EVALUATING THE EFFECTS OF THE MULLIGAN CONCEPT MANUAL THERAPY IN AN ATHLETIC TRAINING PRACTICE: A DISSERTATION OF CLINICAL PRACTICE IMPROVEMENT

A Dissertation

Presented in Partial Fulfillment of the Requirements for the

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by

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AUTHORIZATION TO SUBMIT DISSERTATION

This dissertation of Robinetta A. Hudson, submitted for the degree of Doctor of Athletic Training with a Major in Athletic Training and titled "EVALUATING THE EFFECTS OF THE MULLIGAN CONCEPT MANUAL THERAPY IN AN ATHLETIC TRAINING PRACTICE: A DISSERTATION OF CLINICAL PRACTICE IMPROVEMENT," has been reviewed in final form. Permission, as indicated by the signatures and dates below, is now granted to submit final copies to the College of Graduate Studies for approval.

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ABSTRACT

The Dissertation of Clinical Practice Improvement (DoCPI) was designed to provide evidence of a Doctorate of Athletic Training (DAT) student's development in becoming an advanced scholarly practitioner. A DAT student attains advancement through reflection of patient outcomes and critical self-assessment of clinical competences, which are then applied in clinical research. Through this process, known as an action research philosophy, students are able to identify patterns within their clinic and apply treatment paradigms to solve local issues conducting practice based evidence (PBE). Within this comprehensive document, there are multiple original applied clinical research projects, indicating development of advanced practice. Additionally, a review of literature on the Mulligan Concept specific to mobilization with movement of the knee for meniscal tear symptoms is included to demonstrate a sound foundational knowledge in the specific area of focus. Finally, a multi-site research project, designed *a priori*, is included specifically to restore function and alleviate pain of patients with meniscal symptoms. The culmination of the works provided within this DOCPI will represent scholarly advanced practice of an athletic training clinician.

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CHAPTER 1

Narrative Summary

Athletic training educational programs started in the late 1950s and were based on a secondary schools' need for, improving healthcare for student-athletes as well as the entire student body through teaching (Delforge & Behnke, 1999). The curriculum for athletic trainers (ATs) has continued to grow and develop, moving away from the physical education/health teacher premise to patient-centered care. The National Athletic Trainers Association developed a core curriculum that was based around the foundational knowledge for an AT, and the American Medical Association recognized athletic trainers as allied healthcare professionals in the early 1990s, setting the stage for the advancement of athletic training (Deforge & Behnke, 1999). Traditionally, ATs were trained through a belief based philosophy, which lacked research and evidence, leading to a flawed educational system. (Myer, Kreiswirth, Kahanov, Martin, 2009). However, the profession recognized the need for developing scholarly works and treating patients based on research based evidence (Knight & Ingersoll, 1998). Acknowledging the beginnings of the athletic training profession gives direction to AT's in pursuit of advancing the profession and not regressing to the past or remaining stagnant.

The Doctor of Athletic Training (DAT) program was developed based on the recognized need to train AT's as scholars as well as advanced clinical practitioners with an evidence based foundation. An advanced scholarly practitioner may be defined as one having depth and expertise as a clinician and a researcher in all domains of athletic training, based on evidence. (Naspany, Seegmiller, & Baker, 2013). The DAT program was designed to capture qualities of a professional practice doctorate (PPD), and while all programs are unique, they share similar components: coursework, field work, professional research, and faculty who are practicing professionals (Willis, Inman, & Valenti, 2010). DAT graduates are well versed in advanced clinical practices and research, as well as educators in professional and post-professional athletic training programs. A PPD typically requires a dissertation, capstone project, or portfolio that compiles all the information obtained throughout the program, specifically relating to ones professional practice, which must be defended in order to show evidence of growth (Willis et. al, 2010). Within the DAT program, verification of becoming an advanced scholarly practitioner is completed through the completion of the Dissertation of Clinical Practice Improvement (DoCPI).

Each student within the DAT program has an individualized journey as he or she is introduced to a wide breadth of knowledge on a novice level; however, the individual must expound upon the depth of knowledge of a particular paradigm or concept. A DAT student selects their area of focus, through the use of paradigms in actual practice through practice-based evidence (PBE). Practice-based evidence is scientific evidence developed through real-world clinical practice, which helps clinicians decide which paradigm they will invest more time and effort. (Kryzanowicz, May, & Nasypany, 2014). Using evidence-based practice (EBP), which is based on the best available research and clinical expertise, in conjunction with PBE supports an evidence-centered practice, enhancing overall patient care (Kryzanowicz, May, & Nasypany, 2014), which is promoted by DAT faculty.

Using PBE and EBP allows ATs to disassociate from the belief based philosophy and identify with action research (AR), also known as participatory action research. Action research involves systematic inquiries performed by healthcare practitioners to assist in the improvement of individuals' practice (Koshy, Koshy, & Waterman 2010). Action research is collaborative in nature; individuals with a common purpose generate solutions for everyday problems, empowering practitioners by engaging them in research that is relatable (Meyer, 2000). Embracing an action research philosophy, DAT students create *a priori* designs for common or recurring problems (e.g., injuries) in clinical practice. Creating *a priori* designs early in the DAT program allows students to cycle through the stages of AR by observing, reflecting, planning, and implementing (Koshy et al., 2010). Doctoral students are encouraged to create case series or case studies, focusing on local problems, creating solutions, and disseminating information in a scholarly way.

Meaningful case studies/series are completed through the use of patient outcome measures. There are two distinct categories of outcome measures: patient-oriented evidence, which is patient focused (e.g., function, well-being), and disease-oriented evidence, which provides information about the pathology (e.g., body temperature) (Hurley, Denegar, & Hertel, 2011). In the traditional belief-based philosophy, decisions are made based on clinician perception without data, leading to a non-evidence based approach. Collecting patient outcomes with clinical meaningfulness in mind allows the practitioner and patient to choose the best treatment approach through reflection and objective data. In clinical practice, outcome measures are collected, and each patient outcome scale illustrates a different aspect that contributes to the patient's disability. Baseline (pretreatment) outcome measures are taken prior to the intervention and at appropriate intervals, allowing the patient and the clinician to review the effectiveness or ineffectiveness of the chosen intervention. Measures are then recorded at discharge (post-treatment) documenting the improvement or lack thereof. Through the collection of outcomes and critical reflection, a clinician is able to recognize clinical patterns. Patient outcome measures play a vital role in clinical reflection, contributing to the overall improvement of patient-centered care.

Merriam-Webster's dictionary defines *reflection* simply as careful thought. The DAT has facilitated my view of reflection and has manifested into more. Within my clinical practice and my personal life, I define *reflection* as purposeful and careful thought based on the chosen "lens" or guided viewpoint. Careful thought is a good starting point for reflection, but without purpose, the thought process may end far from where it began. Reflection is often thought to take place only after a situation; however, reflection can take place before, during, and after a situation. Reflection prior to an event has the advantage of having a learning objective in mind that can be challenged (Sanders, 2009). The thought of approaching a situation with prior reflection leads me to a quote by French microbiologist Louis Pasteur: "... chance favors only the prepared mind." Guided reflection through public forum discussions and open communication with professors and attending clinicians has served as an imperative aspect of my growth, challenging my beliefs and assumptions in my clinical practice. Being challenged has forced me to reevaluate my initial opinions and thoughtfully and/or scientifically defend my stance. Reflective clinical practice, meaningful case studies, and discussion amongst professionals in the allied health sciences result in scholarship.

Scholarship in one's profession is important because without scholarship there would be no advancements in knowledge (Knight & Ingersoll, 1998). Since athletic training is a fairly young profession, the need for scholarship is critical to aid in its promotion and refinement. The DAT faculty is dedicated to the development of scholarship in athletic training and demands every student contribute to the enhancement of the profession. Scholars are developed over time through practice and critical reflection. The idea of scholarship is fostered in the DAT by having students create multiple case studies/series, conduct multi-site research, document patient outcomes consistently and present innovative techniques (supported by outcomes) at national and local conferences.

Traditionally, athletic training programs focus on: immediate/emergency care, modalities and progressive resistive rehabilitation programs that may take 4 to 8 weeks to return an athlete back to competition level. The foundational knowledge provided in the traditional programs is a key component. However, advancing one's clinical practice is as equally important to avoid becoming stagnant in the profession and to better serve the patient population. The DAT introduced many paradigms, concepts, and techniques that produced immediate results in my clinical practice. The treatment paradigms used on a consistent basis in my clinical practice included: (a) the Mulligan Concept (MC)—joint mobilization with movement, (b) Total Motion Release (TMR)—regional interdependent manual therapy, (c) positional release therapy (PRT)—local manual medicine, (d) primal reflex release technique (PRRT)—manual therapy, (e) energy medicine (EM)—energy therapy, (f) reactive neuromuscular stabilization (RNS)—manual therapy, (g) breathing techniques—manual therapy and psychotherapy. These paradigms were introduced in a hands-on didactic manner, many followed up with workshops hosted by experts. The information was then transferred to clinical practice and reviewed through clinical outcome measures. I chose to increase my depth of knowledge by focusing on the MC early in the program, which is illustrated throughout my DoCPI. I used all the paradigms in my clinical practice with collected outcomes; however, the MC has proven to be an effective tool for solving many issues in my clinical practice.

In Chapter 2, a case study is presented, which is level 4, in the hierarchy of evidence (Hurley et al., 2011). Case studies provide a detailed description of a single case without any statistical comparison (Hurley et al., 2011). Case studies/series set the foundation to develop level 1 evidence, which includes well-designed randomized controlled trials (Hurley et al., 2011). The foundation is set by providing clinician-based methodology and results on unique cases that can be further researched using larger populations in controlled settings. The case study presented examined the effects of the MC shoulder mobilization with movement (MWM) coupled with reactive neuromuscular training (RNT) in a competitive adolescent football player who sustained an anterior shoulder subluxation. The case study is supported by global and shoulder specific patient outcome measures. The outcome measures identified improvement and assisted in return to play decision making. The results demonstrate the effectiveness of the coupled treatments in the reduction of pain, increased range of motion (ROM), and increased stability.

Chapter 3 contains a case series that investigated the effects of the MC ankle MWM for acute lateral sprains. Lateral ankle sprains (LASs) are common injuries in the athletic population and often result in significant time loss from sporting activity (Beynnon, Renström, Haugh, Uh & Barker, 2006). In this case series the lateral ankle MWM is theorized to treat a positional fault of the fibula, which can lead to pain and dysfunction of the joint (Mulligan, 2010).The case series presents statistical analysis of patient outcome measures identifying statistical and clinical meaningfulness. The positive results of this case series identify the need for further investigation on a larger population with controlled participant activity.

Chapter 4 provides an in-depth review of literature focusing on meniscal tears and the current standard of care, identifying a need for a nonoperative effective treatment. The review describes the epidemiology, pathoanatomics, physiology, classification of tears, clinical diagnosis of tears, outcome measures, instruments, surgical techniques, nonsurgical techniques, and theories of treatment. This chapter summarizes a large portion of the research surrounding the clinical diagnosis of meniscal tears, providing well-established data ranging from level 1 studies to peer-reviewed level 4 studies.

In the final chapter, I present the culmination research of my time in the DAT. Chapter 5 is a multi-site research project investigating the effect of the MC "Squeeze" technique in a symptomatic, physically active population that met the criteria for a clinical diagnosis of a meniscal tear. The research design was a quantitative randomized sham-controlled trial studying the immediate effects (within first treatment) and effects from intake to discharge of the intervention. The concluding results of my research demonstrate my ability and willingness to progress as an advanced practitioner in the profession of athletic training.

The following DoCPI is evidence of my growth as an advanced practitioner and as a scholar in the profession of athletic training. The overall focus of my DoCPI will demonstrate advanced clinical practice in joint mobilizations using the MC to improve patient care in athletic and general populations.

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CHAPTER 2

Applied Clinical Research: Case Study

Title

Treatment of Anterior Shoulder Subluxation Using the Mulligan Concept and Reflex Neuromuscular Stabilization: A Case Study.

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Abstract

Shoulder instability, which is a common issue among athletes who engage in contact sports, leads to recurrent *subluxations*, or partial dislocations of the shoulder. Young athletic patients generally respond poorly to the nonsurgical treatments for shoulder instability that are in use today. The purpose of this case study is to report the outcomes of the Mulligan Concept (MC) coupled with reflex neuromuscular stabilization (RNS) also known as reactive neuromuscular stabilization (RNT), as supported by patient outcome measures, in the treatment of an anterior shoulder subluxation injury sustained by a competitive adolescent football player. The results of this Level-4 case report demonstrate positive patient response to the coupled treatments and include a reduction in pain, an increase in range of motion (ROM) and improvement in stability.

Key Points

1. The Mulligan Concept can be effective in treating pain and limited range of motion in the shoulder.
2. Reflex neuromuscular stabilization can be effective in treating motor control dysfunction in the shoulder.

3. Coupling the Mulligan Concept and reflex neuromuscular stabilization can be effective in treating anterior shoulder instabilities.

Key words: Instability, Mobilization with Movement, Muscle Patterns, Nonsurgical Treatment

Introduction

The shoulder is one of the most mobile joints in the human body, which predisposes it to pathologic instability and contributes to its status as one of the most frequently dislocated/subluxed joints in the body.[1] Instability is a common contributing factor to anterior shoulder subluxations and dislocations in adolescents.[2] *Dislocation* has been defined as requiring manual reduction of the shoulder joint; while *subluxation* has been defined as the joint slipping or popping out of its socket, but returning to the appropriate position without manual assistance, requiring the athlete's removal from activity.[3] The most common shoulder injuries vary, depending on the age group and level of activity; however, anterior instabilities leading to subluxations account for 20% of all shoulder injuries sustained by athletes who engage in contact/collision sports.[4]

Thus, shoulder instability leading to recurrent subluxations is a common problem among collision/contact athletes.[4] Typically, shoulder instability is diagnosed through patient history, observation, palpation, manual muscle testing, and orthopedic tests specific to laxity and instability.[5] The orthopedic testing battery commonly includes a load and shift test (laxity), an apprehension test (instability), and a relocation test (instability).[6] Magnetic Resonance Imaging (MRI), through which diagnostic confirmation is typically made, is considered the gold standard for determining instabilities of the shoulder, because it provides details of laxity in the surrounding soft tissues.[7]

Traditional conservative treatment for shoulder instability consists of strengthening the scapular, glenohumeral, scapulothoracic, and rotator cuff muscles, as well as conducting proprioceptive exercises as part of an 8-week daily rehabilitation program.[5] Traditional treatment exercises are progressive and dependent upon each individual patient's case, but typically, have common components (Table 1).[5, 8] The use of conservative, nonsurgical treatments has resulted in poor outcomes and a high recurrence rate of subluxations/dislocations in adolescent-age patients.[4,9]

The surgical options for recurrent anterior shoulder dislocation generally include either an open or an arthroscopic Bankart procedure. Open Bankart repairs yield a 0 – 10% recurrence rate[10-12] and arthroscopic Bankart procedures yield about a 15% recurrence rate.[10] Despite the low recurrence rates, surgical treatments are not without risks and complications. Open Bankart repairs have a much slower recovery of muscle strength (specifically in regards to forward flexion) than do arthroscopic repairs.[10,11] Open Bankart repairs also require an increased hospitalization time compared to that which is required by arthroscopic treatment.[13] Moreover, there is a 31% post-operative dislocation rate in adolescents who are treated with surgery.[7] These outcomes indicate a need for further research into non-operative treatments and improved post-surgical rehabilitation.

