a rehabilitation program for STS are available. Instability of the talocrural joint or chronic ankle instability (CAI) is a similar and associated entity to subtalar joint instability and STS. Numerous studies of the effects of balance and proprioceptive training for CAI have been conducted, with improvements found in athletes' balance, joint position sense, and functional abilities.[27-29]

Athletes with STS have developed a chronic inflammatory process that results in a synovitis and inflammation of connective tissues and may benefit from a trial of non-steroidal anti-inflammatory medication to help control their symptoms and inflammation.[30] Cryotherapies, especially the use of ice massage over the lateral ankle, may also be useful for diminishing local inflammation and pain associated with this condition. Athletes with STS may have limited joint mobility at the talocrural and mid tarsal joints that can be addressed with specific joint mobilization techniques. Precautions should be made not to place excessive stress across the subtalar joint with these techniques. Muscular stiffness of the gastrocnemius, posterior tibialis, or peroneal muscles may also be found in athletes with STS, but stretching activities for these muscles should be carefully provided or avoided as excessive forces across the subtalar joint may be detrimental.[31]

Orthoses

Stability of the subtalar joint may be initially improved with the use of an orthosis.[32] Ankle braces intended for CAI may be useful for some athletes with STS, but the overall design of these braces may not significantly improve the stability of the subtalar joint during athletic activities. Foot orthosis have also been recommended as a method for limiting motion at the subtalar joint and reducing symptoms associated with STS.[33] The types of shoes the athlete is using for training, practices, and competition should also be considered, as well constructed shoes can restrict excessive rearfoot movements.[34]

General recommendations for shoes include those with a straight last, a firm heel counter, and rigid material through the midsole.[33] Shoes should also be assessed for wear, as materials within a shoe will be begin to break down before the external material show signs of deterioration. The use of a foot orthosis with an athletic shoe should be considered together, as the effect of an orthosis can be inconsistent.[35] An ongoing assessment of shoe and orthosis use is needed to provide adequate support of the foot and ankle throughout an athlete's cycle of training and competition.

Taping or strapping has also been used to specifically limit movements of the subtalar joint and the midfoot. Wilkerson et al[36] have described a taping procedure that combines a closed basket weave with a subtalar sling to control movements at the talocrural and subtalar joints. Viczenzio et al[37] have described a modified Low-Dye taping method that uses a calcaneal sling intended to provide support to the medial longitudinal arch of the foot *(Figure 3)*. This method could be used to control or reduce the amount of pronation through the subtalar joint during walking and running activities. Taping techniques have been used as a precursor for the use and selection of specific types of shoes and foot orthotics.[37]

Figure 3. *Taping for stabilizing the rearfoot. These taping methods can be used in addition to an closed ankle basket weave or a foot Low-Dye method. Figure on the top shows a calcaneal sling with a long strip to control rearfoot pronation, figure on the bottom shows heel lock strips to control rearfoot supination.*

Stability Training

Training programs to improve the stability of the subtalar joint and lower extremity function will be the hallmark of treatment plans for STS. Joint stability relies on passive joint structures, dynamic muscular responses, and neurological control. Because tears or ruptures of the interosseous and cervical ligaments of the subtalar joint are believed to be the essential lesions that lead to STS, the dynamic muscular responses and neurological control of the rearfoot will need to be emphasized to compensate for the loss of passive stability.[38,39]

The muscles that cross the subtalar joint are important for maintaining stability, as they act as force transducers to guide and control the pronation and supination motions of the subtalar joint. The relative strength of these muscles is important, but their reaction time to joint perturbations and the ability to work in a coordinated fashion is even more important for the rehabilitation of STS.[40,41] Dynamic stability will also rely on the proprioceptive information from the muscle spindles and Golgi tendon organs of these muscles to compensate for the lack of proprioceptive information from the stabilizing ligaments of the joint.[42] The endurance of the muscles will also be important to maintain stability during long bouts of exercise or sports activities.

Training programs to improve joint stability have been described as multiphase processes that start the athlete at an appropriate level of activity and progresses to higher levels of activities while maintaining joint stability.[40,42] To help the athlete understand this process the progression of three phases are called: Attain, Maintain, and Sustain. The Attain phase will determine postures or positions the athlete is able to attain in a stable fashion. The Maintain phase will develop coordinated isometric and eccentric muscle contractions of the muscles crossing the joint. The Sustain phase will involve integrating all of the neuromuscular subsystems needed for stability during sports specific activities *(Table 1)*.

The Attain phase for subtalar joint instability is usually started with the athlete in standing positions. Single leg standing, with the contralateral limb held in approximately 30 degrees of hip flexion and 90 degrees of knee flexion, will emphasize ankle balance strategies.[43] The clinician should closely observe the arch of the foot and rearfoot to assess the athlete's ability to attain a stable position for the subtalar joint while avoiding excessive pronation movements *(Figure 4)*. The Attain phase begins with the eyes open and attempting to hold the single leg position for 30 to 60 seconds with minimal alterations in body position. Once the athlete is able to hold a single leg standing position consistently, a progression to eyes closed conditions can be made.

Stage	Activities	Criteria for Progression
Attain	Single leg standing – Eyes open and closed	Athlete demonstrates ability to attain a stable position through the foot and ankle.
Maintain	Single leg standing – Hip swings, and Star pattern reaching. Heel raises, oscillation with theraband, and impulse with medicine ball.	Athlete demonstrates ability to maintain stability and good alignment through the lower extremities.
Sustain	Lunges and step down exercises Bilateral and single leg hops Forward and backward acceleration and deceleration Pivoting and cutting maneuvers	Athlete demonstrates the ability to tolerate loading and pushing-off the involved lower extremity.

Table 1: Progression through three stages of stability training.

The second phase, Maintain, is performed with perturbations to the single leg positions. Perturbation forces are imparted near the level of the athlete's center of gravity to replicate the type of forces that produce subtalar joint instability during athletic activities. The perturbating forces are intended to facilitate rapid isometric and eccentric contractions of the stabilizer muscles of the ankle.[42] Perturbations to standing balance are begun with movements from the contralateral hip starting in the sagittal and coronal planes of motion, progressing to transverse plane motions. Observations of the athlete's rearfoot and hip stability will indicate his/her ability to maintain this position. The clinician needs to insure that the athlete is not using excessive compensatory motions at the rearfoot or hip to maintain a single leg standing position.