In theory, the Mulligan Concept (MC) and reflex neuromuscular stabilization (RNS) also known as reactive neuromuscular training (RNT) are viable treatments for shoulder instability. The Mulligan Concept is a treatment that is theorized to correct a positional fault through pain-free mobilizations with movement (MWM).[14] Resolution of the patient's symptoms during the MWM guides the clinician in treatment application.[14] The positional fault, described by Brian Mulligan as a mal-alignment due to injury, could theoretically result from an anterior subluxation (macro trauma), repeated collisions (e.g., tackles [micro trauma]), muscle imbalance , or poor arthrokinematics.[14] A positional fault can lead to pain, decrease in range of motion (ROM), decrease in strength and overall joint dysfunction, which may, in turn, lead to deficits in motor control.[14, 15] It could also be theorized that the origin of pain associated with a shoulder positional fault is the result of compression on the nerve supply of the glenohumeral joint (GHJ) capsule, which is highly innervated with pain receptors.[16]

Reactive neuromuscular training/reflex neuromuscular stabilization is a treatment that is posited to restore proper muscle movement patterns (motor control) so joint stability can be reestablished and functional ability enhanced.[17] Reactive neuromuscular training facilitates motor responses through the unconscious process of integrating and interpreting the peripheral sensations received by the central nervous system (CNS).[17,18] The treatment term is transiting from RNT to RNS because the treatment is reflexive in nature and does not require progression or long-term treatment, which is inferred by the word “training.” As it relates to the shoulder, perception of the joint movement/position is essential for upper limb function and cannot be accomplished without feedback from the mechanoreceptors and central programming from the motor cortex.[18] Stimulating the joint and muscle mechanoreceptors promotes maximal discharge to the appropriate CNS levels.[16,18] The musculotendinous mechanoreceptors of the GHJ are primarily located within the supraspinatus, infraspinatus and pectoralis minor muscle insertions.[16]

Reflex neuromuscular stabilization is accomplished by applying a light external load to amplify the dysfunctional movement, causing the patient to reactively correct the dysfunctional movement pattern.[17] It is important to note that RNS is often performed at the end of a patient's treatment session to "groove" (i.e., make reflexive) a healthy motor pattern during fatigue/weariness, as well ensure proper proprioceptive control with increased ROM. Quality of movement during fatigue is important, especially in an athletic population where many sport specific repetitions are normally required.[18] No definitive evidence exists to suggest when RNS should be used in a rehabilitation protocol, but clinical reasoning dictates that fatigue be addressed during rehabilitation.[18] The ultimate goal of treatment is to restore normal pain-free ROM with quality movements (i.e. motor control), following a treatment session.

An optimal rehabilitation program for shoulder instability contains an assessment and correction of muscle pattern dysfunction as well as faulty postures.[5] All components are significantly important to maximize treatment. Successfully treating a faulty posture without addressing a muscle pattern dysfunction could inhibit return-to-play or leave the patient more susceptible to repeated injury. Both the MC and RNS theoretically address these imperative components. Notably, a patient that is responsive to this coupled treatment may potentially avoid or delay surgery as well as avoid a lengthy traditional rehabilitation protocol. The purpose of this case study was to investigate the effects of the MC and RNS on an adolescent football player with shoulder instability who suffered an anterior subluxation.

Methods

Participant

The patient, a 17-year-old male, high school football player (running back and linebacker) had a history of diagnosed multidirectional instability (MDI) in both shoulders. He suffered with chronic subluxation of his left shoulder and completed post-surgical rehabilitation for a posterior labrum tear approximately 8 months prior to sustaining the injury to his right shoulder. The patient had also completed 8 weeks of prescribed progressive resistive exercises with a physical therapist prior to injuring his right shoulder (therapy was for diagnosed MDI). The patient was cleared to fully participate in his sport following this therapy, but he participated during competitions using a dual shoulder support (SB05 Dual Shoulder brace). Approximately 6 weeks after completing rehabilitation, the patient suffered a traumatic anterior subluxation while performing a tackle during a football game and was unable to continue to participate in that game after the injury. In addition to agreeing to participate in this case study, the patient and his guardians provided written, informed assent/consent.

Examination

Upon a field examination, obvious deformity and life threatening injuries were ruled out. The patient presented with 2/5 grip strength, limited and painful ROM in flexion and extension (not measured on the field), and 9/10 current pain rated on the numerical pain rating scale (NPRS). The remainder of the field exam was within normal limits (e.g., positive apprehension test, normal dermatome assessment, strong distal pulse) and consistent with a shoulder anterior subluxation. The patient was immobilized in a sling for comfort and was referred for a radiograph. The radiograph was negative for fractures; the treating physician diagnosed the patient with general shoulder pain from an anterior subluxation, for which he prescribed compression, ice, and Motrin®. The physician also recommended an MRI to rule out further structural damage. The patient decided to delay further diagnostic imaging until after the season was over (6 remaining weeks) and was returned to the care of his athletic trainer (AT) for re-evaluation and treatment until the completion of the season, with a directive of "participation as pain tolerated."

During the re-examination by the AT (2 days after subluxation), the patient reported that he had rested throughout the weekend and had experienced pain and difficulty performing overhead activities (e.g., washing hair). Observation and palpation of the bony structures and soft tissues in the shoulder were found to be normal, and no other symptoms were reported. During the clinical examination, the patient presented with pain in his shoulder at the end-range of forward flexion (5/10) and pain/limitation in abduction (170°; 6/10; Table 2). All other motions were pain-free and comparable to the opposite side. Grip strength (5/5) was also comparable to the opposite side. The patient's load and shift test was positive, his apprehension test was positive, and his relocation test was positive (reaffirming the apprehension test). The initial scores of the outcome measures were 5/10 on the NPRS (current), 4/10 on the patient specific functional scale (PSFS), 47/64 on the disablement in the physically active (DPA) scale, and 40%/100% on the shoulder pain and disability index (SPADI). The clinical diagnosis was "anterior shoulder instability with painful and limited ROM."

Outcome Scales

The patient outcome scales that were used in this case study included the following: (a) the NPRS (collected at intake, pre/post treatment, and at discharge), which is a valid and reliable pain scale that is used to assess the patient's pain (0 = no pain, 10 = extreme pain); [19] (b) PSFS (collected at intake, pre/post treatment, and at discharge), which is a valid and reliable scale that is used to assess the patient's function (0 = unable to perform, 10 = performs without problem);[20] (c) DPA (collected at intake, treatment-4, and at discharge), which is a valid and reliable scale that is used to assess disablement over four dimensions: impairment, functional limitation, disability, and quality of life (0 = no disability, 64 =

maximum disability);[21] and (d) SPADI (collected at intake and at discharge), which is a valid and reliable scale that is used to assess pain and disability due to musculoskeletal pathology (0 = best, 100 = worst).[22] Goniometric measurement was used to measure ROM at intake pre/post treatment and at discharge. Discharge criteria consisted of full, pain-free ROM; an NPRS average of 1 or less; and a PSFS of 9 or higher.

Intervention

The patient was treated with a MC shoulder MWM, first: The clinician applied a belt-assisted shoulder abduction MWM, with the clinician standing behind the seated patient. The glide consisted of a posterior, lateral, inferiorly directed force on the humeral head, which was provided through the belt while the patient performed humeral abduction and the clinician applied overpressure at his end ROM[14] (Figure 1). The belt was wrapped around the clinician's hips and the patient's shoulder [mobilization was applied by the clinician, who moved her hips away from patient (Figure 1)], allowing the humeral head to glide in an oblique and slightly inferior direction.[14] Throughout the MWM, the clinician supported the belt position (on the patient's shoulder; Figure 2) with one hand and applied a stabilizing force to the scapula of the patient with the opposite hand (Figure 1). Following the MC guidelines, the patient reported being completely pain-free throughout the treatment. The belt-assisted shoulder abduction MWM consisted of 3 sets of 10 repetitions.

Reflex neuromuscular stabilization was performed immediately following the MWM treatment. While both the patient (eyes closed) and clinician were in a standing position, the clinician used her fingertips to provide a light, anterior-to-posterior force on the patient's sternum, with the verbal cue "do not let me move you" (Figure 3; two sets of 10). As the patient reactively resisted the force from the clinician, he also abducted the shoulder. Based on the RNS principles the force should have been from posterior-to-anterior at the glenohumeral joint (exaggerating or "feeding" the dysfunction), however the patient was apprehensive and reported discomfort with hand placement. The clinician moved away from the shoulder and direction of discomfort resolving apprehension, and also remaining pain-free. The RNS modification used in this case series may have been successful because of a core stability motor control dysfunction in the patient. Two sets of 10 repetitions were completed every treatment session (all repetitions were pain-free while the clinician applied the force). After the first treatment session, the patient was instructed to employ *kinesthetic imagery*, which refers to the human ability to use the imagination to sense the position and movement of the body, while abducting his shoulder.[23] During imagery, the patient was directed to focus on the muscles he felt being used during the light force (as if the clinician force was present), while simultaneously abducting his shoulder. This was performed to continue the process of making the motor pattern reflexive.

The patient received 6 treatments over 19 days and continued to play football competitively throughout the entire rehabilitation process. He would also ice sporadically after practices and consistently after games and reported using Motrin® during the first week of treatments. Each treatment took place a minimum of 24 hours after the previous treatment session.

Results

The patient obtained 180 degrees of pain-free shoulder abduction after the first treatment session. The PSFS activity (catching an overhead pass) was tested after the first visit, and the patient reported no discomfort (9/10). All pain with forward flexion was resolved with treatment of the abduction, using both MWMs and RNS (Table 2). Treatments

2 and 3 remained consistent with the first treatment; however, during RNS, the second set was performed using kinaesthetic imagery, alone. During the fourth treatment, the MC was applied in the same manner as during the previous treatments, but RNS was applied by pushing on the sternum for the first repetition in the set and kinaesthetic imagery was used during the remainder of repetitions. Prior to Treatment 5, however, the patient reported taking a hard tackle and feeling unsure of whether or not his shoulder had again subluxed; but he did report an increase in pain (Table 2). Treatment was continued without modification at the next session, and the patient's reported pain dissolved post-treatment (Table 2). During the final treatment, the patient reported resolved (0/10) pain with all shoulder movements (Table 2).

Minimal clinically important differences (MCIDs) were reported in 3 patient outcome scales: NPRS, PSFS, and the DPA scale (Table 2).[19-21] The patient was taped in a manner that supported the treatment glide prior to each football game, and he also wore a dual shoulder support brace. He performed in 2 games (playing defense and offense) during treatment and used ice for 10-15 minutes after every game. The patient completed the remainder of the football season (3 games, 28 days) without the need of further therapy. However, after discussion with his personal physician and guardians, the patient decided that, following the conclusion of the season, he would undergo arthroscopic repair of a Bankart lesion that had been found on his MRI.

Discussion

Prior to treatment, the patient lacked 10 degrees of shoulder abduction, and motion was painful after 90 degrees of forward flexion and abduction. Traditional, non-operative treatment for an anterior subluxation with limited movement would involve 8 weeks of strengthening the surrounding muscles of the shoulder and forcing ROM through active and passive stretching.[5] The MC technique, coupled with RNS, provided immediate relief of all of the patient's pain and increased ROM after the first treatment, which is a result that is not documented in any literature that discusses traditional progressive resistance exercises. Furthermore, the patient was cleared to return to a collision sport within 4 days of a traumatic subluxation with full ROM and strength in the upper extremity when compared bilaterally. Time-loss from competition/sporting activity was reduced drastically, compared to surgery and traditional rehabilitation. After the full course of treatment, the patient was able to continue to participate in his sport throughout the entire season without subsequent injury or the need for further treatment.

In patients who have shoulder instability or a history of anterior shoulder subluxation, coupling the MC and RNS may be an effective treatment in lieu of, or adjunct to a traditional exercise program. Even though current literature indicates that surgery is the optimal treatment in young athletes who participate in contact sports and have a shoulder instability leading to recurrent subuxlations,[4] the patient must: (a) recover from the effects of anesthesia, (b) experience a delayed return of muscle strength (especially with an open repair), and (c) partake in a lengthy rehabilitation process. [8, 10, 13] Therefore, the consideration of the discussed non-operative treatment is essential.

The outcomes in this case report provide some evidence that utilizing MWMs and RNS may assist in returning an athlete to competition following a shoulder subluxation, even when working with a collision/contact athlete. The combined therapy may produce rapid changes in pain, ROM, and shoulder function. Despite the positive outcomes in this case report, further research on the combined use of the MC and RNS is needed to determine the effects of the treatment. Additionally, this case study was a single, short-term patient case, without controlled activity, with a patient who elected to have surgery to repair a Bankart lesion. More research is needed to determine long-term effects of the intervention as well as its potential for reducing the need for surgical repair in certain patient cases. Given the limited risks of performing MWMs and RNS, clinicians can utilize the outcomes in this case to guide the inclusion of their techniques into their patient care.

Conclusion

The results of the treatment used in this case study, with the addition of taping and bracing the patient prior to each football game, produced immediate results and were maintained for 4 weeks after the conclusion of rehabilitation. The MC coupled with RNS could be considered in the treatment of anterior shoulder subluxation, assuming the clinician follows the treatment recommendations (e.g., indications, contraindications) of each treatment paradigm. This case study identifies positive results following the use of the MC and RNS in a case of unilateral shoulder instability.

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Table 2.1: Progressive Resistive Exercise

Anterior Shoulder Instability – Traditional Rehab	Phase 1	Phase 2	Phase 3
Each phase must be mastered prior to advancing to the next phase.			
Pain w/restricted ROM	Modalities for pain/PROM & AROM	Isometric →Eccentric →Plyometric/Proprioceptive Exercises	Sport-Specific Drills → Full Contact
Pain w/full ROM	Modalities for pain/AROM/Isometric Exercises	Eccentric→Plyometric/Proprioceptive Exercises	Sport-Specific Drills → Full Contact
No pain	Isometric /AROM/Proprioceptive Exercises	Eccentric→Plyometric/Proprioceptive Exercises	Sport-Specific Drills → Full Contact

PROM = Passive ROM
AROM = Active ROM
→ = Progression

Table 2.2: Pre/Post Treatment (Trt.) Outcome Measures

	Trt. 1		Trt. 2		Trt. 3		Trt. 4		Trt. 5		Trt. 6		Discharge
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	No Treatment
NPRS (current)*	5	0*	3	0*	1	0	0	0	6	0*	0	0	0
PSFS*	4+	9*	7	9*	8	10	9	10	4+	9*	9	10	10
DPA Scale*	47	N/A	N/A	N/A	N/A	N/A	12*	N/A	N/A	N/A	N/A	N/A	0*
SPADI	40%	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1.5%
Abduction	170°+	180°	180°	180°	180°	180°	180°	180°	180° +	180°	180°	180°	180°
Forward Flexion	180°+	180°	180°	180°	180°	180°	180°	180°	180°	180°	180°	180°	180°

+ = *pain*
*MCID met or exceeded

Figure 2.1: Belted shoulder abduction w/mobilzation.

Figure 2.2: Hand position supporting mobilization belt.

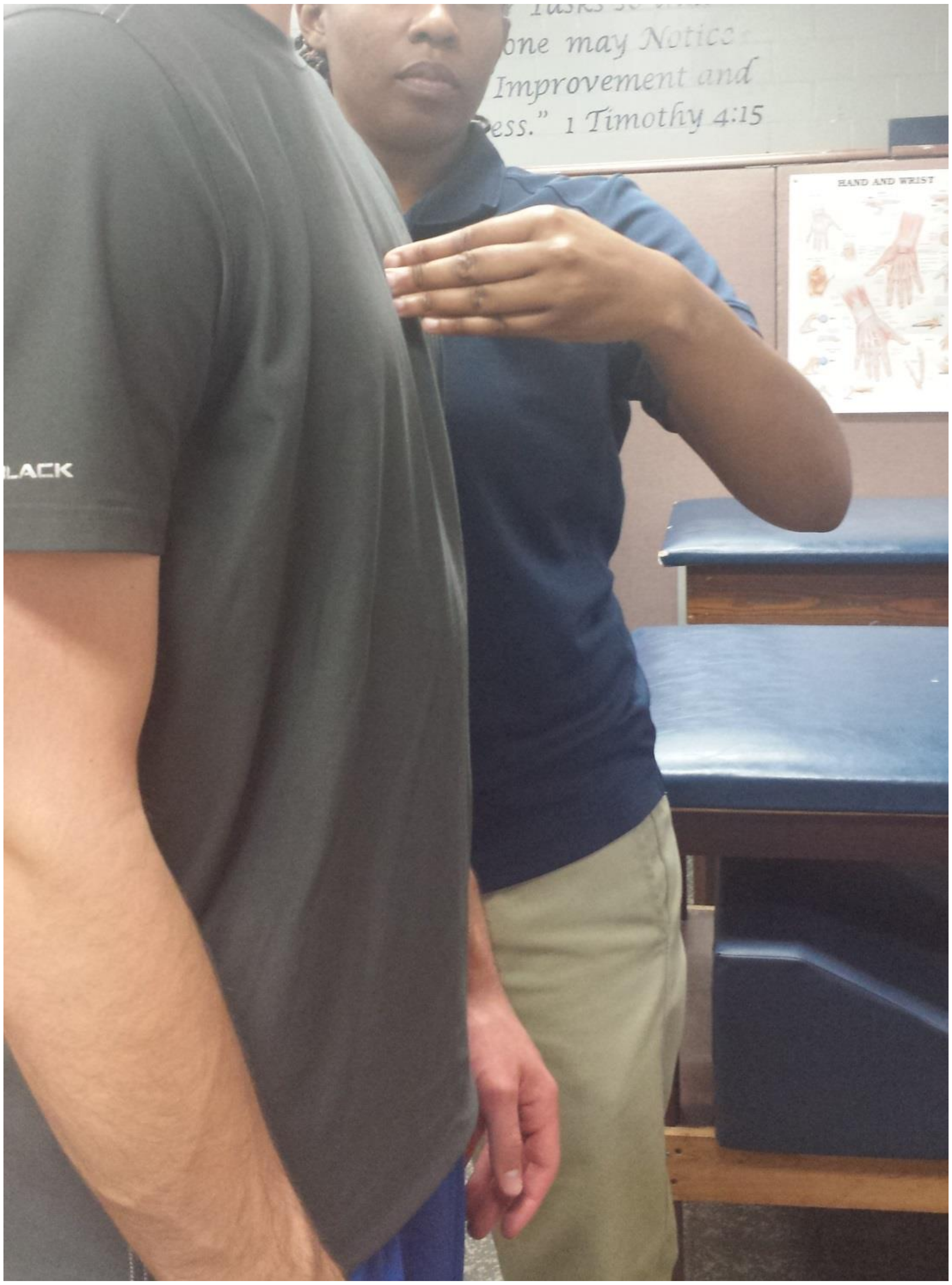

Figure 2.3: Hand position for reactive neuromuscular training (RNS).

CHAPTER 3

Applied Clinical Research: Case Series

Title

Novel Treatment of Lateral Ankle Sprains: An Exploratory Case Series Analysis

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Abstract

Objective: The purpose of this study was to examine the effect of the Mulligan Concept MWM in the treatment of clinically diagnosed acute lateral ankle sprains in competitive athletes.

Methods: A prospective case series of 5 adolescent patients, ages ranging from 14-18 years (mean = 15.8± 1.64), that suffered a lateral ankle sprain (LAS). Patients were treated with the Mulligan Concept lateral ankle mobilization with movement (MWM). Mobilization was directed at the distal fibula or, using a modified MWM, 2-3 inches proximal to the distal fibula.

Results: Treatment lasted an average of 9 days (mean = 9.2, ± SD 3.96) from intake to discharge. During that time frame, patients reported decreases in pain on the numeric pain rating scale (NRS), disability on the Disablement in the Physically Active (DPA) scale and an increase in function on the patient-specific functional scale (PSFS); and an immediate decrease in pain on the NRS within the first treatment. Minimally clinical important differences (MCID) were reported on all outcome measures.

Conclusion: The evidence presented in this case series supports the use of the MC lateral ankle MWM to treat patients diagnosed with acute grade II LAS. Patients in this case series reported immediate decreases in pain and immediate increases in function.

Key Words: Lateral Ankle Sprain (LAS), manual therapy, conservative care, mobilization with movement (MWM).

Introduction

Inversion ankle sprains are one of the most common injuries reported in the physically active population.[1] The National Collegiate Athletic Association (NCAA) conducted a 16 year observational study where up to 70% of all injuries affect the lower extremity, with ankle injuries as one of the most prevalent injuries, particularly identified in men and women's basketball and soccer.[2-5] Injuries to the ankle was the most common injury in all of the 15 sports observed.[3] Ankle sprains are generally known to have a high occurrence rate in individuals under 35 years of age who participate in athletic and sporting events (e.g., basketball, soccer, football, running, or dance).[7, 8]

The most commonly described mechanism of injury of the ankle is a combination of a plantar-flexed (PF) foot with supination and adduction (inversion) of the foot[9] resulting in possible disruption of the lateral ligaments of the ankle,[9] which includes the anterior talofibular ligament (ATFL), calcaneofibular ligament (CFL), and posterior talofibular ligament (PTFL).[10] The lateral ankle sprain is classified/graded based on severity. There are many classification systems, most based on the number of ligaments involved in the injury.[12] However, a major shortcoming to the ligamentous grading process is that, unless the injury is treated with surgical intervention, there is no objective data allowing determination of damage to each ligament.[12] A 3-category classification system including classic signs and symptoms of a LAS included the following objectives: decreased range of motion (function), extent of edema, tenderness (pain), and joint stability[1] (Table 1), which are pertinent in the classification of acute LAS.[13]

A history of ankle sprains is a common predisposing factor for the occurrence of an ankle sprain;[11] and without adequate treatment, ankle injuries may progress into chronic ankle instability (CAI), which can lead to further injury of the joint.[7] Further, many active individuals view ankle sprains as an inconsequential injury, thus up to 55% of the athletic population does not seek professional treatment following an ankle sprain.[14] Neglecting proper treatment often leads to repetitive ankle injuries (an indicator of CAI), ligamentous disruption, neurophysiological changes, and alteration in both ankle osteokinematic and arthrokinematic function.[15-17] Moreover, mechanical or structural alterations at the ankle joint lead to changes in joint loads potentially leading to CAI.[17] Chronic ankle instability is typically associated with recurrent swelling, feeling of "giving out", and chronic pain.[18] The long-term effects of CAI can include posttraumatic ankle osteoarthritis and articular degeneration.[19,20] Chronic ankle instability could possibly become a widespread condition, due to the lack of significance placed on the care and treatment of ankle injuries.

In contrast, a growing trend is becoming more accepted that the LAS mechanism is thought to create minor displacement or positional fault at the distal fibula and tibia complex. During the LAS mechanism of injury, the fibula is theorized to be subluxed anteriorly, causing a positional fault (arthrokinematic change) of the fibula at the talocrural joint.[21,22] In several studies, the presence of a distal fibular positional fault has been confirmed to have a direct relationship with lateral ankle instability and CAI.[15,16,23,24] The Mulligan Concept (MC) mobilization with movement (MWM) is a treatment paradigm theorized to correct positional faults and reduce patient reported pain and dysfunction.[21] A MWM is a pain-free sustained accessory glide applied at a joint, with active and/or passive movement (important for the clinician to be familiar with arthrokinematics of the joint). While pain-free, the MC MWM is expected to provide immediate and long-lasting effects of decreased pain, increased range of motion, and increased function, referred to as the PILL effect.[21] The PILL effect is one of the core principles of the MC and an indication of proper treatment. If the PILL effect is not elicited after technique fine tuning (e.g., change in angle or intensity of MWM) the MC technique is considered a contraindication for continued treatment.[21] Mulligan concept taping techniques are often used in conjunction with therapy to reinforce the PILL effect, by taping the joint while matching the direction of the pain-free MWM.

The current management standards of LAS, based on severity, include various rehabilitation and treatment techniques, such as rigid immobilization (e.g., a cast), functional immobilization (e.g., a brace), progressive resistive exercise (PRE), and/or surgery coupled with modalities for pain relief.[1,25] The National Athletic Trainer's Association Position Statement: Conservative Management and Prevention of Ankle Sprains in Athletes recommends early use of modalities and mobilization techniques to treat grades I and II LAS.[26] Also, multiple research studies provide evidence supporting the use of MWMs in the treatment of LAS.[13, 15-17] While early mobilizations are recommended,[13] there is a paucity of literature supporting the efficacy of the MC MWM to treat patient classified with grade I and II acute LAS. The purpose of this case series was to examine the effect of the Mulligan Concept MWM in the treatment of clinically diagnosed acute lateral ankle sprains in competitive athletes.

Methods

Participants

Five patients, whose ages range from 14 – 18 years (mean age = 15.8, standard deviation (SD) ± 1.64 years; males = 4, females = 1) presented to the athletic training clinic, reporting acute pain at the lateral ankle, meeting the criteria for this study (Table 2). Each patient was evaluated in the same manner to determine eligibility for inclusion: a detailed history, observation, palpation, orthopedic tests[26] and Ottawa Ankle Rules.[27] For the purpose of this case series, an *acute* injury was defined as an injury that was sustained within 72 hours of initial evaluation. The study protocol was approved by the school's committee on human research, and all patients received parental informed consent and provided assent. Patients were excluded from the study if they had any current evidence of a fracture in the lower limbs, and/or any open wounds in the area of treatment. Patients 101 and 104 both received radiographic imaging ruling out fractures prior to clinical assessment and treatment (Patient 101 & 104 received imaging based on parental concern). All patients were classified with a Grade-II sprain (Table 3).

Outcome Measures

Patient outcome measures were collected prior to the treatment intervention and used to identify progress, regression and treatment effects. The outcome measures included in this case series quantify pain, function and disablement. The Numeric Pain Rating Scale (NRS) and the Patient Specific Functional Scale (PSFS), was collected during intake, pre/post treatment, and at discharge. The Disability in the Physically Active (DPA) Scale, was collected during intake, at the fourth treatment, and at discharge.

- **NRS.** The Numerical Rating Scale (NRS) is a valid scale used to assess the patient's pain (0 = no pain, 10 = extreme pain).[28] The minimally clinical important difference (MCID) for the NRS is regularly reported as a 2 point or 30% change.[28]
- **PSFS.** The patient specific functional scale (PSFS) is a valid scale used to assess the patient's perception of function (0 = unable to perform, 10 = performs without issue).[29, 30] The minimal detectable change (MDC) for the PSFS is regularly reported as an increase of 3 points for a single activity score.[29, 30] During intake, the patient chose up to 5 activities based on their perception of difficulty to function. The patient and clinician then discussed which activity they viewed as pertinent to their sport (each patient chose an individual activity that could be performed in clinic), and that activity was used as the marker for assessing function pre/post for all treatments.
- **DPA scale.** The disablement in the physically active (DPA) scale is a valid scale that is used to assess disablement over four dimensions: impairment, functional limitation, disability, and quality of life (0 = no disability, 64 = maximum disability).[31] The DPA scale lists the MCID for acute conditions as a decrease of 9 points.

Intervention

All patients were treated with the traditional or modified MC LAS MWM, and patients were allowed to continue activities of daily living and athletic activities as tolerated. Patients were treated in a long-seated position on a treatment table, with the injured ankle suspended off the plinth. The clinician performed the treatment in a standing position and placing the thenar eminence on the anterolateral distal end of the fibula (lateral malleolus). The clinician applied a dorso-cranially mobilization force (note: proper direction/mobilization will elicit a slight dorsiflexion and eversion of the patients foot) and used the opposite hand to support the ankle mortise (Figure 1).[21] During the MWM, the patient was instructed to plantar flex and invert the foot. At the end of the patient's range of motion (ROM), the clinician applied overpressure with her abdomen.[21] The MWM remained painless throughout the entire application of the treatment, following the MC PILL principle. The MC guidelines were followed in all patients; however, patients who experienced pain (due to hand placement) during application of the traditional LAS MWM were treated with a modified LAS MWM. A modified MWM is indicated when soft tissue damage obstructs normal hand placement on the specified landmarks.[21] Similar to the traditional LAS MWM the modified MWM is expected to be applied in a pain-free manner with immediate and long-lasting results (i.e., PILL effect). The modified MWM thenar eminence is placed approximately 2-3 inches proximal to the lateral malleolus with a similar dorso-cranial MWM (Figure 1).[32] Outside of the hand placement modification, all other MC guidelines were followed. Three patients were treated with the traditional technique, and two were treated with the modification (Table 1). Each patient performed 3 sets of 10 MWM repetitions during one treatment session, with at least 30 seconds of rest between each set.

After each treatment, the clinician applied the fibular repositioning tape (FRT) by applying a strip of rigid Leukotape®P tape (BSN Medical, Inc-Charlotte, NC) directly to the skin in the direction of the MWM to reinforce the effects of the MWM. Patients were instructed to leave tape in place until the next treatment session (Figure 2), at which time the FRT was removed and the patient's skin was cleaned and prepped for the subsequent treatment and FRT application. Each patient reported their PSFS activity after FRT application. All patients were treated with a 3" wide tubular Cramer™ Compressionette (Cramer Products, Inc-Kansas City, MO) sleeve providing mild to moderate compression for the reduction of edema, worn during activities of daily living and sleep. Also, all patients except patient #101 were treated with natural (bagged) ice within the first 24 hours of injury, by placement of ice directly on the area of perceived pain (lateral ankle).

Discharge Criteria and Follow-up

Patients were discharged from the study once they reached the predetermined criteria and maintained the outcomes a minimum of 24 hours post treatment. The discharge criteria consisted of: a PSFS score of nine or higher, NRS current pain of 1 or less, and a DPA scale score of 23 or less (Table 4-6).[28-31] Patients were progressively released to activity as tolerated based on sport-specific return to competition criteria. Additionally, all patients retained discharge criteria standards for 2 weeks and 4 weeks after discharge (Table 7). After being discharged, patients could receive continued FRT application (Leukotape®P), without any other therapy, prior to each of their individual competitions, at their request; however, patients could not continue to receive FTR application without therapy if symptoms returned or re-injury occurred.

Results

Five individuals with acute grade II LASs participated in this study. Patients received an average of 4 treatments (mean = 4.4, SD ± .56) per patient over approximately 9 days (mean = 9.2, SD ± 3.96), from initial evaluation to patient discharge. A paired t-test was used to analyze the immediate pre/post treatment effects of the MC lateral ankle MWM on the patient's current NRS pain rating. Additionally, paired t-tests were used to analyze the change in score from intake to discharge for the NRS, PSFS and DPA Scale. Cohen's *d* was calculated to determine the effect size of each outcome measure. For Cohen's *d*, an effect size of 0.2 to 0.3 is considered a "small" effect, 0.5 is a "moderate" effect, and ≥ 0.8 a "large" effect.[33] All data was analyzed using SPSS version 23.0 (SPSS Inc., Chicago, IL, USA).