Figure 4. *Foot held in an excessive pronated position.*

The star excursion balance test activities can also be used in this phase, with the athlete in the single leg standing position and touching different lines drawn on the floor in a star pattern.[27] Standing heel raises and lowering exercises can be performed at a slow speed in double leg and single leg standing. Emphasis is placed on promoting controlled concentric and eccentric muscle contraction of the ankle plantarflexors and subtalar joint pronator muscles.[24] External perturbations can be imparted with the athlete holding a two-foot length of theraband. With both hands in front of the umbilicus, the therapist can then pull on the theraband with oscillating motions. Catching and throwing a small ball or medicine ball while in single leg standing can also be used for perturbations in multiple directions and different timing.[40]

The Sustain phase will begin with the athlete learning to "close the chain" meaning moving from an open kinematic chain to a stable closed kinematic chain position. The emphasis is on developing the feedforward motor control of the lower extremities.[40] This activity can be started by having the athlete perform lunging steps and then stepping down from a 4 or 8 inch step onto the involved extremity into a single leg standing position. Progression can be to lateral lunge steps and lateral step downs. Observations of the athlete's overall control of motion through the lower extremities with an emphasis on alignment of the knee and foot will insure that excessive subtalar joint motion is not occurring.

Progressions of the Sustain phase can be performed with the athlete jumping or hopping in place and then into hopping in different directions. Running activities can begin by acceleration and deceleration with forward and backward motions. Athletes needing to perform pivoting or cutting maneuvers can begin these activities at a slow speed maintaining good alignment of the foot and leg and avoiding excessive motions through the rearfoot.

Return to play criteria is based on the athlete's ability to move in all directions and at appropriate speeds. Athletes performing cutting and jumping maneuvers on firm surfaces, such as basketball and volleyball players, should be returned to full activities over a period of days to insure their tolerance to these stressful maneuvers.[15,20] A progression of the athletic activities should be assessed with the athlete in his or her normal practice or competitive environment. The athlete's anterolateral ankle symptoms will need to be well controlled to insure that the return to competition will not create chronic inflammation of the sinus tarsi tissues.

Surgery

Athletes who fail a course of rehabilitation may need an arthroscopic exploration and reconstruction of the subtalar joint in order to return to their athletic pursuits. Arthroscopy of the subtalar joint has allowed for a more precise examination of the subtalar joint and the sinus tarsi. A synovectomy of the subtalar joint along with an arthrotomy of the subtalar joint can be used to remove chronic synovitis and arthrofibrosis that is commonly found in STS.[44] Surgical reconstructions of the cervical and interosseous ligaments are made by splitting the tendon of the peroneus brevis and routing the graft through bone tunnels made through the calcaneus and the talus.[2,18] Patients with instability of the talocrural and subtalar joints may require a tri-ligamentous reconstruction of the anterior talofibular, calcaneofibular, and cervical ligaments.[18] Patients who present with significant joint degeneration or continue to have persistent symptoms even after ligamentous reconstruction may require an arthodesis resulting in an isolated fusion of the subtalar joint.[45]

Athletes who have undergone ligamentous reconstructions will commonly be immobilized for a 6-week period, followed by a rehabilitation program to regain normal ankle mobility, strength, and balance. Return to athletic activities usually begins at 4 to 6 months post-operatively.[18] Common post-operative problems are transient loss of sensation of the lateral ankle and foot and persistent peroneal weakness.[3]

SUMMARY

Sinus tarsi syndrome is a condition of the ankle and foot that results from instability of the subtalar joint. Athletes with this condition typically have complaints of instability with functional activities and persistent anterolateral ankle discomfort. The joints of the ankle should be assessed for mobility and reproduction of feelings of instability and discomfort. Treatments for this condition will need to control the athlete's ankle discomfort and improve the overall stability of the foot and ankle. Therapists should design intervention plans based on the athlete's need for training and competition.

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NAJSPT

CLINICAL COMMENTARY

EXAMINATION AND INTERVENTION FOR SINUS TARSI SYNDROME

Kevin Helgeson, PT, DHSc[1]

ABSTRACT

Athletes with persistent anterolateral ankle discomfort may have developed sinus tarsi syndrome (STS). Sinus tarsi syndrome develops from excessive motions of the subtalar joint that results in subtalar joint synovitis and infiltration of fibrotic tissue into the sinus tarsi space. Physical therapists treating athletes with ankle conditions should examine the talocrural and subtalar joints for signs of hypermobility as injuries can affect both of these important articulations of the lower extremity. Localized ankle discomfort to the sinus tarsi space and feelings of instability with pronation and supination movements of the subtalar joint will help identify STS. Intervention for this condition will focus on enhancing subtalar joint stability and function of the lower extremities. The purpose of this clinical commentary is to discuss the etiologies and signs of STS and describe the components of an intervention plan appropriate for athletes with STS.

Key Words: ankle injuries, subtalar joint, joint instability

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INTRODUCTION

Sinus tarsi syndrome (STS) is a clinical entity characterized by persistent anterolateral ankle pain secondary to traumatic injuries to the ankle. Historically, the etiology of this condition has not been well understood. Recent discussions of STS now describe this entity as primarily an instability of the subtalar joint due to ligamentous injuries that results in a synovitis and infiltration of fibrotic tissue into the sinus tarsi space.[2,3] This clinical commentary will describe the possible etiologies and examination findings of athletes with STS and treatment options for this condition for the sports physical therapist.

ANATOMICAL AND KINESIOLOGICAL CONSIDERATIONS

The subtalar joint is comprised of the articulation of the talus and calcaneus across an anterior, middle, and posterior facet. These facets may have variations in their structure and alignments that will affect the movement and stability of the subtalar joint.[4] Extrinsic and intrinsic ligaments provide static stability for the subtalar joint. Extrinsic ligaments include the calcaneofibular ligament and the deltoid ligament, which also provide stability for the talocrural joint. The talocalcaneal, interosseuous, and cervical ligaments are the intrinsic ligaments that provide a strong connection for the calcaneal and talar joint surfaces.[5] Ruptures of the intrinsic ligaments allow increased movement of the subtalar joint that may result in instability.[6-8]

The motions of the subtalar joint and the entire rearfoot are complex and have been the subject of extensive study and controversy.[4,9,10] The osteokinematics of the subtalar joint occur about a triplanar axis to create pronation and supination movements.[5] Supination motions of the subtalar joint create a bony stability through the rearfoot and midfoot that is important for propulsive movements through the foot. Pronation motions create increased mobility of the rearfoot and midfoot joints allowing the foot to accommodate to uneven surfaces.[5,11] During running activities, athletes may weight bear entirely onto the forefoot, with ground reaction forces creating supination and pronation motions that occur from the midfoot into the rearfoot. Ground reaction forces during running create movements through the subtalar joint at a higher rate of acceleration and forces than during walking activities.[12]

The sinus tarsi space is filled with many connective tissues that contribute to the stability and the overall proprioception of the ankle. The space is filled with adipose tissue that serves as a bedding for numerous mechanoreceptors and free nerve endings, which along with the ligaments and muscles provide proprioceptive information on the movement of the foot and ankle.[2,13] The vascular supply of the sinus tarsi is provided by an anastomosis of the sinus tarsi and tarsal canal arteries.[14] The extensor digitorum brevis muscle attaches to the medial and distal aspect of the sinus tarsi, running over the calcaneocuboid joint towards the toes. The inferior extensor retinaculum lies over the lateral aspect of this space and serves as a covering over the sinus tarsi.[2]