NRS

The immediate effect of the MC lateral ankle MWM as assessed on the NRS after the first treatment (mean = 3.6 ± SD 2.88) was significantly lower than the pre-treatment score (mean = 5.6 ± 2.61, $t_{(4)} = 6.33$, p = .003, two-tailed). The mean decrease in the NRS during the first treatment was 2 points, with a 95% CI ranging from 1.12 to 2.88. The mean difference satisfied the established MCID.[28] The Cohen's *d* effect size (*d* = .73) indicated a moderate level of practical significance of the treatment, and the mean change indicated the treatment was clinically effective in one treatment. The NRS score at discharge was significantly lower (mean = 0.2 ± 0.45) than the initial score (mean = 5.6 ±2.61, $t_{(4)} = 4.47$, p = .011, two-tailed). The mean decrease was 5.4 points, with a 95% CI ranging from 2.05 to 8.75. The mean difference exceeded the established MCID. [28] The Cohen's *d* effect size (*d* = 2.89) indicated a high level of practical significance of the treatment. All patients were discharged with an average NRS score that was less than or equal to 1 (Table 5) and maintained discharge criteria at the 2 week and 4 week follow-up (Table 7).

PSFS

The PSFS score at discharge (mean = 9.6 ± SD .55) was significantly higher than the initial scale score (mean = 3.2 ± 2.49, $t_{(4)} =-6.53$, p = .003, two-tailed), which indicates a significant improvement of function. The mean difference in the PSFS score was -6.4, with a 95% CI ranging from -9.12 to -3.68. The mean difference exceeds the established MDC, and each patient sustained a reduction (at least 4 weeks post discharge) exceeding the MDC, as well (Table 4).[29,30] The Cohen's *d* effect size (*d* = 3.6) indicated a high level of meaningfulness of the treatment. All patients were discharged with a PSFS score of greater than or equal to 9 (Table 4) and maintained discharged criteria at the 2 week and 4 week follow-up (Table 7).

DPA Scale

The DPA scale score at discharge (mean = 8.4 ± SD 8.04) was significantly lower than the initial scale score (mean = 34.8 ± 9.20, $t_{(4)} = 4.85$, p = .008, two-tailed). The mean decrease in the DPA scale score was 26.4 with a 95% CI ranging from 11.28 to 41.52. The mean difference exceeds the established MCID, and each patient sustained a reduction (from intake to discharge) exceeding the MCID, as well.[31] The Cohen's *d* effect size (*d* = 3.1) indicated a high level of meaningfulness of the treatment. All patients were discharged within a range expected of active, healthy individuals (score less than 23), as recorded in the established literature (Table 6)[31], discharge criteria was maintained at the 2 week and 4 week follow-up (Table 7).

Discussion

The results of this case series indicate that a single treatment of MWM for a LAS led to an immediate reduction of pain and an increase in function in all patients (N = 5; Table 4 & 5). From intake to discharge, all reported scales illustrated statistical and clinical meaningfulness. Also, all of the patients in this case series reported MCIDs on NRS from initial to post first treatment. The patients also reported clinically significant improvements from initial exam to discharge in pain on the NRS, function on the PSFS, and disablement on the DPA Scale. The outcomes presented in this case series appear to be similar to those of O'Brien et al.,[34] who reported an immediate decrease in pain and an increase in function and ROM beyond the natural course of healing. More importantly, in 5 treatments or less over the average of 9 days, patients with grade II ankle sprains were able to reach discharge criteria, return to competition, return to normal function (9 or higher on the PSFS), and report healthy disablement levels expected on the DPA Scale without suffering a return of symptoms or re-injury within the 4 week follow-up period.

The intervention produced long-lasting results with 100% of the patients remaining pain-free and competitively functional at 2 weeks and 4 weeks post discharge (Table 7). All Patients continued to receive the MC FRT prior to each competition throughout their individual sporting activity, at their request; however, patients did not receive the FRT application or use any bracing during sport specific practices or activities of daily living after being discharged.

In this case series, patients were assessed and treated based on arthrokinematic changes,[21] which contradicts many recommendations to focus on muscle strengthening, tissue healing, and protection of disrupted ligaments.[1,25,32] The Mulligan Concept LAS MWM addresses the positional fault theory[21] versus the traditional ligamentous damage theory.[10] The position of the distal fibula, after an acute lateral ankle sprain, is proposed to be subluxed (anterior or posterior), with the majority of subluxations being anterior.[15,16,23,24] The technique used potentially addresses arthrokinematic dysfunction of the ankle joint that is often neglected in ankle rehabilitation and may lead to CAI.[15,17,19,24] Although no radiographic exams were conducted to confirm fibula malalignment, application of the lateral ankle MWM resulted in pain-free movement and reduction in patient reported dysfunction that was maintained post-treatment. Another mechanism potentially explaining the benefit of MWMs is a neurophysiological component; it is likely that a MWM has a positive pain-altering effect, mediated by large A-Beta fibers stimulated by peripheral touch and transmitting non-painful contact stimuli to the central nervous system (CNS) faster than the smaller delta fibers transmit noxious stimuli.[35] Also observed in research is a pain relieving sympathetic nervous system response after a treatment of MWMs, similar to those after a spinal manipulation.[36] In addition to the resulting improvement in pain, the treatment is thought to improve function and ROM through the theorized correction of the positional fault caused by the LAS.[13, 32] Moreover, the FRT application is used to support the correction of the arthrokinematic positional fault, continually providing a mobilizing force as the patient participates in activities.

In the past, clinicians have been encouraged to delay the complete physical exam following a LAS for 5 to 7 days after the initial trauma, due to pain and swelling thought to inhibit the physical examination.[37] In contrast, the application of MWMs are encouraged immediately once the PILL effect can be obtained after the initial injury.[21] Mobilizations with movement, in the MC, are utilized as part of the evaluation process to determine if the application is indicated; if the PILL effect cannot be created or sustained, then a different treatment is indicated.[21] When applied in these cases, the initial MWM was able to be applied pain-free within 72 hours of injury and produced an immediate and clinically significant change in pain on the NRS.

Current standards of care related to the treatment of acute LAS recommend protection rest, ice, compression, elevation (PRICE), and other modalities within the early phase of the injury; however not all ankle sprains are alike and an individualized plan should be created after a comprehensive assessment. [6, 26, 39, 40] In this case study, patients were treated with a compression sleeve throughout the course of their treatment and reported using ice only on the day of injury (except patient 101). Specifically, focal compression directed to the soft tissue around the fibular malleolus appears to reduce edema, assisting with increased function over time, which is why compression was used in conjunction with the MC technique.[41] It is possible that a traditional PRICE treatment could have had a positive effect on the recovery time seen within this case series. Currently, there is insufficient evidence available from randomized controlled trials to determine the relative effectiveness of PRICE for acute grade II ankle sprains; [38-40] however, based on the literature, it seems unlikely that PRICE treatment would explain the immediate benefit of improved function and ROM.[38-40]

Limitations and Future Research

This study is limited by the small sample size and the limitation to an adolescent athletic population. The sample population in this case study does not represent the general population, which may make it difficult to translate these findings to a more diverse population. In addition, activity was not restricted during treatment, which could have improved or hindered outcomes. Furthermore, there was no control or comparison group to support the findings in this five person case series. Further research is needed to determine if the MC lateral ankle MWM will have the same positive effect on other patient populations. Specific strength testing (e.g., Y-balance test) should also be investigated evaluating changes in measure prior to MWM versus post MWM treatment. Patient outcome measures should be collected on larger populations with controlled activity; and patients should be evaluated for long-term ankle instabilities and/or osteoarthritis.

Conclusion

The outcomes of this case series provide evidence for the integration of the MC LAS MWM into treatment and rehabilitation protocols for patients with an acute grade II LAS. The patients in this case series reported immediate decreases in pain and immediate increases in functional activity while maintaining positive patient reported outcomes for 4 weeks post discharge. More importantly, the results in the case series demonstrate a quick return to activity (average of 4.4 treatments across 9 days) without a return of symptoms or re-injury 4 weeks post-discharge. Although the current results support the use of the MC lateral ankle MWM for acute LASs, more research is needed to establish this treatment as the standard of care in treating patients with LAS.

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Table 3.1: Ankle Sprain Grading System (Beynnon et al., 2006)

Clinical Grade	Description of Grade Level
Grade I (Mild)	Minimal swelling(edema) and tenderness; minimal or no function loss; no mechanical joint instability
Grade II (Moderate)	Moderate pain, swelling, and tenderness over involved structures; some loss of joint motion; joint stability is mild to moderately impaired
Grade III (Severe)	Complete ligament rupture with evident swelling, hemorrhage, and tenderness over involved structures; function lost; joint motion and instability evident as abnormal

Table 3.2: Patient Demographics

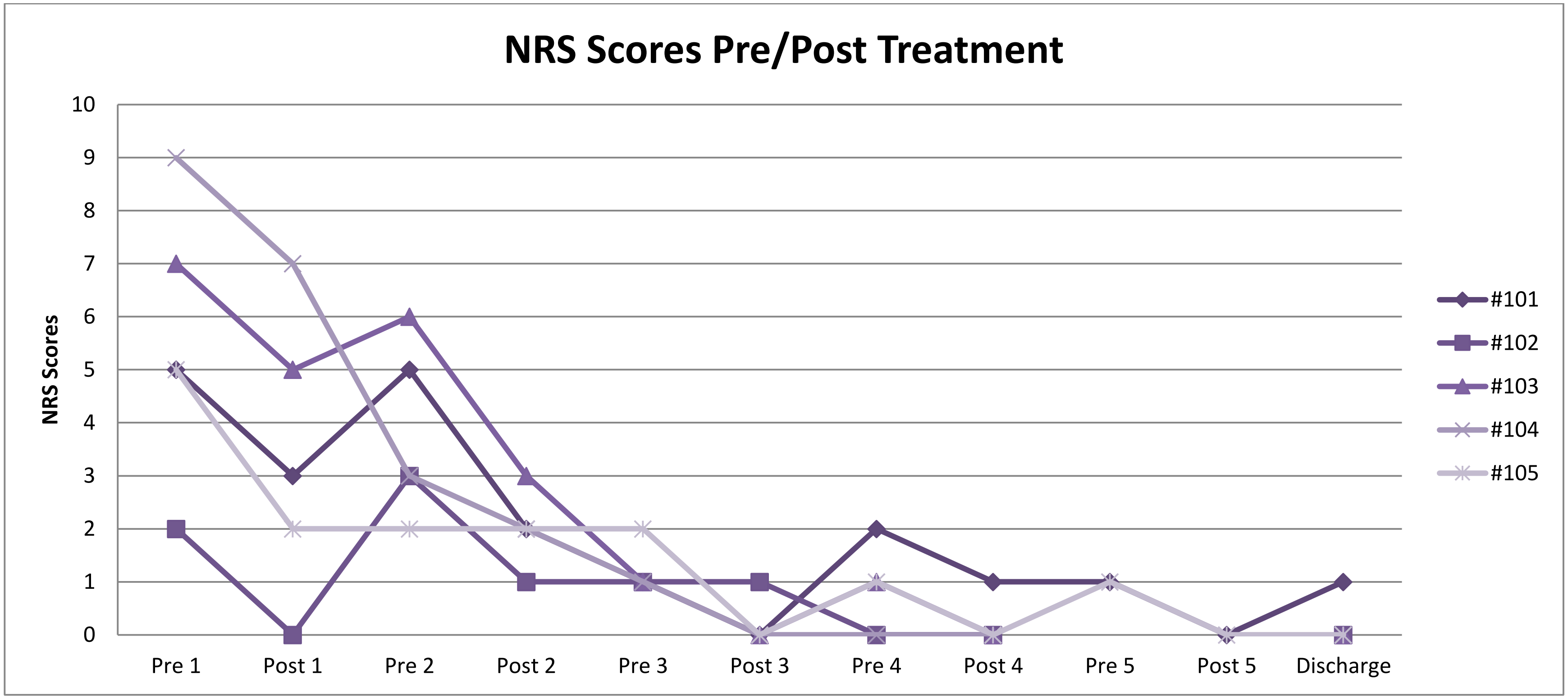
Patient Demographics	Sex	Sport	Age	Height	Weight	# of Treatments	Days to Discharge	Days out of all sport activity	MWM Applied	Time from Injury to 1st Treatment
#101	M	Basketball	18	6’4	215	5	8	1	Modified	72hrs
#102	M	Soccer	14	5’9	145	4	6	0	Traditional	24hrs
#103	M	Basketball	17	6’3	205	4	7	2	Traditional	24hrs
#104	F	Basketball	15	5’3	178	4	16	2	Modified	48hrs
#105	M	Soccer	15	5’8	155	5	9	2	Traditional	24hrs

Table 3.3: Patient Symptoms and Classification at Intake

Patient Symptoms (Intake)	**Ankle Injury Grade**	**Palpation of Joint**	**Joint stability (Anterior Drawer)**	**Edema**	**Eccymosis**	**ROM (compared to uninjured limb)**
#101	II	Pain over ATFL & CFL	*Laxity	Moderate	Lateral ankle/lateral mid-foot	*Restricted in DF & PF
#102	II	Pain over ATFL	*No Laxity	Minimal	N/A	*Restricted in DF
#103	II	Pain over ATFL	*No Laxity	Minimal	N/A	*Restricted in DF
#104	II	Pain over ATFL & CFL	*Laxity	Moderate	Lateral rear-foot	*Restricted in DF & PF
#105	II	Pain over ATFL & CFL	*Laxity	Moderate	Lateral rear-foot	*Restricted in DF & PF

*Pain

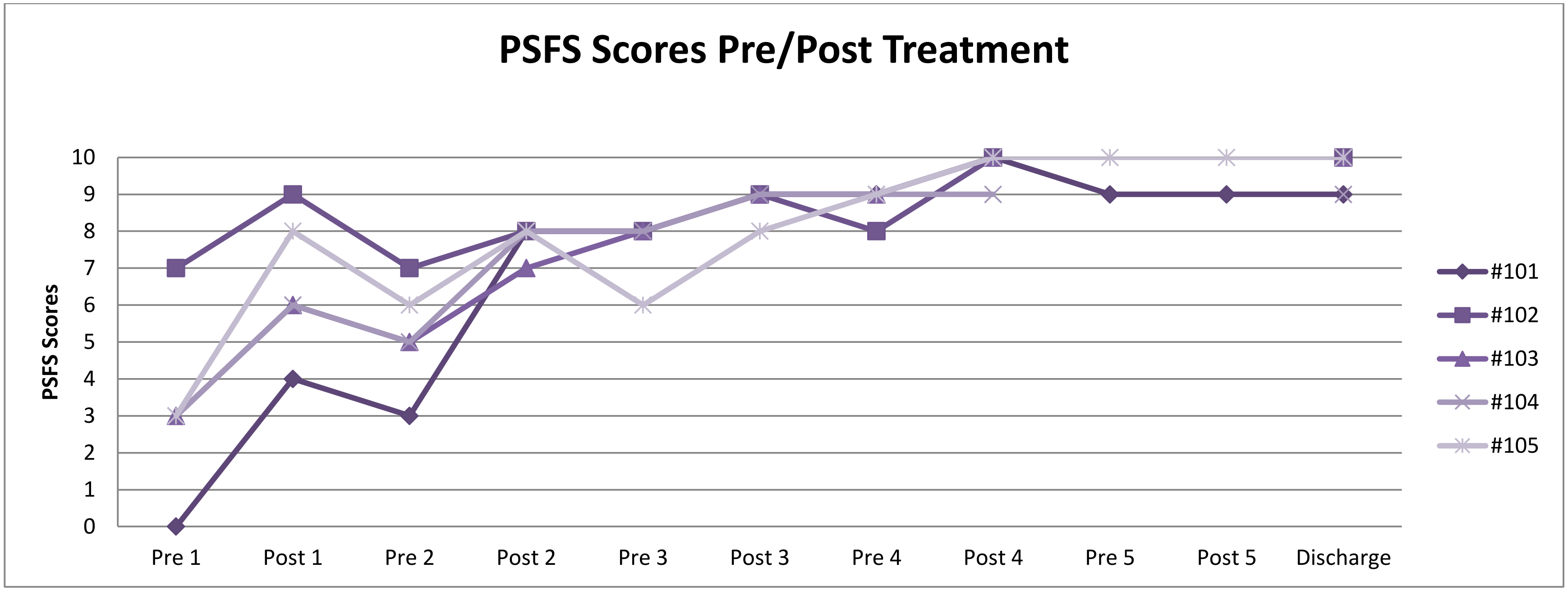
Table 3.4: Change in Current NRS Pain Rating Pre- to Post-treatment