ETIOLOGY

Sinus tarsi syndrome is believed to occur following a single traumatic event or a series of ankle sprains that result in significant injuries to the talocrural interosseous and cervical ligaments.[2,5] These injuries cause instability of the subtalar joint resulting in excessive supination and pronation movements. The excessive movement of the subtalar joint imparts increased forces onto the synovium of the subtalar joint and across the sinus tarsi tissues. The excessive forces result in subtalar joint synovitis with chronic inflammation and infiltration of fibrotic tissues in the sinus tarsi that are responsible for the characteristic anterolateral ankle pain of STS.[2] These traumatic injuries may also injure ligaments of the tibiotalar and talocalcaneal joints resulting in increased mobility and instability of the rearfoot and midfoot. Athletes with increased mobility of the talocrural and subtalar joints may be at a greater risk for developing instability after an ankle injury.[4]

The incidence of STS is unknown, but has been associated with ankle sprains that may also result in talocrural joint instability. Keefe and Haddad[15] estimated that 10-25% of patients with chronic talocrural joint instability will also have subtalar joint instability. Hertel et al[16] found that 9 out of 12 patients with recurrent ankle sprains had signs of increased talocrural and subtalar joint motions upon a radiographic examination. Hubbard and Hertel[17] have advocated that a large percentage of injuries classified as an ankle sprain will include an injury to the subtalar joint ligaments.

EXAMINATION

Athletes with STS usually describe a history of a traumatic ankle injury, typically with a supination/inversion mechanism of injury. Athletes involved with jumping sports may incur an injury to the subtalar joint after coming to an abrupt stop after a jump or a fall. This mechanism is thought to create a "whiplash injury" to the rearfoot with the talus moving anteriorly over the calcaneus.[15] This mechanism may result in a sprain to the ligaments of the talocrural joint as well. Physical therapists should also be cautious with athletes who have an extended history of talocrural joint instability even after undergoing reconstruction of the lateral ankle ligaments, as these procedures are intended to improve stability of the talocrural joint and may not improve stability at the subtalar joint.[18]

An acute ankle injury will typically present with pain accompanied by swelling, ecchymosis, and tenderness in the anterolateral ankle. Because the synovitis and fibrotic tissues associated with STS will take time to develop, athletes with injuries to the subtalar joint may not initially have symptoms that can be localized to the sinus tarsi *(Figure 1)*. Athletes with STS will typically describe a feeling of instability of the foot and ankle that is provoked upon walking over uneven ground, stepping off a curb, or running or sprinting activities.[5,15,19] Athletes involved with cutting and jumping activities on firm surfaces will have the greatest difficulty with subtalar instability as these activities will cause excessive movements of the subtalar joint to the end ranges of pronation and supination.[15,20]

Assessment of standing posture in athletes with STS may demonstrate a pes planus posture or an asymmetry of the rearfoot angle with the leg, but these are not typical findings.[19] Passive range of motion of the ankle and subtalar joint may not reveal excessive motion, but pain over the sinus tarsi at the end range of ankle plantarflexion with foot supination is typical of STS. Muscles that cross the ankle joint should be assessed for any loss of strength, especially the plantarflexor muscles.

Before examining the subtalar joint, a careful assessment of the talocrural joint should be performed. Anterior and posterior glides of the talus on the tibia and a talar tilt test that produces movement of the talus in the frontal plane are recommended for assessing talocrural joint stability.[21,22] Mobility of the contralateral ankle and foot joints should be assessed to determine if the athlete has increased joint mobility that will make them susceptible to developing an instability.

Stability of the subtalar joint is assessed with medial and lateral subtalar joint glides performed by moving the calcaneus over a stabilized talus in the transverse plane and with subtalar joint distraction.[16,17] Therman et al[20] described a stability test that is thought to recreate instability of the subtalar joint *(Figure 2)*. The test is performed with the athlete in supine with the ankle in 10 degrees of dorsiflexion to keep the talocrural joint in a stable position. The forefoot is first stabilized by the examiners hand, while an inversion and internal rotational force is applied to the calcaneus. Then an inversion force is applied to the forefoot. The examiner assesses for an excessive medial shift of the calcaneus and a reproduction of the athlete's complaint of instability and symptoms.

Figure 1. *Symptoms associated with STS are usually described as deep in the ankle and can be localized by athlete pointing to the sinus tarsi space.*

Figure 2. *Clinical test for reproduction of subtalar instability. The forefoot is first stabilized by the examiners hand, while an inversion and internal rotational force is applied to the calcaneus.*

Reproduction of the athletes feeling of instability or giving way may be reproduced by having the athlete single leg stand on the affected side and perform rotating motions of the leg and foot that may reproduce their symptoms.[5] Therapists may also want to assess the athlete during functional activities of walking, running, stepping down from a step, and hopping on the affected extremity. Activities that produce feelings of instability should be assessed for the relative position of the rearfoot and leg for any compensation through the lower extremity the athletes makes when the instability is produced. The activity levels of athletes with STS can be assessed using the Ankle Disability Index, which includes the athlete's rankings of sports related activities.[23]

DIFFERENTIAL DIAGNOSIS

Athletes with recurrent ankle sprains or symptoms of ankle instability should be suspected of having instability of the talocrural and subtalar joints. Localization of pain to the sinus tarsi with the presence of ankle instability is a good indication that the athlete has developed STS. Conditions that may also produce lateral ankle discomfort include a cuboid subluxation and peroneal tendon subluxation.[24] The diagnosis of STS has typically been confirmed by the cessation of symptoms upon injection of lidocaine into the sinus tarsi.[1]

IMAGING

Athletes suspected of having subtalar joint instability and STS may be referred for diagnostic imaging. Although imaging studies have been proposed to assess the stability of the subtalar joint, most of these methods have been proven to be inconsistent in their findings with low levels of specificity for subtalar joint instability.[15,16] Radiographs of the subtalar joint are usually performed with Broden stress views which are a series of oblique-lateral views performed with the ankle and foot placed in inverted and supinated positions.[5] Stress fluoroscopy is a method of visualizing the motions of the subtalar joint in real time using low level radiation. The advantage of fluoroscopy over radiographs is that the examiner can attempt to replicate the movements that are causing the athlete's sensation of instability or discomfort from the sinus tarsi.[16]

Magnetic resonance imaging (MRI) is the best method to visualize the structure within the sinus tarsi, especially the interosseous and cervical ligaments.[2] The most distinct finding for individuals with STS is a bright signal seen on T2 weighted images found in the area for sinus tarsal adipose tissue as this represents an infiltration or replacement of this tissue with inflammatory cells and fibrotic tissue.[25,26] The MRI findings may also include alterations in the structure of the interosseous and cervical ligaments and degenerative changes in the subtalar joint.[2,25]

INTERVENTION

Recommendations for rehabilitation of STS include balance and proprioceptive training, muscle strengthening exercises, bracing, taping, and foot orthosis.[2,15,24] No random control trials for the efficacy of a rehabilitation program for STS are available. Instability of the talocrural joint or chronic ankle instability (CAI) is a similar and associated entity to subtalar joint instability and STS. Numerous studies of the effects of balance and proprioceptive training for CAI have been conducted, with improvements found in athletes' balance, joint position sense, and functional abilities.[27-29]

Athletes with STS have developed a chronic inflammatory process that results in a synovitis and inflammation of connective tissues and may benefit from a trial of non-steroidal anti-inflammatory medication to help control their symptoms and inflammation.[30] Cryotherapies, especially the use of ice massage over the lateral ankle, may also be useful for diminishing local inflammation and pain associated with this condition. Athletes with STS may have limited joint mobility at the talocrural and mid tarsal joints that can be addressed with specific joint mobilization techniques. Precautions should be made not to place excessive stress across the subtalar joint with these techniques. Muscular stiffness of the gastrocnemius, posterior tibialis, or peroneal muscles may also be found in athletes with STS, but stretching activities for these muscles should be carefully provided or avoided as excessive forces across the subtalar joint may be detrimental.[31]

Orthoses

Stability of the subtalar joint may be initially improved with the use of an orthosis.[32] Ankle braces intended for CAI may be useful for some athletes with STS, but the overall design of these braces may not significantly improve the stability of the subtalar joint during athletic activities. Foot orthosis have also been recommended as a method for limiting motion at the subtalar joint and reducing symptoms associated with STS.[33] The types of shoes the athlete is using for training, practices, and competition should also be considered, as well constructed shoes can restrict excessive rearfoot movements.[34]

General recommendations for shoes include those with a straight last, a firm heel counter, and rigid material through the midsole.[33] Shoes should also be assessed for wear, as materials within a shoe will be begin to break down before the external material show signs of deterioration. The use of a foot orthosis with an athletic shoe should be considered together, as the effect of an orthosis can be inconsistent.[35] An ongoing assessment of shoe and orthosis use is needed to provide adequate support of the foot and ankle throughout an athlete's cycle of training and competition.

Taping or strapping has also been used to specifically limit movements of the subtalar joint and the midfoot. Wilkerson et al[36] have described a taping procedure that combines a closed basket weave with a subtalar sling to control movements at the talocrural and subtalar joints. Viczenzio et al[37] have described a modified Low-Dye taping method that uses a calcaneal sling intended to provide support to the medial longitudinal arch of the foot *(Figure 3)*. This method could be used to control or reduce the amount of pronation through the subtalar joint during walking and running activities. Taping techniques have been used as a precursor for the use and selection of specific types of shoes and foot orthotics.[37]

Figure 3. *Taping for stabilizing the rearfoot. These taping methods can be used in addition to an closed ankle basket weave or a foot Low-Dye method. Figure on the top shows a calcaneal sling with a long strip to control rearfoot pronation, figure on the bottom shows heel lock strips to control rearfoot supination.*

Stability Training

Training programs to improve the stability of the subtalar joint and lower extremity function will be the hallmark of treatment plans for STS. Joint stability relies on passive joint structures, dynamic muscular responses, and neurological control. Because tears or ruptures of the interosseous and cervical ligaments of the subtalar joint are believed to be the essential lesions that lead to STS, the dynamic muscular responses and neurological control of the rearfoot will need to be emphasized to compensate for the loss of passive stability.[38,39]

The muscles that cross the subtalar joint are important for maintaining stability, as they act as force transducers to guide and control the pronation and supination motions of the subtalar joint. The relative strength of these muscles is important, but their reaction time to joint perturbations and the ability to work in a coordinated fashion is even more important for the rehabilitation of STS.[40,41] Dynamic stability will also rely on the proprioceptive information from the muscle spindles and Golgi tendon organs of these muscles to compensate for the lack of proprioceptive information from the stabilizing ligaments of the joint.[42] The endurance of the muscles will also be important to maintain stability during long bouts of exercise or sports activities.

Training programs to improve joint stability have been described as multiphase processes that start the athlete at an appropriate level of activity and progresses to higher levels of activities while maintaining joint stability.[40,42] To help the athlete understand this process the progression of three phases are called: Attain, Maintain, and Sustain. The Attain phase will determine postures or positions the athlete is able to attain in a stable fashion. The Maintain phase will develop coordinated isometric and eccentric muscle contractions of the muscles crossing the joint. The Sustain phase will involve integrating all of the neuromuscular subsystems needed for stability during sports specific activities *(Table 1)*.

The Attain phase for subtalar joint instability is usually started with the athlete in standing positions. Single leg standing, with the contralateral limb held in approximately 30 degrees of hip flexion and 90 degrees of knee flexion, will emphasize ankle balance strategies.[43] The clinician should closely observe the arch of the foot and rearfoot to assess the athlete's ability to attain a stable position for the subtalar joint while avoiding excessive pronation movements *(Figure 4)*. The Attain phase begins with the eyes open and attempting to hold the single leg position for 30 to 60 seconds with minimal alterations in body position. Once the athlete is able to hold a single leg standing position consistently, a progression to eyes closed conditions can be made.

Stage	Activities	Criteria for Progression
Attain	Single leg standing – Eyes open and closed	Athlete demonstrates ability to attain a stable position through the foot and ankle.
Maintain	Single leg standing – Hip swings, and Star pattern reaching. Heel raises, oscillation with theraband, and impulse with medicine ball.	Athlete demonstrates ability to maintain stability and good alignment through the lower extremities.
Sustain	Lunges and step down exercises Bilateral and single leg hops Forward and backward acceleration and deceleration Pivoting and cutting maneuvers	Athlete demonstrates the ability to tolerate loading and pushing-off the involved lower extremity.

Table 1: Progression through three stages of stability training.

The second phase, Maintain, is performed with perturbations to the single leg positions. Perturbation forces are imparted near the level of the athlete's center of gravity to replicate the type of forces that produce subtalar joint instability during athletic activities. The perturbating forces are intended to facilitate rapid isometric and eccentric contractions of the stabilizer muscles of the ankle.[42] Perturbations to standing balance are begun with movements from the contralateral hip starting in the sagittal and coronal planes of motion, progressing to transverse plane motions. Observations of the athlete's rearfoot and hip stability will indicate his/her ability to maintain this position. The clinician needs to insure that the athlete is not using excessive compensatory motions at the rearfoot or hip to maintain a single leg standing position.

Figure 4. *Foot held in an excessive pronated position.*

The star excursion balance test activities can also be used in this phase, with the athlete in the single leg standing position and touching different lines drawn on the floor in a star pattern.[27] Standing heel raises and lowering exercises can be performed at a slow speed in double leg and single leg standing. Emphasis is placed on promoting controlled concentric and eccentric muscle contraction of the ankle plantarflexors and subtalar joint pronator muscles.[24] External perturbations can be imparted with the athlete holding a two-foot length of theraband. With both hands in front of the umbilicus, the therapist can then pull on the theraband with oscillating motions. Catching and throwing a small ball or medicine ball while in single leg standing can also be used for perturbations in multiple directions and different timing.[40]

The Sustain phase will begin with the athlete learning to "close the chain" meaning moving from an open kinematic chain to a stable closed kinematic chain position. The emphasis is on developing the feedforward motor control of the lower extremities.[40] This activity can be started by having the athlete perform lunging steps and then stepping down from a 4 or 8 inch step onto the involved extremity into a single leg standing position. Progression can be to lateral lunge steps and lateral step downs. Observations of the athlete's overall control of motion through the lower extremities with an emphasis on alignment of the knee and foot will insure that excessive subtalar joint motion is not occurring.