Patient#	Pre 1	Post 1	Pre 2	Post 2	Pre 3	Post 3	Pre 4	Post 4	Pre 5	Post 5	Discharge
#101	5	3*	5	2*	1	0	2	1	1	0	1
#102	2	0*	3	1*	1	1	0	0	N/A	N/A	0
#103	7	5*	6	3*	1	0	1	0	N/A	N/A	0
#104	9	7*	3	2	1	0	0	0	N/A	N/A	0
#105	5	2*	2	2	2	0	1	0	1	0	0

*MCID met or exceeded in one treatment

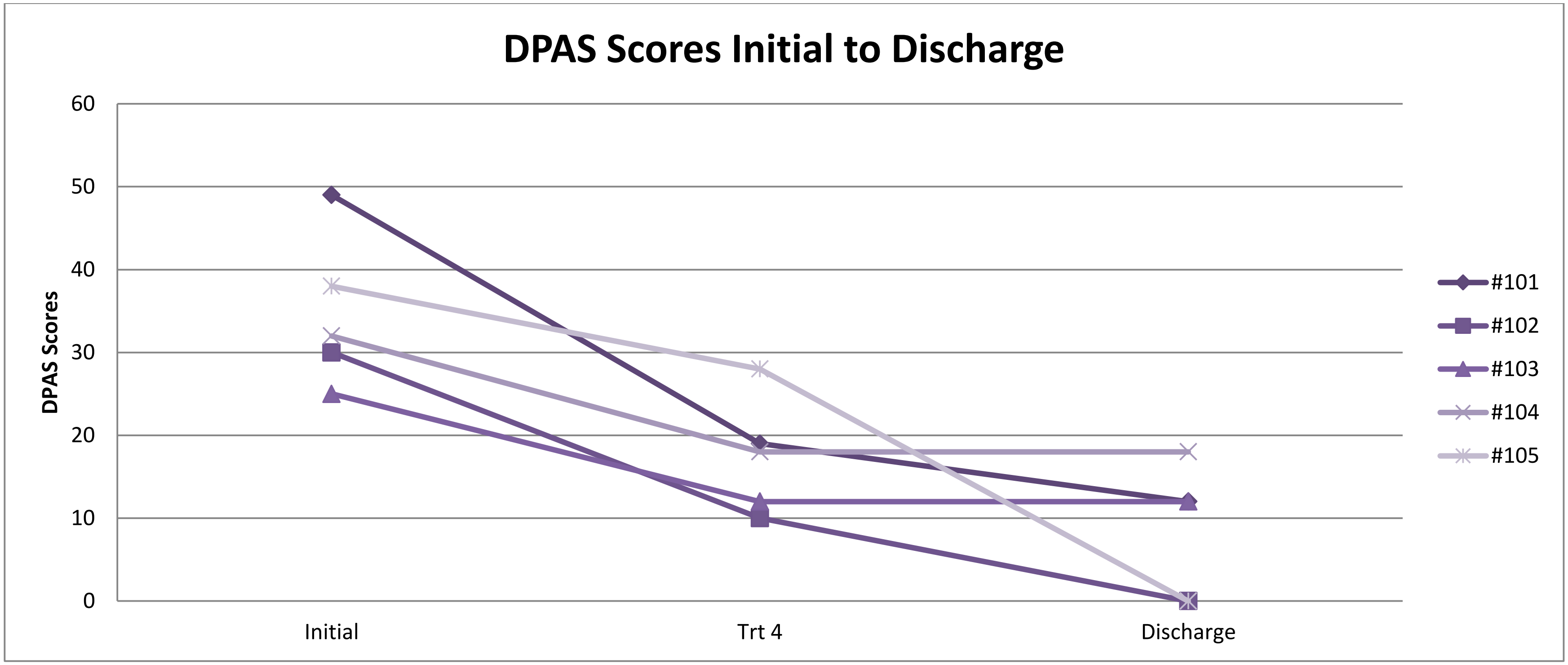
Table 3.5: Change in PSFS Scores Pre- to Post-treatment



Patient#	Pre 1	Post 1	Pre 2	Post 2	Pre 3	Post 3	Pre 4	Post 4	Pre 5	Post 5	Discharge
#101	0	4*	3	8*	8	9	9	10	9	9	9
#102	7	9	7	8	8	9	9	10	N/A	N/A	10
#103	3	6*	5	7	8	9	9	10	N/A	N/A	10
#104	3	6*	5	8*	8	9	9	9	N/A	N/A	9
#105	3	8*	6	8	6	8	9	10	10	10	10

*MDC met or exceeded in one treatment session

Table 3.6: Change in DPA Scale Scores from Intake to Discharge



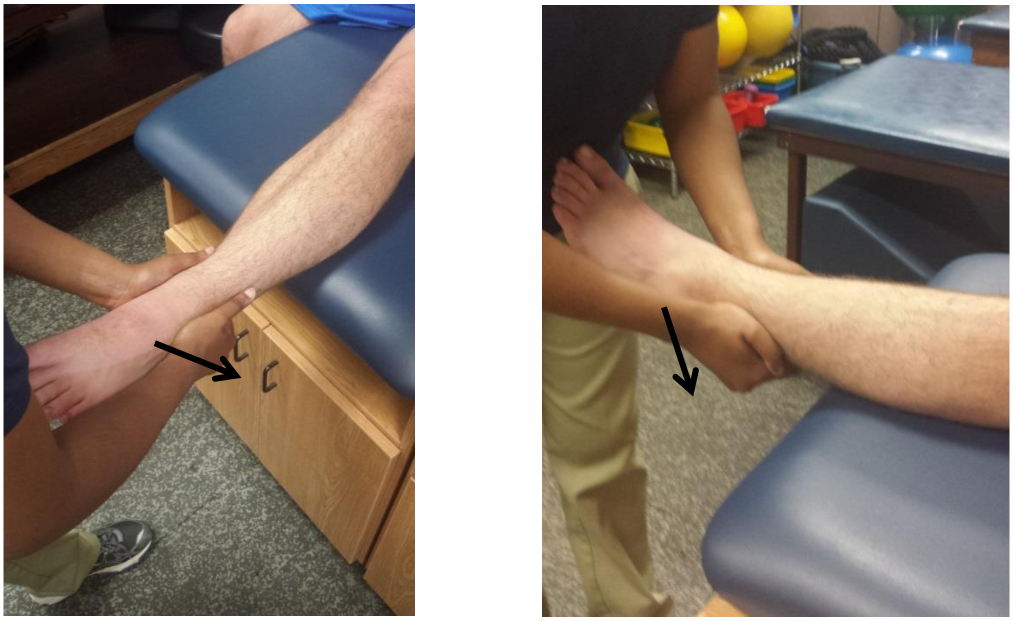
Patient#	Initial	Trt 4	Discharge
#101	49	19*	12
#102	30	10*	0*
#103	25	12*	12
#104	32	18*	18
#105	38	28*	0*

Intake					**Comparison to Intake Scores**
Patient #	**NRS**	**PSFS**	**DPA**	**ROM**	
#101	5	0	49	Restricted in DF & PF	MCID reached on NRS & PSFS after 1st treatment
#102	2	7	30	Restricted in DF & PF	MCID reached on NRS after 1st treatment
#103	7	3	25	Restricted in DF & PF	MCID reached on NRS & PSFS after 1st treatment
#104	9	3	32	Restricted in DF & PF	MCID reached on NRS & PSFS after 1st treatment
#105	5	3	38	Restricted in DF & PF	MCID reached on NRS & PSFS after 1st treatment
Discharge					**Comparison to intake scores**
Patient #	**NRS**	**PSFS**	**DPA**	**ROM**	
#101	1	9	12	Equal to opposite limb	MCID reached on all scales
#102	0	10	0	Equal to opposite limb	MCID reached on all scales
#103	0	10	12	Equal to opposite limb	MCID reached on all scales
#104	0	9	18	Equal to opposite limb	MCID reached on all scales
#105	0	10	0	Equal to opposite limb	MCID reached on all scales

*MCID met or exceeded

Table 3.7: Follow-up Data at 2 Weeks and 4 Weeks Compared to Intake and Discharge

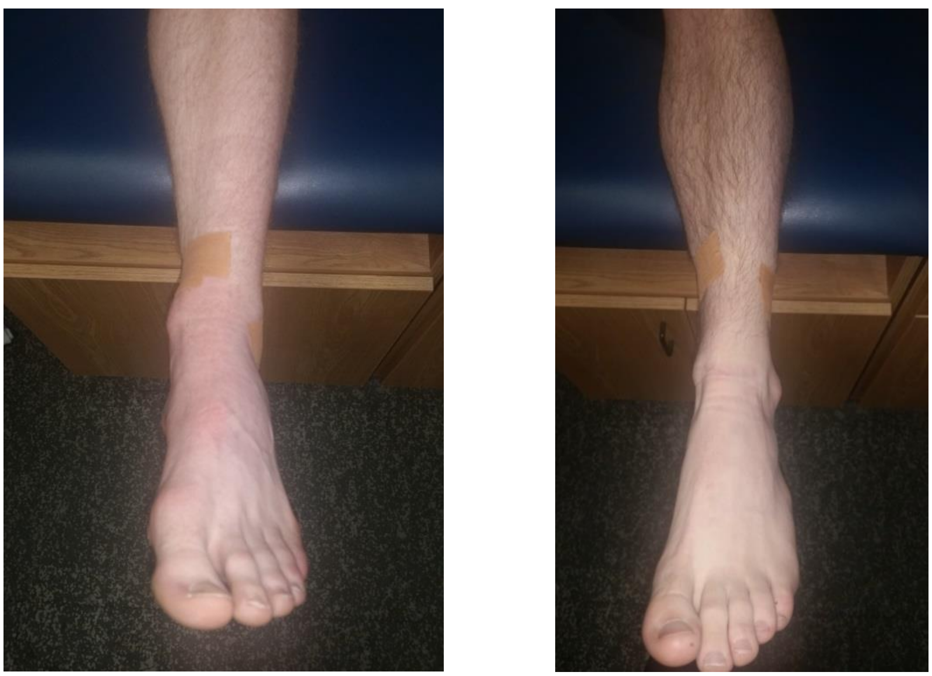
2 Week Follow-up					**Comparison to discharge scores**
Patient #	**NRS**	**PSFS**	**DPA**	**ROM**	
#101	1	9	12	Equal to opposite limb	No change from discharge
#102	0	10	0	Equal to opposite limb	No change from discharge
#103	0	10	10	Equal to opposite limb	Patient decreased on DPA scale
#104	0	9	20	Equal to opposite limb	Patient increased on DPA scale, but within discharge criteria
#105	0	10	0	Equal to opposite limb	No change from discharge
4 Week Follow-up					**Comparison to discharge scores**
Patient #	**NRS**	**PSFS**	**DPA**	**ROM**	
#101	1	9	12	Equal to opposite limb	No change from discharge
#102	0	10	0	Equal to opposite limb	No change from discharge
#103	0	10	12	Equal to opposite limb	Returned to discharge scores
#104	0	10	16	Equal to opposite limb	Patient decreased on DPA scale
#105	0	10	0	Equal to opposite limb	No change from discharge



A. B.

Figure 3.1: MC LAS MWM hand placement (A) and modified hand placement (B) on left ankle.

Note: Arrow is in direction of the mobilization



A. B.

Figure 3.2: MC LAS MWM tape application (A) and modified tape application (B) on left ankle.

CHAPTER 4

Review of Literature

Introduction

Meniscal lesions are the second most common knee injury in sports (Majewski, Susanne, & Klaus, 2006), and as many as 50% of orthopedic surgeries performed in the United States involve the meniscus (Englund et al., 2010). Tears in the meniscus are more prevalent among males than females, both in adults and adolescents (Drosos & Pozo, 2004; Shieh, Bastrom, Roocroft, Edmonds, & Pennock, 2013), with tears among adolescent populations occurring almost exclusively during sports-related activities (Drosos & Pozo, 2004; Shieh et al., 2013). The current standard of care for treating meniscal tears is surgical intervention. Surgical options for the treatment of meniscal tears include partial meniscectomy, meniscal repair, and meniscus transplant (Brophy & Matava, 2012); when diagnostically indicated (e.g., a tear in the outer vascular zone), arthroscopic surgical repair is generally the first choice due to the salvation of meniscal tissue which delays the onset of osteoarthritis (OA; Getgood & Robertson, 2010). Osteoarthritis of the knee has been associated with meniscal tears, especially in those treated with surgical meniscectomies (Snoeker, Bakker, Kegel, & Lucas, 2013; Englund, 2008).

Patients who undergo any type of meniscal surgery are at a significant risk for requiring a subsequent surgery (Paxton, Stock, & Brophy, 2011). Failure rates of meniscal surgical interventions range from 9% to 49% (Getgood and Robertson, 2010; Hwang & Kwoh, 2014; Katz et al., 2013; Lyman et al., 2013; Nepple, Dunn, & Wright, 2012; Peters & Wirth, 2003; Pujol Barbier, Boisenroult & Beaufils, 2011; Vundelinckx, Vanlauwe, & Bellmans, 2014). Additionally, no difference was found when comparing the outcomes of meniscectomy to those of sham surgery (Sihvonen et al., 2013) or conservative rehabilitation (Herrlin, Hallander, Wange, Wiendenhielm, and Werner, 2007).

The recommendation to exhaust conservative treatment options prior to seeking surgical intervention is commonly reported in the literature (Hwang & Kwoh, 2014; Katz et al., 2012; Herrlin, Hallander, Wange, Wiedenhielm, and Werner, 2007; Bin, Kim, & Shin, 2004). Conservative treatment may involve various manual therapy techniques that are effective in resolving symptoms and increasing function (Englund et al., 1992). To improve the treatment of meniscal pathology it is important to understand that the conservation of meniscal tissue is critical. Research into alternative methods of retaining meniscal tissue post meniscal tears is warranted.

Basic Anatomy and Function of the Meniscus

The medial “C-shaped” meniscus covers 50% of the medial tibial plateau surface area and is wider at the posterior horn than the anterior (Rath & Richmond, 2000). The periphery of the medial meniscus attaches firmly to the joint capsule and to the medial collateral ligament (MCL) at its midsection via the deep medial collateral ligament fibers (Lee & Fu, 2000). The deep medial collateral ligament restricts the medial meniscus from excessive motion (Masouros, McDermott, Amis, & Bull, 2008). The lateral “O-shaped” meniscus accounts for 70% of the surface area on the lateral tibial plateau (Rath & Richmond, 2000). The lateral meniscus is only loosely attached to the joint capsule and has no attachment to the lateral collateral ligament (LCL), allowing for greater mobility during activity (Rath & Richmond, 2000). Also contributing to the mobility of the lateral meniscus are fibers of the popliteal tendon that insert along the lateral meniscus at the posterolateral corner (Rath & Richmond, 2000).