Progressions of the Sustain phase can be performed with the athlete jumping or hopping in place and then into hopping in different directions. Running activities can begin by acceleration and deceleration with forward and backward motions. Athletes needing to perform pivoting or cutting maneuvers can begin these activities at a slow speed maintaining good alignment of the foot and leg and avoiding excessive motions through the rearfoot.

Return to play criteria is based on the athlete's ability to move in all directions and at appropriate speeds. Athletes performing cutting and jumping maneuvers on firm surfaces, such as basketball and volleyball players, should be returned to full activities over a period of days to insure their tolerance to these stressful maneuvers.[15,20] A progression of the athletic activities should be assessed with the athlete in his or her normal practice or competitive environment. The athlete's anterolateral ankle symptoms will need to be well controlled to insure that the return to competition will not create chronic inflammation of the sinus tarsi tissues.

Surgery

Athletes who fail a course of rehabilitation may need an arthroscopic exploration and reconstruction of the subtalar joint in order to return to their athletic pursuits. Arthroscopy of the subtalar joint has allowed for a more precise examination of the subtalar joint and the sinus tarsi. A synovectomy of the subtalar joint along with an arthrotomy of the subtalar joint can be used to remove chronic synovitis and arthrofibrosis that is commonly found in STS.[44] Surgical reconstructions of the cervical and interosseous ligaments are made by splitting the tendon of the peroneus brevis and routing the graft through bone tunnels made through the calcaneus and the talus.[2,18] Patients with instability of the talocrural and subtalar joints may require a tri-ligamentous reconstruction of the anterior talofibular, calcaneofibular, and cervical ligaments.[18] Patients who present with significant joint degeneration or continue to have persistent symptoms even after ligamentous reconstruction may require an arthodesis resulting in an isolated fusion of the subtalar joint.[45]

Athletes who have undergone ligamentous reconstructions will commonly be immobilized for a 6-week period, followed by a rehabilitation program to regain normal ankle mobility, strength, and balance. Return to athletic activities usually begins at 4 to 6 months post-operatively.[18] Common post-operative problems are transient loss of sensation of the lateral ankle and foot and persistent peroneal weakness.[3]

SUMMARY

Sinus tarsi syndrome is a condition of the ankle and foot that results from instability of the subtalar joint. Athletes with this condition typically have complaints of instability with functional activities and persistent anterolateral ankle discomfort. The joints of the ankle should be assessed for mobility and reproduction of feelings of instability and discomfort. Treatments for this condition will need to control the athlete's ankle discomfort and improve the overall stability of the foot and ankle. Therapists should design intervention plans based on the athlete's need for training and competition.

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NAJSPT

ORIGINAL RESEARCH

ACETABULAR LABRAL TEARS: DIAGNOSTIC ACCURACY OF CLINICAL EXAMINATION BY A PHYSICAL THERAPIST, ORTHOPAEDIC SURGEON, AND ORTHOPAEDIC RESIDENTS

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ABSTRACT

Background. Previous studies have shown military physical therapists (PT) to have comparable clinical diagnostic accuracy (CDA) and interobserver agreement to orthopaedic surgeons (OS). However, no studies have examined hip pathology or used intraoperative findings as the reference standard for diagnosis.

Objective. To compare the CDA of physical examination findings among a PT, an OS, and two surgical orthopaedic residents (ORs) for hip labral tears.

Methods. Thirty-six patients (15 males, 21 females) aged 18-47 (mean + SD, 31.4 + 8.1 years) with 37 symptomatic hips were enrolled in a prospective study and underwent a standardized clinical examination followed by hip arthroscopy. A PT, an OS, and two ORs independently performed history and examinations with the emphasis of diagnosis on the results of six special tests.

Results. Thirty-two of 37 individuals (86%) had labral tears to the hip at arthroscopy. Analysis of agreement between clinical diagnosis and intra-operative findings of a labral tear produced a CDA of 85.3% (29/34 correct) for the PT, 84.4% (27/32 correct) for the OS, and 80.0% (24/30 correct) for ORs. No significant difference in CDA occurred in comparing the PT, OS, and ORs.

Conclusions. Using arthroscopy as the reference standard, hip labral tears were clinically suspected with 80-85% accuracy. The clinical diagnostic accuracy of the PT, OS, and ORs was high with no significant difference between examiners. In this study, an experienced PT, an OS, and two ORs demonstrated similarly high diagnostic skills.

Key Words: diagnosis, physical exam, hip joint, labral tear, direct access.

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INTRODUCTION

United States Army physical therapists (PTs) have been practicing in orthopaedic management roles since the Vietnam War[1-3] and their primary role is to provide evaluation and treatment to alleviate or prevent physical impairments stemming from injury, pre-existing problems, or disease.[2,4,5] In their role as physician extenders, Army PTs can also gain privileges to evaluate patients without physician referral; order radiographs, bone scans, magnetic resonance imaging (MRI), and computed tomography scans; order certain lab tests; refer patients to medical specialty clinics; perform electromyographic and nerve conduction studies; restrict service members to their living quarters for up to 72 hours; restrict work and training for up to 30 days; and prescribe certain medications.[2,6-8] It is well documented that Army PTs have performed successfully as physician extenders in the evaluation and treatment of patients with neuromusculoskeletal dysfunction.[1,2,4,5,9-12] Further, evidence points towards minimal risk for negligent care when patients are evaluated and managed by PTs, through direct access or by referral.[13]

Diagnostic accuracy is fundamental to direct access providers. Previous studies in the military health care system have shown that PTs have comparable clinical diagnostic accuracy and interobserver agreement to orthopaedic surgeons (OSs) comparing MRI findings for multiple conditions or radiographs following patients with acute ankle sprains.[11,12] However, no research currently exists which prospectively compares the accuracy of diagnosis between PTs and OSs from a battery of clinical examination tests and compares it to the gold standard for orthopaedic diagnosis-intraoperative findings.

One condition for which limited evidence exists in the accuracy of the clinical examination is hip labral pathology. The acetabular labrum functions to both enhance joint stability and decrease contact stresses between the acetabular and femoral cartilage.[14,15] A patient with a labrum tear can be symptomatic and may require open or arthroscopic debridement, or possibly repair.[14,16-21]

Table 1 describes the clinical signs and symptoms of acetabular labral tears. An examiner would not rely on the finding of just one clinical item in isolation, but should use information gathered from the history, site of pain, mechanical symptoms, and physical examination to determine a diagnosis. Mechanisms of injury and risk factors noted in the literature include hip hyperabduction, twisting, falling, motor vehicle accidents, sports (especially those that require hip external rotation or hyperextension such as soccer, karate or ballet), a direct blow, or hip dislocation.[22] The anterior inguinal area is the most common site of pain in patients with labral pathology; this sign is highly sensitive and pain is typically rated as moderate to severe.[22] For mechanical symptoms, some patients with labral pathology report clicking, catching, or locking of the hip with motion, though the significance of these signs is questionable.[22] Currently, research has not demonstrated sufficient specificity of individual or clusters of clinical tests to confidently rule in a diagnosis of hip labral lesion; but high sensitivity of many tests allows a negative finding to increase confidence that a hip labral lesion is absent.[22] The decision, therefore, to perform hip arthroscopy on a patient suspected of having labral pathology is typically based on a number of factors to include patient history, conservative treatment results, clinical examination, magnetic resonance arthrography (MRA), and response to intra-articular injection of anesthetic. While the value of MRA and intra-articular injections in diagnosis has been shown, the accuracy of clinical examination tests in detecting labral tears is less well defined.[15,16,18,19,21-26]

TABLE 1. Clinical signs and symptoms of hip labral pathology.

History	Trauma, fall, twisting injury
Site of pain	Commonly anterior groin/inguinal, but can be in greater trochanter or buttocks region
Mechanical symptoms	Painful clicking, clunking, catching, locking, giving way
Physical exam	+ McCarthy sign + Internal rotation load/grind test + Fitzgerald test + Resisted straight leg raise (SLR) + Resisted SLR in external rotation - Eccentric hip flexion (patient controlled lowering) for iliopsoas tendon snapping

Physical therapists in orthopaedic and sports medicine practices manage patients with suspected hip labral tears and are trained to perform physical examinations using clinical tests shared by orthopaedics and physical therapy practice. It is important for a PT to determine how his or her clinical diagnostic accuracy (CDA) compares with an OS and ORs working in the same facility in order to diagnose, treat, or refer patients most appropriately during the conservative treatment phase. Therefore, the purpose of this study was to prospectively assess the CDA of physical examination findings for hip labral pathology among a PT, an OS, and ORs using arthroscopy as the definitive diagnosis. The hypothesis to be tested was that all providers would have similar CDAs.

METHODS

Subjects

Thirty-six consecutive military health care beneficiaries presenting to the orthopaedic sports medicine clinic at a tertiary military medical center with hip pain were recruited by ORs. All subjects provided informed consent to their participation and the rights of the subjects were protected as governed by the Clinical Investigation and Human Use Committees of the Department of Clinical Investigation at Walter Reed Army Medical Center. Subjects included active-duty military members or Department of Defense beneficiaries who were between 18-47 years of age and who were seeking treatment for hip pain refractory to conservative treatment. Subjects who were pregnant or with previous hip surgery were excluded. Subjects with a primary diagnosis of hip osteoarthritis, congenital hip pathology (i.e. dysplasia), avascular necrosis, or femoral neck stress fracture were also excluded.

Procedures

Before initiation of the study, a PT with 19 years of experience, two ORs (one with 4 years, one with 5 years surgery experience) and an OS (with 7 years experience as a fellowship-trained sports surgeon) who performed all hip arthroscopies participated in a 30 minute practice session to standardize the following clinical examination techniques: Thomas hip flexion-to-extension maneuver (aka McCarthy Sign), internal rotation load/grind, Fitzgerald Test, eccentric hip flexion, resisted straight leg raise (SLR), and resisted SLR in external rotation.

Patients were examined independently by the PT, one of two ORs, and the OS in varied order based on provider availability. Physical examinations were performed first and the results recorded prior to gathering clinical histories and radiographic findings. Each examiner was blinded to the results of the other providers. For the purposes of this study, the test was considered positive if the patient had one or more of these symptoms during the test: click, clunk, or pain in the groin region which reproduced their chief complaint. The final diagnosis was not algorithmically derived, instead the diagnosis was driven by clinical reasoning based on meaningful interpretation of all the factors (pain, location, mechanical symptoms) integrated across all six tests. A description of physical examination tests follows.

Thomas hip flexion-to-extension maneuver (aka McCarthy Sign)[17,20,21]

In supine, the subject fully flexed both hips *(Figure 1)*, then the examiner slowly and passively extended the subject's lower extremities with hips going into external rotation (ER) *(Figure 2A)*. This test was repeated, but with the subject's hip going into internal rotation (IR)*(Figure 2B)*.

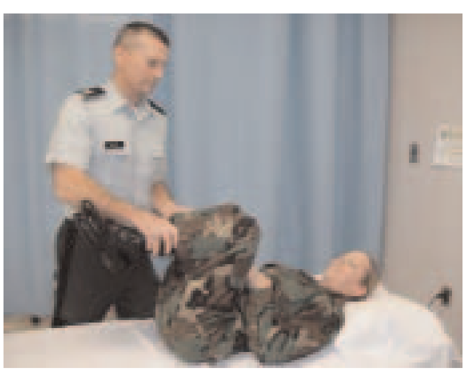

Figure 1. *Thomas hip flexion-to-extension maneuver (McCarthy Sign) starting position.*

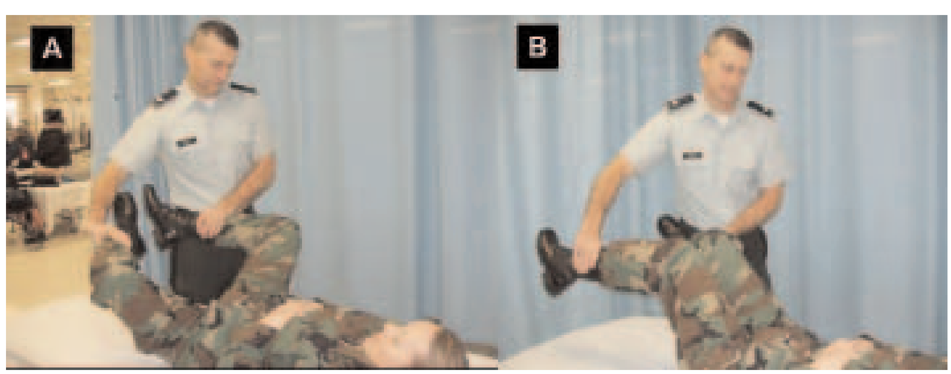

Figure 2. *Thomas hip flexion-to-extension maneuver (McCarthy Sign) going into external rotation and internal rotation.*

Sensitivity and specificity of this test has yet to be published.[22,27]

Internal rotation load/grind test
In supine, the examiner flexed the subject's hip passively to approximately 100 degrees and then rotated the subject's hip from IR to ER while pushing along the long axis of the femur through the knee to cause "grind" (axial compression of the femoral head in the acetabulum through knee) *(Figure 3)*. This movement mimics, and is very similar to, the flexion-internal rotation-axial compression test, which has a reported specificity of 0.43 and a sensitivity of 0.75.[28]