Tibial attachment sites of the medial and lateral menisci exist anteriorly adjacent to the anterior cruciate ligament (ACL) and posteriorly adjacent to the posterior cruciate ligament (PCL; Greis, Bardana, Holmstrom, & Burks, 2002). The anterior horns of the medial and lateral menisci are connected by the transverse ligament (Fox, Bedi, & Rodeo, 2012). The lateral meniscus is supported by two meniscofemoral ligaments: the ligament of Humphry, or anterior meniscofemoral ligament, and the ligament of Wrisberg, or the posterior meniscofemoral ligament (Greis et al., 2002; Poynton, Javadpour, & Finegan, 1997). The occurrence of these ligaments is highly variable.

Microstructure

The meniscus is composed of approximately 70% water and additional dry substance that includes fibrochondryte cells and an extracellular matrix (McDevitt, Cahir A., Webber, 1990; Renstrom & Johnson, 1990). The dry substance is 60-75% collagen (McDevitt, Cahir A., Webber, 1990; Renstrom & Johnson, 1990), 90% of which is type I collagen (McDevitt, Cahir A, Webber, 1990). The concentration of collagen in the meniscus increases from birth until the age of thirty and remains fairly consistent until age of 80, at which point it begins to decline. Elastin and non-collagenous proteins also exist in the meniscus in small quantities (0.6% and 8-13% of the dry substance; McDevitt, Cahir A., Webber, 1990).

The fibers on the surface of the meniscus are organized in a multi-directional mesh-like fashion. The meshed network functions to dissipate shear stress exerted on the surface by the femoral condyles (Greis et al., 2002). Deeper fibers are orientated circumferentially, contributing to the meniscus' ability to withstand weight-bearing loads from the femur. Radial fibers run perpendicular to the circumferential fibers, and both are crimped at rest and elongate under tension (Renstrom & Johnson, 1990). The radial fibers add structural integrity to the meniscus and prevent longitudinal tearing during stress (Renstrom & Johnson, 1990). While the circumferential fibers expand to allow for the dispersal of load, the radial fibers act as ties that prevent excessive expansion.

Vascular Anatomy

The meniscus receives its blood supply from the superior and inferior portions of the medial and lateral genicular arteries via premeniscal capillary plexuses (Arnoczky & Warren, 1982). Radial branches from these plexuses extend into the menisci and travel a short distance toward the center of the joint, ending in terminal capillary loops (Arnoczky & Warren, 1982). The well vascularized periphery is referred to as the “red zone.” The narrow transitional region is the “red-white zone,” or “pink zone,” and the inner most region of the meniscus, which is completely avascular, is the “white zone” (Rodkey, 2000). The depth of vascularity from the periphery ranges from 10-30% in the medial meniscus and 10-25% in the lateral. The lateral meniscus is also avascular at the popliteal hiatus (Arnoczky & Warren, 1982). The zones are useful in describing the location of tears and discussing healing potentials. Tears in the red zone have a potential for healing, while those in the white zone do not (Fox, Bedi, & Rodeo, 2012).

Infants are born with an abundance of blood supply throughout the menisci. Newborn vascularity ranges from 50% (Renstrom & Johnson, 1990) to 100% (Greis et al., 2002). By nine months, the inner portion loses most of its vascularity and continues to diminish until it reaches the reported averages at approximately 10 years of age (Greis et al., 2002). Because the avascular portions of the meniscus depend on diffusion from the synovial fluid for nutrition (Fox, Bedi & Rodeo, 2012; Greis et al., 2002; Renstrom & Johnson, 1990), movement at the knee and weight-bearing activities may aid vascular supply due to mechanical pumping and compression of the menisci (Fox, Bedi & Rodeo, 2012).

Neuroanatomy

The neural supply of the meniscus follows the same path as the vascular anatomy. Local nerve branches have been reported to stem from the posterior and medial articular nerves (Lee & Fu, 2000; Wilson, Legg, & McNeur, 1969). The premeniscal region of the joint capsule is highly innervated, and branches from these nerves extend into the peripheral third of the meniscus as myelinated and unmyelinated free nerve endings. The nerve fibers are more abundant in the anterior and posterior horns of the menisci than they are in the body (Renstrom & Johnson, 1990). Nerve fibers become less dense in the middle third of the meniscus and are absent in the inner third, insertion sites, and at the meniscofemoral ligaments (Lee & Fu, 2000, Wilson et al., 1969). The majority of nerve fibers at the menisci are reported to be mechanoreceptors, providing proprioceptive feedback during extreme end ranges of motion (Fox, 2007; Greis et al., 2002).

Sensory neuromapping, charting areas of the menisci which detect painful versus pain-free sensation, produced similar findings to those previously reported on neural anatomy of the knee (Dye, Vaupel, & Dye, 1998). Mapping of the internal structures of the knee has been conducted without intraarticular anesthesia. Palpation of the peripheral regions of the menisci via arthroscopic probing produced slight to moderate discomfort, while palpation of the inner rims produced only an awareness of the palpation without pain (Dye et al., 1998). Palpation of the synovium, capsule, and retinacula produced the second highest amounts of pain and discomfort (Dye et al., 1998).

Function & Biomechanics

The menisci play a functional role in optimizing articular congruency (Fox, Bedi & Rodeo, 2012; Lee & Fu, 2000; Masouros et al., 2008; Rath & Richmond, 2000; Renstrom & Johnson, 1990); load transmission (Fox Bedi & Rodeo, 2012; Greis et al., 2002; Lee & Fu, 2000; Rath & Richmond, 2000; Renstrom & Johnson, 1990); shock absorption (Fox, Bedi & Rodeo, 2012; Greis et al., 2002; Lee & Fu, 2000; Masouros et al., 2008); stability (Fox, Bedi & Rodeo, 2012; Lee & Fu, 2000; Masouros et al., 2008; McDermott, Masouros, & Amis, 2008; Rath & Richmond, 2000); proprioception (Fox, Bedi & Rodeo, 2012; Greis et al., 2002); joint lubrication (Fox, Bedi & Rodeo, 2012; Lee & Fu, 2000; Rath & Richmond, 2000; Renstrom & Johnson, 1990); and nutrition (Fox, Bedi & Rodeo, 2012; Lee & Fu, 2000; Rath & Richmond, 2000; Renstrom & Johnson, 1990). Limited evidence exists to support conclusions about the function of the meniscus in joint lubrication and nutrition, but these functions are reported as a secondary effect at the meniscus during weight-bearing activities (Renstrom & Johnson, 1990). Additionally, the existence of mechanoreceptors within the meniscal horns and attachments sites may suggest that the meniscus plays a functional role in joint proprioception (Lee & Fu, 2000; Renstrom & Johnson, 1990).

The biomechanical role of the meniscus is prevalent during weight-bearing activities. On average, the knee joint transmits three times a person’s body weight while weight-bearing. The shape of the meniscus allows for better congruency between the articulating surfaces of the flat tibial plateaus and the convex femoral condyles (Masouros et al., 2008). Greater forces are placed on the medial tibial condyles as loads increase (Morrison, 1970), and therefore the meniscus is essential in transmitting and dissipating these forces equally on the tibia. The congruency of the meniscus adds to its role as a secondary stabilizer, especially in resisting anterior translation of the ACL-deficient knee (Renstrom & Johnson, 1990); the meniscus-meniscofemoral ligaments also play a role in the rotational stability of the tibia (Masouros, Bull, & Amis, 2010).

The role of load transmission is critical throughout the entire range of motion at the knee. In full knee extension, the meniscus is centered on the tibial plateau. As the knee flexes, the meniscus moves posteriorly (Masouros et al., 2008; McDermott et al., 2008). The anterior horns have more mobility than do the posterior horns and the lateral meniscus has greater posterior mobility than does the medial meniscus due to its loose peripheral attachment. The greater concavity of the medial tibial condyle may also contribute to the decreased mobility of the medial meniscus (Masouros et al., 2008). Although this posterior translation benefits the load-dispersal capabilities of the meniscus, limited mobility, along with the increased load-bearing responsibility of the medial meniscus, may contribute to the increased prevalence of medial meniscal tears (Fox, Bedi & Rodeo, 2012).

Shock absorption in the meniscus is attributed to its tissue properties. High water content allows for displacement of fluids under pressure, creating a drag force that resists external forces (Masouros et al., 2008; Renstrom & Johnson, 1990). Additionally, the crimped resting state of the circumferential fibers allows for an expansion under hoop stress during weight-bearing activities (Masouros et al., 2008; McDermott et al., 2008).

Meniscal Tears

Meniscal tears commonly result from the compressive forces on the meniscus by the tibia and femur during flexion and rotation of a weight-bearing knee (McDermott, 2006). A tear in young individuals often occurs from a sudden excessive force, while older adults more commonly experience the gradual onset of degenerative tears (McDermott, 2006). Young patients who sustain pathology will recall a specific mechanism of injury 80-90% of the time (Lento & Akuthota, 2000). Classic signs and symptoms of a meniscal tear include: catching, locking, or clicking; joint line pain; and a feeling of "giving out" or instability (Lowery, Farley, Wing, Sterett, & Steadman, 2006). Pain and/or inability to fully squat and a gradual onset of swelling over the first 24 hours following an injury are also commonly reported symptoms (Bower, 2013; McDermott, 2006). Joint-line tenderness has been reported as the most accurate finding in diagnosing meniscal involvement in adolescent patients (Willis, 2006). Common risk factors for sustaining an acute meniscal tear include participation in sports (Snoeker et al., Bakker, Kegel, & Lucas, 2013); chronic tears often occur as a result of persistent kneeling, repetitive squatting, or climbing stairs (Drosos & Pozos, 2003; Snoeker et al., 2013).

Classification of Meniscal Tears

Tears are classified based on their appearance and location. Horizontal tears occur in the mid-substance of the meniscus, separating it into superior and inferior segments. Longitudinal tears occur vertically along the circumferential orientation of the collagen fibers (Jee et al., 2003). A radial, or transverse, tear also occurs vertically and perpendicularly across the circumferential fibers; the disruption of the circumferential collagen fibers will affect the dispersal of weight-bearing loads (Harper, Helms, Lambert, & Higgins, 2005). Oblique, or parrot-beak, tears are a combination of radial and longitudinal tears. A tear of this kind will start in a radial direction at the inner rim and change direction longitudinally as it approaches the periphery (Jee et al., 2003). Bucket-handle tears are longitudinal tears in which the mid portion of the tear has flipped over itself (Jee et al., 2003). Complex tears are those that present with two or more of the previously described classification characteristics (Jee et al., 2003).

Longitudinal and oblique tears are the most viable for surgical repair, so long as they occur in the vascularized periphery. A particular prospective study involving 1,485 meniscal tears found 40% of the tears in the vascular peripheral portion (Metcalf & Barrett, 2014). Of those, 28% were complex tears, and 32% horizontal. Complex tears were more prevalent in patients over the age of 40 (found in 35% of patients) than in younger patients (found in 13%; Metcalf & Barrett, 2004). Tears in the avascular inner rims, as well as radial and complex tears have a lower success rate for surgical repair (Barber-Westin & Noyes, 2014).

Evaluation and Diagnostics

A battery of tests should be used by an experienced practitioner to clinically diagnose meniscal lesions, as no single test is pathognomonic for a meniscus tear (Lowery et al., 2006). The tests, palpations, and history components that have been identified (i.e. inclusion criteria) have a high specificity and high sensitivity, and they have been tested in a battery of tests. Many tests have been identified to detect meniscal tears upon clinical diagnosis. Among these tests include Apley’s test, Anderson grind test, McMurray’s test, bounce home test, axially loaded pivot shift test, knee compression rotation test, Ege’s test, and Thessaly’s test (Chivers & Howitt, 2009). In addition to special tests, a detailed history including catching or locking of the knee joint will alert an examiner of a possible meniscal tear (Lowery et al., 2006). The research of Lowery et al., (2006) recommend using the following when assessing patients for suspected meniscal pathology: (a) catching or locking as described by the patient during the history; (b) palpation of joint line tenderness; (c) McMurray’s test; (d) pain with hyperextension; and (e) pain with forced flexion.

Additionally, two other tests have been identified and are recommended when assessing meniscal lesions. The first being Thessaly's test at 20 degrees, which is a dynamic weight bearing reproduction of the mechanism of injury. The second is Apley's compression and distraction test which also reproduces the compressive and rotating force involved in the mechanism of injury. Both tests have been studied in a battery, with one or more of the five tests identified by Lowery et al. (2006). Accuracy of Thessaly's test was assessed with joint line tenderness and McMurray's test, indicating that a battery of tests increases the accuracy of physical diagnosis (Konan et al., 2009). Accuracy of Apley's test was assessed with joint line tenderness, pain with forced extension, and the McMurray's test by Kurosaka et al., (1999). The results described in the article concluded physical examination is essential to the diagnosis of meniscal lesions (Kurosaka et al., 1999).

Patient History, Range of Motion, and Palpation

Patient history. One of the most important elements to any diagnosis is taking a detailed history. A few key history components will alert an examiner to meniscal pathology outside of the mechanism of injury (Lowery et al, 2006). Losses of flexion greater than 10 degrees, loss of extension greater than five degrees, crepitus, and/or joint line swelling are common history components of meniscal pathology (Magee, 2008). Catching, locking, or the sensation of catching or locking in the knee has been identified throughout literature as symptoms of meniscal pathology (Lowery et al., 2006). Lowery et al. (2006) investigated the mechanical history component further with an intact ACLs, identifying catching, locking, or the sensation of catching to have a sensitivity of 21% and specificity of 92%. The positive predictive value (PPV) associated with the history component was 74%, and the positive likelihood ratio (PLR) was 3.34 in knees treated surgically (Lowery et al., 2006).

Pain with forced joint movement. Pain associated with forced knee flexion and pain associated with hyperextension were identified by Lowery et al. (2006) as a part of a clinical composite score used to accurately detecting meniscal pathology. Forced knee flexion is performed by having the patient lie supine with examiner on the involved side (Lowery et al., 2006). The patient then actively moves his or her knee into maximum flexion, and the examiner applies an over pressure if pain is not elicited in active movement (Lowery et al., 2006). A positive test is elicited by pain within the joint line in active movement or forced overpressure (Lowery et al., 2006; Fowler & Lubliner, 1989). Lowery et al. (2006) investigated forced knee flexion with intact ACLs, identifying a sensitivity of 47% and specificity of 59%, respectively. The PPV associated with the range of motion (ROM) component was 55%, and the PLR was 1.16 in knees treated surgically (Lowery et al., 2006).

Pain with hyperextension (modified bounce home test) is performed by having the patient lie in the supine position with the examiner on the involved side (Lowey et al., 2006). The examiner cups the heel of the patient's foot with one hand and the other hand on the knee guiding the knee from flexion into passive extension (Lowery et al., 2006). A positive test is indicated by pain in the joint line of the knee (Magee, 2008; Lowery et al., 2006; Kurosaka et al., 1999; Fowler & Lubliner, 1989). If extension is not complete or a "springy" block is felt, this is thought to be a block from the torn meniscus (Magee, 2008). Lowery et al. (2006) investigated pain with hyperextension with an intact ACL identifying a sensitivity of 33% and specificity of 88%. The PPV associated with the ROM component was 75% and the PLR was 2.59 in knees treated surgically (Lowery et al., 2006).