Fitzgerald Test[18]
To test the anterior labrum, the examiner started with the subject's hip in maximum flexion, ER, and full abduction *(Figure 4A)*; then extended the subject's hip while placing it into full IR, and adduction *(Figure 4B)*. To test the subject's posterior labrum, the examiner started with the subject's hip in maximum flexion, IR, and adduction *(Figure 5A)*; then extended the subject's hip while placing it into full ER and abduction *(Figure 5B)*. Sensitivity is reported to be 1.00.[18] For inter-rater reliability of the flexion-internal rotation-adduction-impingement test, which is described like the Fitzgerald test for anterior labral tears, Kappa was 0.58 with a 95% confidence interval of (0.29-0.87).[29]

Eccentric hip flexion (patient-controlled lowering)
While supine, the subject lifted the lower extremity into full hip flexion with knee extended, then slowly lowered the leg to the table, reporting any clicks, clunks, or pain. This test was used to identify possible iliopsoas tendon snapping.

Resisted SLR[21]
While supine, the subject actively raised the lower extremity to 30 degrees of hip flexion with the knee fully extended. The subject held the lower extremity while the examiner applied resistance to the ankle. The resisted SLR is thought to load the joint antero-superiorly and to cause anterior groin pain if an intra-articular lesion is present.[30] Sensitivity and specificity of this test has yet to be published.[22,27]

Figure 3. *Internal load/grind test. Axial compression is applied along the long axis of the femur while the hip is internally and external rotated.*

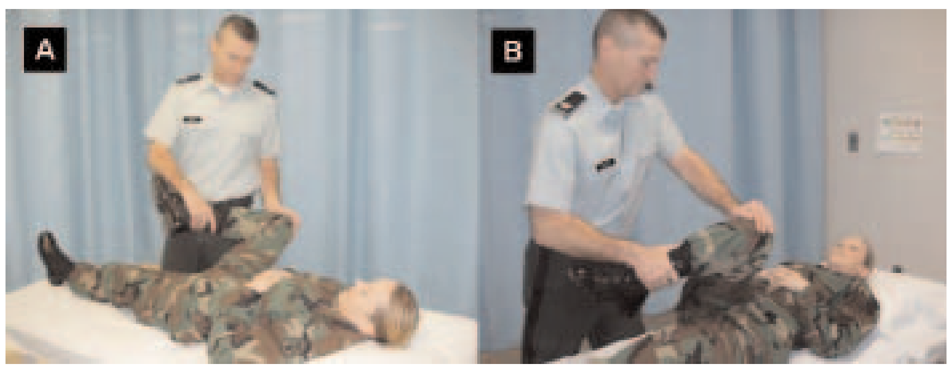

Figure 4. *Fitzgerald test for anterior labrum starting position mid-range position. The test is completed by then extending the hip from the mid-range position.*

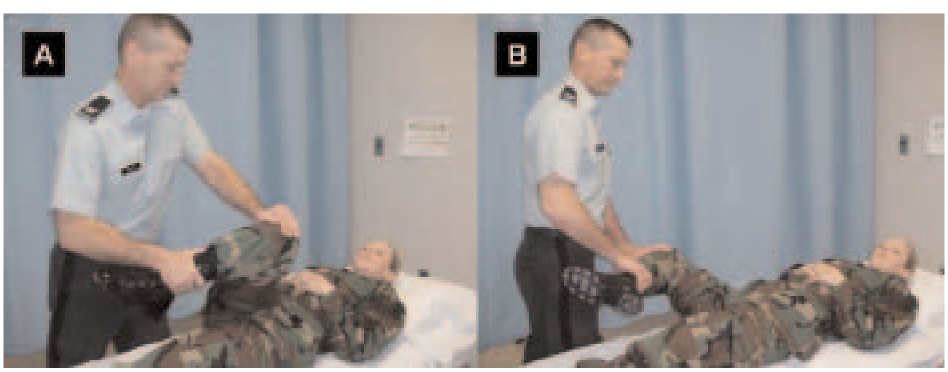

Figure 5. *Fitzgerald test for posterior labrum starting position mid-range position. The test is completed by then extending the hip from the mid-range position.*

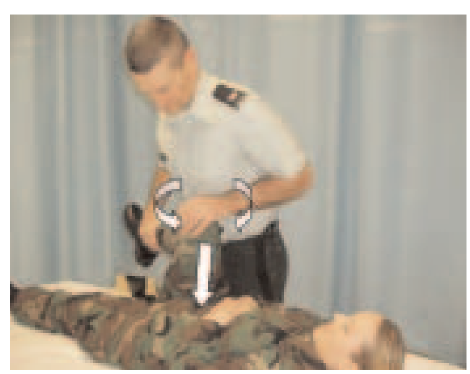

Figure 6. *The resisted straight leg raise test in external rotation.*

Resisted SLR in ER

The test was repeated, but subject's hip was in ER *(Figure 6)*. This test is thought to "wind up" the iliopsoas and place more tension at the labrum. Sensitivity and specificity of this test has yet to be published.[22,27]

Statistical Analysis

Descriptive statistics, frequency tables, and Cochran's Q test[31-32] (repeated measures test for dichotomous data with three or more independent variables- examiners in this case) were used to determine whether a PT could demonstrate a comparable degree of CDA with an OS and one of two ORs when conducting hip examination tests targeting labral pathology (alpha level set at $p < .05$). Clinical diagnostic accuracy has been used in a previous study[11] and is a ratio represented by the number of correct diagnoses as the numerator and the total number of diagnoses made as the denominator (number correct diagnoses/total number diagnoses).[33] The number of false negatives (condition in which the examiner diagnosed a subject without a tear but a tear existed) and false positives (condition in which the examiner diagnosed a subject with a tear but no tear existed) were also determined for each examiner. All statistics were performed with SPSS 9.0 for Windows (SPSS Inc., Chicago, IL).

RESULTS

Over an 18 month period, 36 patients (15 male and 21 females) aged 18-47 (mean 31.4 + SD 8.1 years) with 37 symptomatic hips were enrolled in this study. All 36 enrolled subjects completed the study. The PT, OS and ORs independently examined the patients, documented results of their clinical tests, and then made a diagnosis based on their findings. Table 2 shows the frequency of positive clinical findings among the examiners. Only one test (Fitzgerald test going into external rotation and abduction) showed a large variability between providers.

In this cohort, 34 patients had complete examination and diagnosis data by the PT, 32 patients by the OS, and 30 patients by the ORs. The ORs examined approximately 15 patients each. All 36 patients underwent hip arthroscopy, one bilaterally. Results from the hip arthroscopy provided the definitive diagnosis. Thirty-two of 37 subjects (86%) had acetabular labral tears at the hip confirmed at the hip during hip arthroscopy. Some subjects had multiple tears at the hip and the locations noted were: 11 tears located anterior, 21 anterior-superior, six superior, and one tear posterior-superior.