Palpation. Joint line tenderness is a well-known assessment for meniscal lesions and has a high sensitivity and a low specificity (Malanga et al., 2003; Rose, 2006). Joint line tenderness is assessed by having the patient supine with the examiner on the involved side (Malanga et al., 2003). The patient flexes the affected limb to approximately 90 degrees (Malanga et al., 2003). The medial edge of the medial meniscus is palpated by having the patient internally rotate the tibia, and external rotation allows for improved palpation of the lateral meniscus (Malanga et al., 2003). A positive test is indicated by pain over the palpation site in the joint line (Malanga et al., 2003; Rose, 2006). Joint line tenderness has a high sensitivity in both medial (68%-92%) and lateral (87%-95%) meniscal pathology, but best results are in lateral meniscal tears with only 8% variability between the lowest and highest sensitivity percentage reported (Eren, 2003).

Lowery et al. (2006) investigated joint line tenderness on patients with an intact ACL, identifying a sensitivity of 65% and specificity of 62%. The PPV of joint line tenderness associated with the ROM component was 65%, and the positive likelihood ratio was 1.83 in knees treated surgically. Fowler and Lubliner (1989) identified joint line tenderness with a sensitivity of 86% and a specificity of 29%. Karachalios et al., (2005) report a medial meniscus joint line tenderness sensitivity of 87%, a medial meniscus sensitivity of 87%, a lateral meniscus sensitivity of 78%, a lateral meniscus specificity of 90%, a medial meniscus diagnostic accuracy of 71%, and a lateral meniscus diagnostic accuracy of 78%. Konan et al. (2008) identify this test with a medial meniscus sensitivity of 83%, a medial meniscus specificity of 76%, a lateral meniscus sensitivity of 68%, a lateral meniscus specificity of 97%, a medial meniscus diagnostic accuracy of 81%, a lateral meniscus diagnostic accuracy of 90%, a PPV medial meniscus of 91%, and a PPV lateral meniscus of 87%. Kurosaka et al. (1999) report joint line tenderness to have an overall sensitivity of 55%, overall specificity of 67%, and an overall diagnostic accuracy of 57%. Rose et al. (2006) identify this test with a medial meniscus sensitivity of 92%, a medial meniscus specificity of 78%, a lateral meniscus sensitivity of 95%, a lateral meniscus specificity of 93%, a PPV medial meniscus 73%, and a PPV lateral meniscus of 86%.

ACL assessment. The clinician should rule out ACL involvement prior to assessing a patient for a meniscal tear, so tests used for identifying meniscal pathology will not lead to false positives due to a concurrent injury (Fowler & Lubliner, 1989; Lowery et al., 2006). Lachman's test and the pivot shift test serve as accurate diagnoses of ACL-deficient knees preoperatively, effectively ruling out ACL injuries when these tests are negative (Katz et al., 1986). Katz et al. (1986) identified the pivot shift test and Lachman's test as having a sensitivity of 81.8% individually, the Lachman's test as having a specificity of 98%, and the pivot shift test as having a specificity of 98.4% for all ACL tears (acute and chronic). Twenty studies were included in a 2012 meta-analysis, where the overall sensitivity and specificity (without anesthesia) of the Lachman test was 81% , positive predictive value (PPV) of 88%, negative predictive value (NPV) of 72%, positive likelihood ratio (PLR) of 4.5 and negative likelihood ratio (NLR) of .22 (Eck et al., 2013). The sensitivity of the pivot shift (without sedation) was 28%, specificity 81%, PPV 94%, NPV 30%, PLR 5.35, and NLR 0.30 (Eck et al., 2013). In 2015, Leblanc et al. reaffirmed high sensitivities in both Lachman's test (89% for complete and partial, 96% for complete tears) and pivot shift (79% for complete and partial, 86% for complete tears) during non-sedation evaluation, by conducting a systematic review of 8 studies. Overall, the Lachman's test has the highest sensitivity (without sedation) for diagnosing complete ACL ruptures in clinic but the pivot shift was the most specific (with sedation) (Eck et al., 2013).

- **Lachman's test.** The Lachman's test is performed in the supine position with patient relaxed, examiner on the involved side (Katz et al., 1986). The examiner holds the knee joint in 10 to 20 degrees of flexion in a slight external rotation by stabilizing the distal femur with one hand (the outside hand, when facing a patient's head) and placing the other hand behind the proximal tibia (Katz et al., 1986). The hand on the tibia applies the anterior tibial translation, and force should be applied from the posteriormedial aspect; a negative test is one in which there is steady restraint and an immediate end point is felt (Katz et al., 1986). A positive sign is indicated by a "soft" end feel and the disappearance of the infapatellar tendon slope from tibial translation (Makhmalbaf et al., 2013; Katz et al., 1986). The Lachman's test has many modifications based on examiner hand size or patient limb size, but all positive signs are the same (Makhmalbaf et al., 2013; Katz et al., 1986).
- **Pivot shift test.** The pivot shift test is performed in the supine position with patient relaxed and examiner on the involved side (Malanga et al, 2003). The patient's hip is flexed and abducted about 30 degrees (Malanga et al., 2003). The examiner holds the patient's foot with one hand and places the other at the knee, which is placed in 10 to 20 degrees of flexion. Torque is applied to the tibia while rotating it internally (Malanga et al., 2003). A valgus force is applied to the knee joint, while the leg is flexed to 30 to 40 degrees (Malanga et al., 2003). A positive test is indicated by an anterior subluxation of the lateral tibial plateau under the femoral condyle (Katz et al., 1986; Malanga et al., 2006).

Special Tests for Meniscal Tears

According to Fowler and Lubliner (1989), McMurray's test, Apley's compression and distraction test, and the joint line tenderness test are the most commonly used tests for identifying meniscal pathology. In a 2003 review of orthopedic special tests of the knee, the 3 stated tests plus the bounce home test (forced extension) were examined and identified as reliable tests for the clinical diagnosis of meniscal tears (Malanga et. al., 2003). Thessaly's test is a more recent addition which offers a dynamic element to these well-established tests.

McMurray test. The McMurray's test has been studied by many researchers and its' specificity is reported at various ranges throughout studies. The varying range could be attributed to specific clinician deviations and/or modifications from McMurray's (1928) original methodology, but a positive sign remained the same across all studies reviewed. Modern text books often deviate from McMurray's original work clarifying hand placement, and varying flexion of the knee joint. McMurray's test is performed with the patient in supine with a flexed hip and flexed knee (heel to buttock, if possible) (McMurray, 1928). The examiner on the side of the involved limb places one hand over the joint line with the thumb and middle fingers centered on the joint line to feel for any "popping." The other hand grasps the sole of the foot, and while the patient is relaxed, the examiner has full control over the limb, externally rotating the foot while slowly extending the knee (McMurray, 1928). The examiner checks the medial meniscus with external rotation of the foot while slowly extending the knee, and the lateral meniscus with internal rotation (Hing et al., 2009). The process is repeated several times. A positive test is indicated by a palpable "click" or "pop" in the joint line; pain may be associated, but pain alone is not a positive test (McMurray, 1928; Evans et al., 1993, Hing et al., 2009)).

Lowery et al. (2006) investigated McMurray's test with an intact ACL, identifying a sensitivity of 21% and specificity of 95%. The PPV of McMurray's test associated with the ROM component was 81% and the positive likelihood ratio was 5.00 in knees treated surgically. Evans et al., (1993) stated that McMurray's "thud" is only significant in medial meniscal tears in a prospective study of 104 patients, all of whom received arthroscopy. Accuracy of medial "thud" had a specificity of 98%, sensitivity of 16%, and PPV of 83%; however, lateral pain elicited in internal rotation had a specificity of 94%, sensitivity of 50, and PPV of 29%, illustrating the "thud" was not significant in the lateral joint line, but that pain was indicative of a meniscal tear (Evans, Bell, & Frank, 1993). Kurosaka et al. (1999) identify this test with an overall sensitivity of 37%, overall specificity of 77%, and an overall diagnostic accuracy of 45%. Fowler and Lubliner (1989) identify overall sensitivity as 16% and overall specificity as 95% for McMurray's test. Konan et al. (2008) identify this test with a medial meniscus sensitivity of 50%, a medial meniscus specificity of 77%, a lateral meniscus sensitivity of 65%, a lateral meniscus specificity of 86%, a medial meniscus diagnostic accuracy of 57%, a lateral meniscus diagnostic accuracy of 77%, a PPV medial meniscus of 86%, and a PPV lateral meniscus of 50%. Karachalios et al. (2005) identify this test with a medial meniscus sensitivity of 48%, a medial meniscus specificity of 94%, a lateral meniscus sensitivity of 65%, a lateral meniscus specificity of 86%, a medial meniscus diagnostic accuracy of 78%, and a lateral meniscus diagnostic accuracy of 84%.

Apley's compression and distraction test. Apley's compression and distraction test is normally tested in conjunction with the McMurray test and the joint line tenderness test (Scholten et al., 2001; Meserve et al, 2008; Kurosaka, et al., 1999). In Apley's original research in 1947, he describes the need to recreate the mechanism of injury through compression and rotation during examination. Apley's test is performed by having the patient lie prone, with the knee flexed to 90 degrees and the examiner on the involved side (Apley, 1947). The patient's thigh is stabilized on the table with the examiner's knee (Apley, 1947). The examiner grasps the foot in both hands medially and laterally rotates the tibia, combined with a distraction force (Aply, 1947). The process is then repeated using compression. A positive test is indicated by pain with the compression force and a relief of pain with the distraction force (Magee, 2008; Malanga, et al., 2003).

Kurosaka et al. (1999) identify Apley's test with a sensitivity of 13%, specificity of 90%, and a diagnostic accuracy of 28%. Fowler and Lubliner (1989) identify the overall sensitivity as 16% and specificity as 80%. Karachalios et al., (2005) identify this test with a medial meniscus sensitivity of 41%, a medial meniscus specificity of 93%, a lateral meniscus sensitivity of 41%, a lateral meniscus specificity of 86%, a medial meniscus diagnostic accuracy of 75%, and a lateral meniscus diagnostic accuracy of 82%. All studies were based on the methodology of Apley's original work.

Thessaly's test. Thessaly's test is a dynamic reproduction of load transmission performed at 5 and 20 degrees of flexion. The examiner supports the patient by holding the patient's outstretched arms. The patient stands on a flat surface and flexes the knee to the either 5 or 20 degrees and then internally and externally rotates the knee and body three times (Karachalios et al., 2005). A positive test is indicated by discomfort in the medial or lateral joint line (Karachalios et al., 2005). A feeling of locking or catching may be felt during this test as well, which further supports the diagnosis of a meniscal tear (Karachalios et al; 2005, Harrison et al., 2009) Thessaly's test at 20 degrees has a high specificity (97.7) as well as a high sensitivity (90.3; Harrison et al., 2009.) Thessaly's test has been studied in conjunction with McMurray test, Apley's compression and distraction test, and the joint line tenderness test, and has been identified as superior to all three in a level-one study (Karachalios et al., 2005).

Harrison et al. (2009) identify this test's overall sensitivity as 90%, overall specificity as 98%, overall diagnostic accuracy as 89% and PPV as 99%. Konan et al. (2008) identify this test with a medial meniscus sensitivity of 59%, a medial meniscus specificity of 67%, a lateral meniscus sensitivity of 31%, a lateral meniscus specificity of 95%, a medial meniscus diagnostic accuracy of 61%, a lateral meniscus diagnostic accuracy of 80%, a PPV medial meniscus of 83%, and a PPV lateral meniscus sensitivity of 66%. Karachalios et al. (2005) identify this test with a medial meniscus sensitivity of 89%, a medial meniscus specificity of 97%, a lateral meniscus sensitivity of 92%, a lateral meniscus specificity of 96%, a medial meniscus diagnostic accuracy of 94%, and a lateral meniscus diagnostic accuracy of 96%. All studies followed the original procedures described by Karachalios in 2005.

Clinical Composite Tests

Using a combination of reliable tests is essential in the clinical diagnosis of a meniscal tear. The components of the composite score identified by Lowery et. al., in 2006 are as followed: positive McMurray's test, pain with terminal knee flexion, pain with terminal knee extension, joint line tenderness, and a history of clicking and/or popping. The clinical composite score has a PPV of 92.3%, specificity of 99% and a sensitivity of 11.2% for detecting meniscal tears when all 5 signs are present (Lowery et. al., 2006). The PPV and specificity decrease to 81.8% and 96.1% respectively, while sensitivity increases to 17% when only 4 signs are present (Lowery et. al., 2006). When 3 of the 5 signs are present, the PPV is 76.7%, specificity is 90.2%, and sensitivity is 30.8% (Lowery et. al., 2006); superior or comparable to magnetic resonance imaging (MRI) alone in detecting meniscal pathology (Miller, 1996).

Imaging

Magnetic resonance imaging. Magnetic resonance imaging (MRI) is routinely recommended after a clinical diagnosis of a meniscal tear prior to any surgery discussions with a patient (Miller, 1996). Four major factors are taken into consideration when using MRIs as your only diagnostic tool: (1) image quality affects the recurrence of false positive interpretations; (2) inexperienced scanners; (3) incorrect image parameters yield less than favorable diagnostic accuracy; (4) interpretation issues (Miller, 1996). Structures such as the transverse meniscal ligament, lateral inferior geniculate artery, and the popliteus tendon may replicate the presence of a meniscal tear (Boden et al., 1992; Nikolaou et al., (2008). Meniscal tears and meniscal degeneration have a similar presence on MRIs, leading to false positives (Nikolaou et al., 2008).

MRI compared to clinical exam. Magnetic resonance imaging has been compared to the accuracy of the clinical diagnosis of meniscus tears and has been found to be comparable (Miller, 1996); in some cases, a clinical exam was found to be superior than an MRI (Miller, 1996). The clinical exam using a battery of meniscal specific tests had an accuracy of 80.7%, and MRI had 73.7% accuracy (Miller, 1996). The clinical diagnosis in Miller's study consisted of detailed history, and the assessment of: persistent pain, buckling, locking, effusion, joint line tenderness, and limited function. Muellner et al. (1997) illustrated that clinical diagnoses alone had an accuracy of 89% and 89% in MRI. The clinical diagnostic accuracy in Muellner et al. (1997) study consisted of six tests: joint line tenderness, McMurray's test, Apley's test, Pahyr's test, Steimenn's test and Bohler's test.

In a retrospective analysis of MRI efficacy in detecting internal lesions of the knee, MRI was reported to be slightly better than a clinical exam, but the clinical exam did not include a detailed history and only utilized two special tests (McMurray's and Apley's; Nikolaou et al., 2008). Diagnostic accuracy using clinical exam was reported as 60%, sensitivity as 65%, and specificity as 50%, while the diagnostic accuracy of MRI was reported as 81%, sensitivity as 83%, and specificity as 69% (Nikolaou et al., 2008).

Clinical examination has been determined to have a similar, and in some cases better, diagnostic accuracy than the MRI, concluding that MRI is only necessary in cases lacking a detailed history or one that is confusing (Rose, 2006; Boden et al., 1992; Kurosaka et al., 1999; Lowery et al., 2006; Mohan & Gosal, 2007; Miller, 1996). Surgeons may also advocate for an MRI so as to not appear too aggressive in support of surgery or for financial gains (Muellner et al., 1997). Relying on MRI results in the absence of a proper clinical examination may lead to unnecessary arthroscopic procedures, as it has been well documented that meniscal tears are often found in asymptomatic patients (Troupis et. al., 2014).

Arthroscopy. Arthroscopy is considered the "gold standard" for the detection of meniscal pathology, allowing a surgeon to visually confirm an issue through a scope. Arthroscopy is a demanding procedure and dependent on the surgeon's level of experience; especially in areas that are difficult to view due to overlapping structures or small spaces (Nikolaou et al., 2008). Arthroscopy may not be a desired diagnostic tool because of the risks involved: infection, reaction to general anesthetics, and/or scarring.