Analysis of agreement between clinical diagnosis and intra-operative findings of a labral tear produced a CDA of 85.3% (29/34) for the PT (five false positives), 84.4% (27/32) for the OS (five false positives), and 80.0% (24/30) for ORs (four false positives, two false negatives). No significant difference in CDA existed among all three examiners ($Q = 2.00$, $p = .999$). A remarkable observation was that the PT and OS each had five false positives which were on the same five patients.

TABLE 2. Percentage of positive clinical findings for the physical therapist (PT), orthopaedic surgeon (OS) and orthopaedic residents (ORs).

	PT n = 34	**OS** n = 32	**ORs** n = 30
Thomas maneuver (McCarthy Sign) in external rotation	83.8	75.7	67.6
Thomas maneuver (McCarthy Sign) in internal rotation	78.4	89.2	83.8
Full flexion internal rotation load/grind	89.4	97.3	81.1
Fitzgerald (into internal rotation and adduction)	89.2	62.2	75.7
Fitzgerald (into external rotation and abduction)	86.5	37.8	62.2
Eccentric hip flexion (controlled lowering)	45.9	54.1	54.1
Resisted straight leg raise	62.2	59.5	62.2
Resisted straight leg raise in external rotation	86.5	73.0	70.3

DISCUSSION

The findings from this study support the hypothesis regarding CDA by demonstrating that the PT, OS, and ORs practicing at a tertiary military medical center during the period of this study demonstrated a high degree of CDA on hip labral pathology diagnosis, confirmed with arthroscopy, for patients referred with hip pain. Though responses of individual tests during the clinical exam showed some variability between providers (i.e. Fitzgerald test), the overall interpretation of all clinical exam tests combined yielded very similar diagnoses. As a result, no significant difference occured in diagnostic accuracy between the PT, OS and ORs.

The results of this study are comparable to previously published literature. Other studies which have addressed PT clinical accuracy have found similar interobserver or CDA agreements.[11,12] Moore et al[11] conducted a retrospective review of 560 patients with musculoskeletal injuries referred for magnetic resonance imaging and compared CDA of PTs to OSs and non-orthopaedic providers. The authors reported no significant difference in CDA between PTs (74.5%; 108/145) and OSs (80.8%; 139/172) across a variety of orthopaedic conditions, though hip labral tears were not assessed. Physical therapists and OSs both showed significantly higher CDAs than non-orthopaedic providers (35.4%; 86/243). Therefore, the current study reinforces the diagnostic accuracy of PTs. Further, the present study design improves on the validity of these findings by overcoming two limitations Moore et al[11] describe: 1) the need for a prospective analysis of CDA, and 2) a reference standard based on surgical confirmation of the diagnosis.

The results are in agreement with previous literature on the diagnostic accuracy of Army PTs and their orthopaedic colleagues. The high agreement in exam findings and diagnosis translates into better consistency in management of orthopaedic-related conditions and ultimately benefits the patient and the medical system. The strength of the accuracy may be explained by several factors, some intrinsic to the Army physical therapy education, training, and credentialing model, and others related to the nature of the Army medical system.

The Army has always emphasized training physical therapists in strong orthopaedic evaluation skills to serve as physician extenders. Almost all Army PTs attend a postgraduate training course in which specialized skills including orthopaedic examination, advanced diagnostic imaging, and pharmacological management are emphasized. Additionally, as part of the process for PTs to become credentialed as neuromusculoskeletal evaluators, PTs will typically shadow physician colleagues in orthopaedics for up to a week at a time, and shadow radiologists and primary care physicians, as well.

The Army medical system further strengthens the evaluation skill sets of PTs by the close relationship in most facilities where PTs and OSs routinely see patients together in combined clinics to manage nonsurgical or perioperative conditions. Combined training is critical and greatly emphasized in a deployed theater, where the PT's role in managing the large volume of nonsurgical orthopaedic conditions frees the OS to concentrate on individuals with complicated trauma and surgical cases.

Limitations

The subjects enrolled in this study were all selected from a tertiary-level orthopaedic sports medicine clinic. Since this clinic is completely referral based, all patients presenting for evaluation would have been previously evaluated by a PT or physician. Further, the OS has developed a specialization in hip arthroscopy for the treatment of patients with labral pathology, which is known to the referring providers. As a result, this sample is biased towards hip labral pathology, as other etiologies for hip pain, which may indeed be more common, were typically excluded prior to final referral to the clinic. Therefore, it is not known how many people might have similar hip symptoms or complaints who were never referred to the clinic. A limitation known as "spectrum bias" could have occurred which could have improved the overall diagnostic accuracy by eliminating patients with conditions in which the physical examination tests assessed in this study are less discriminate. Results of this study may be different if the PT, OS, and ORs had evaluated the subjects in a general practice setting prior to any other evaluations and interventions.

Additionally, the use of arthroscopy as the gold standard reference in this study significantly improves validity, but at the consequence of furthering spectrum bias. Spectrum bias can cause an overestimation when diagnostic accuracy is studied in samples in which the vast majority of subjects have the disease in question. These studies tend to overstate the accuracy when applied to the general population. Regardless, this population bias effect would be expected to equally impact each of the examiners. Thus, spectrum bias may have artificially elevated the CDA; however, it should not have impacted the finding of equivalent CDA for PT, OS and ORs conducting physical exams of the subject's hip to detect labral tears.

Lastly, the use of a single PT, OS, and two ORs limits the generalizability of the findings. This limitation could have been overcome by having more than one of each type of provider perform examinations. While the external validity of our results may have improved, such a study was not practical in the present clinic setting.

Clinical Relevance

Army PTs frequently perform initial evaluations for a myriad of orthopaedic and sports injuries while serving in a physician extender role. Recent studies have shown the effectiveness of using Army PTs as primary neuromusculoskeletal screeners during peace and war, including during deployments to Operations Desert Shield and Storm, Bosnia, and Operation Iraqi Freedom.[9,10] This study provides further evidence that military PTs demonstrate competency in making sound, independent clinical judgments regarding the evaluation and management of patients with hip labral pathology.

Future Research

These findings warrant further studies to evaluate CDA between PTs and other health care providers in a variety of settings for the patients with the most common musculoskeletal conditions across the full spectrum of a disease or injury process. In addition, prospective studies involving PTs with varying levels of clinical experience, board certification, and fellowship training will provide important data to further conclusions regarding the abilities of PTs to manage patients in a direct access environment.

CONCLUSION

Using arthroscopy as the reference standard, hip labral tears in the subjects were clinically suspected with 80-85% accuracy among the examining clinicians. Clinical diagnostic accuracy of an experienced physical therapist, orthopaedic surgeon, and orthopaedic residents on patients with hip labral pathology was excellent with no significant difference among examiners. This study further strengthens the evidence that the use of Army PTs in the role of managing, evaluating, and treating patients with neuromusculoskeletal dysfunction is a successful model.

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