Patient Outcomes Scales and Instruments

In addition to the diagnostic assessment of meniscal lesions, the patient should also be assessed with reliable patient-oriented and disease-oriented outcomes. Outcome scales help to monitor and assess the patient's well-being, pain and functionality throughout the course of treatment, allowing the clinician to assess the effectiveness of the chosen treatment. Consideration of the population for which the instrument is intended is an important aspect for the validity of any instrument (Garratt et al., 2004). Accurate outcome measures are the cornerstone in determining effective treatments from non-effective treatments (Roos, et al., 1998). An awareness of how patients perceive their injury through a physical, psychological, and social well-being lens plays a large role in the treatment process. A clinician must be able to determine the need for referral based on psychological components exceeding their scope of practice and when the presence of psychological or social components are hindering the physical healing process (Garratt et al., 2004).

Reliability refers to an instrument's' internal consistency. Validity is whether the instrument measures what it is intended to measure. Responsiveness is whether the instrument is sensitive to changes in health (Garratt, 2004). The following instruments have high reliability, high validity, and high responsiveness.

KOOS

The Knee injury and Osteoarthritis Outcomes Score (KOOS) is a self-administered patient-oriented tool that assesses five dimensions: pain, symptoms, activities of daily living, sport and recreational function, and knee-related quality of life. The KOOS is intended for patients with knee injuries that can result in OA, and has been assessed in men and women from 14 to 79 years of age (Roos & Lohmander, 2003; Roos et al., 1998). The KOOS is a self-explanatory questionnaire that assesses short- and long-term patient relevant outcomes following knee injury, including meniscal pathology. The questionnaire takes about 10 minutes to complete. Each dimension of KOOS is scored separately, and each item is answered on a 5-point Likert scale of 0 to 4; a total score of 100 indicates no symptoms. (Roos et al., 1998) Aggregate scores are not desirable, as the instrument is intended for clinicians to thoroughly assess patients on each component of the KOOS on a regular basis (Roos et al., 1998; Roos & Lohmander, 2003). Each dimension of the KOOS is scored separately, however a composite score ($KOOS_5$) from the average of all five subsections has been used for researcher purposes (Roos & Lohmander, 2003). There are currently no published MCID values for the $KOOS_{5.}$ A total score for the KOOS has not been assessed for validity or reliability; however, reliability for each subsection is as follows: ICC for pain is 0.85-0.93, symptoms are 0.83-0.95, activities of daily living are 0.75-0.91, sports/recreation are 0.61-0.89, and quality of life is 0.83-0.95 (Roos et al., 1998).

PSFS

The Patient Specific Functional Scale (PSFS) is a patient-oriented tool that assesses patients' perceptions of their functional ability and is designed to complement generic or condition specific measurement scales (Chatman et al., 1997). The PSFS should be administered during the history intake at the time of initial assessment. The patient is asked to identify up to five activities, deemed important, that they have difficulty with or are incapable of performing due to injury. The activities are rated by the patient on an 11-point scale, where 0 represents "unable to perform" and 10 represents "able to perform at level before injury." The tool takes approximately four minutes to complete. The clinician's role is to read instructions and record activities with corresponding ratings and remind patients of activities at follow-up appointments.

The PSFS score is calculated using an average of the ratings associated with each activity given by the patient. The minimum important difference (MID) noted by Abbott and

Schmitt (2014) in patients with lower limb injuries was an increase of 2.3 points for a small change, 2.7 for a medium change, and greater than 2.7 for a large change. The reported minimal detectable change (MDC) is a change in 2.5 points when using an individual activity in patients with a lower limb injury (Chatman et al., 1997). The test-retest reliability for the PSFS was found to be excellent and had an ICC of 0.84 (Chatman et al., 1997).

DPA Scale

The Disablement in the Physical Active (DPA) is a patient-oriented scale created to assess disablement across the three interrelated domains of impairment, functional limitation, and disability, as well as health related quality of life (Vela & Denegar, 2010). Responses to the DPA scale range from 1 to 5, where a score of 1 indicates that the patient does not have a problem with the listen item, and a score of 5 indicates that the patient is severely affected by the problem. During the calculation of the patient's score, 16 points are subtracted from the final score, to make 0 the lowest score and 64 the highest. The 16 points are subtracted because the scale uses a 1-5 interval to rate each item; without the 16-point adjustment a patient with no disablement would score 16 points on the scale rather than 0 (Vela & Deneger, 2010). A normal, healthy range for the DPA is a score of 34 or less, and a score less than or equal to 23 in acute patients indicates that a patient is ready for further functional testing by an athletic trainer or physician (Vela & Denegar, 2010). An MCID is a decrease of 9 points for an acute injury and a decrease of 6 points for a chronic injury (Vela & Denegar, 2010). The DPA scale was found to have a high test-retest reliability with an ICC of 0.943 and high validity for acute (r = -0.751) and chronic (r = -0.714) patients (Vela & Deneger, 2010).

NRS

The numerical rating scale (NRS) for pain has been widely used throughout the medical field and is accepted as a valid patient-oriented scale to assess levels of pain in many patient populations (Krebs et al., 2007). The NRS is a commonly used rating scale in athletic training. The NRS scale is scored on an 11-point scale, where a score of 0 represents no pain, and a score of 10 represents severe pain (Downie et al., 1978). The MCID for the NRS is a decrease of 2 points, or 33% in patients with chronic musculoskeletal pain (Salaffi et. al., 2004). The MID noted by Abbott and Schmitt (2014) was a decrease of 1.5 points for a small change, 3.0 for a medium change, and 3.5 for a large change. The NRS is widely accepted as a valid ($r = 0.90 - 0.92$, $P < 0.5- 0.1$; Good et al., 2001) and reliable (ICC of 1.00) scale (Herr et al., 2004).

Inclinometry

The Clinometer smartphone application has been found to be both valid and reliable when compared to the gold standard goniometry measurements at the shoulder (Werner et al., 2014). Inter-rater reliability was reported to be 0.8 (ICC 2,1; Werner et al., 2014), and validity was reported to be 0.98 at the shoulder in symptomatic patients (Werner et al., 2014). Currently, no studies exist validating the use of the Clinometer smartphone application in the lower extremity.

Goniometry

The goniometric levels of intra-tester and inter-tester reliability have been reported for a universal goniometer when measuring knee joint flexion (ICC of 0.997 and 0.977-0.982) and extension (ICC of 0.972-0.985 and 0.893-0.926). Validity varied from 0.975-0.987 for flexion and 0.390-0.442 for extension (Brosseau et al., 2001).

Treatment

Accurate diagnosis of meniscal lesions is the first step to producing quality outcomes in patients with meniscal tears. However, accurate diagnosis alone does not solve the patient's problem. Following up an accurate diagnosis with the proper course of treatment should be the primary focus of any experienced practitioner.

Currently, there is no general consensus on the proper treatment of meniscal injuries based on sound foundational research (Howell & Handoll, 1996). Previously, clinicians thought that meniscal surgery was necessary to prevent OA after a patient sustained meniscal lesion (Belzer & Cannon, 1993; O'Donoghue, 1980) because of increased contact forces on the articular surfaces of the joint (Belzer & Cannon, 1993). However, a cadaveric study of meniscal tears found that a patients can sustain a tear of up to 90% in either meniscus before joint arthrokinematics are significantly altered as compared to an uninjured knee (Bedi et al., 2010).

There are several surgical treatment options for meniscus injuries, including partial meniscectomy, meniscal repair, and meniscus transplant (Brophy & Matava, 2012). However, a patient's age, activity level, and lifestyle must be considered in addition to the size and location of the meniscal tear (Belzer & Cannon, 1993). Furthermore, Englund et al., (2012) reported that surgery might not be recommended for all meniscal lesions. The researchers found that almost one-third of all meniscal lesions found on an MRI are asymptomatic (Englund et al., 2012). Because surgeries have significant associated risks (Brophy & Matava, 2012), a new trend based on the arthrokinematics of the meniscus, surgery is only necessary if the meniscal tear interferes with normal joint motion is being embraced by researchers (Englund et al., 2012); others believe that conservative therapy should be exhausted first

(Hwang & Kwoh, 2014; Katz et al., 2012; Herrlin et al., 2007; Bin, Kim, & Shin, 2004). Finally, some researchers believe partial meniscectomies should be discontinued all together for certain populations, specifically middle-aged patients with degenerative medial meniscal tears (Sihvonen et al., 2013).

Partial Meniscectomy

The most common surgery performed to treat meniscus injury is an arthroscopic partial meniscectomy. Using an arthroscopic procedure, the torn section of the meniscus is removed. The goal is to retain as much intact meniscus as possible to decrease articular forces on the joint. Initially, partial meniscectomy was thought to be indicated regardless of the location of the meniscal lesions (O'Donoghue, 1980). Prevalence of partial meniscectomies has increased significantly over the past five years because of the current clinical philosophy surrounding meniscal injuries (Sihvonen et al., 2013).

In 2004, Bin et al. published a case series on 96 patients with radial tears of the medial meniscus who were treated with a partial meniscectomy after pain persisted following three months of conservative therapy. There was a statistically significant improvement in patients who had less than 50% of the meniscus torn, but no change in patients who had greater than 50% torn. The researchers suggested that partial meniscectomy should be used in patients older than 50 years of age where any portion of the meniscus was torn (Bin et al., 2004). The researchers acknowledged that preserving meniscal tissue was necessary to prevent OA, but older patients were more likely to have OA regardless of meniscal pathology (Bin et al., 2004). Removing damaged meniscal tissue to alleviate mechanical symptoms is the more appropriate option because the articular cartilage was most likely already compromised in the older patients (Bin et al., 2004).

Several years later, Herrlin et al. (2007) contradicted the results of Bin et al. (2004) in a randomized control trial. Herlin et al. (2007) found that there was no significant difference between partial meniscectomy and conservative therapy at eight weeks post-surgery and six months post-surgery and no significant difference in pre- and post-treatment activity level. The researchers suggested that conservative therapy should be exhausted before pursuing surgical options (Herrlin et al., 2007). In 2012, the researchers of another randomized control trial compared the long-term outcomes of conservative therapy to partial meniscectomy, and their results confirmed those of Herrlin et al. (2007): no significant difference in the outcomes existed in 351 patients at six months or 12 months post treatment (Katz et al., 2013).

The Meniscus Repair in Osteoarthritis Research (METEOR) study (Katz et al., 2013), the first large-scale, longitudinal study on partial meniscectomy outcomes in patients with knee comorbidities, was a randomized control trial conducted over seven sites with 351 participants. As stated previously, the researchers found no clinically significant difference between partial meniscectomy and conservative therapy at six and 12-months post treatment. While there was a 30% crossover rate from the physical therapy group to the surgery group, at six months there was no clinically significant difference in the outcomes of the crossover group and the surgery group (Hwang & Kwoh, 2014; Katz et al., 2013).

Finally, in an effort to discontinue the use of partial meniscectomies in middle-aged patients with degenerative medial meniscal tears all together, Sihvonen et al. (2013) conducted a randomized sham study on 146 patients. The researchers found no significant difference between the outcomes of a partial meniscectomy and sham surgery and no significant difference in the patients' ability to identify which surgery they underwent. The researchers also highlighted the fact that since the publication of results of Katz et al. (2013), the use of partial meniscectomies continued to grow exponentially when they should have decreased significantly (Sihvonen et al., 2013).

Over the last decade, evidence is mounting that partial meniscectomies may not lead to improved patient outcomes (Hwang & Kwoh, 2014; Katz et al., 2013; Sihvonen et al., 2013; Herrlin et al., 2007) as once believed (Belzer & Cannon, 1993; O'Donoghue, 1980), and patients also have a significant risk of developing OA in the long term, the exact outcome which the surgical technique intended to prevent (Brophy & Matava, 2012). A Cochrane review of all meniscus surgery studies performed prior to 1996 found an astounding problem: Most of the studies produced only reported surgical outcomes and surgical technique with no control or alternative therapy outcomes, and the ones that did exist were significantly biased and flawed (Howell & Handoll, 1996). While the aforementioned research studies are not without their minor flaws (e.g., small sample sizes, studies conducted on the general population, not controlling for outside treatments (Herrlin et al., 2007; Bin et al., 2004; Hwang & Kwoh, 2014), the results published in these studies account for the level 1 evidence requested by Howell and Handoll (1996).

Meniscal Repair

Meniscus repair is a procedure in which the lesion is sutured, and all of the meniscal tissue is retained; however, meniscal repair is not always indicated. Meniscal repair is only successful when the tear occurs in the small vascular portion of the meniscus (Getgood & Robertson, 2010). Tears in the vascular portion of the meniscus occur in 60.7% of ACL comorbidity patients, but only in about 40% of ACL-intact patients (Metcalf & Barrett, 2014). Currently, several studies have been published where the researchers identify the failure rates of meniscal repair procedures (Lyman et al., 2013; Nepple, Dunn, & Wright, 2012; Pujol

Barbier et al., 2011), but published research studies comparing the outcomes of meniscal repair against any other treatment paradigm are limited in quantity.

The statistics on the failure rates of meniscal repair surgery vary greatly. Getgood and Robertson (2010) estimated that meniscal repair surgeries had a 42% failure rate, but only if performed more than three months post-injury. Nepple et al. (2012) concluded that the overall failure rate greater than five years was between 22.3% and 24.3%, and 29% of the failures occurred after two years. In contrast, Pujol et al. (2011) conducted a retrospective cohort study on the failure rates of meniscus repair and subsequent partial menisectomy; the failure rate was 12.3% overall, of which 53% of patients sustained a subsequent lesion equal to, but not greater than, the initial lesion, and 31.3% sustained a smaller subsequent lesion (Pujol et al., 2011). Finally, in patients under 40 years of age, the failure rate was estimated to be 8.9% if the patient sustained a medial meniscal tear and the surgeon performing the procedure participated in more than 24 meniscal repair surgeries per year (Lyman et al., 2013).

While the failure rate is widely disputed, the outcomes of meniscal repair compared to partial meniscectomies are limited in quantity, but clear. Paxton et al. (2011) conducted a systematic review of four studies comparing the outcomes of partial meniscectomies with those of meniscal repair, finding that the latter group had a lower reoperation rate than the former. The meniscal repair groups also had improved disability outcomes compared to the partial meniscectomy group (Paxton et al., 2011). Most researchers are hesitant to refute the efficacy of meniscal repairs, even with a failure rate between 8.9% and 42% (Lyman et al., 2013; Nepple et al., 2012; Pujol Barbier et al., 2011) because more research is needed to corroborate not only the failure rates, but the effect and the efficacy of the treatment and its outcomes as compared to conservative therapy.

Meniscal Transplant

Meniscus transplant is a fairly new development in the treatment of meniscal lesions and was developed through an anatomic cadaveric study (Kohn & Moreno, 1995). Meniscal transplant surgeries were performed as early as 1980, but were and continue to be mainly experimental. As of 2010, only 4,000 procedures total had been performed in the United States (Getgood & Robertson, 2010), which is minuscule compared to partial meniscectomies occurring at the rate of 700,000 per year (Sihvonen et al., 2013).

The meniscus does not have an immune response, so replacement or transplant is fairly uncomplicated, and allograft tissue can either be sutured to meniscal remnants or to posterior and anterior attachments (Getgood & Robertson, 2010). Meniscal lesions must be measured extensively in order to ensure the correct size of the allograft. This can be accomplished through X-ray, bone scan, computerized tomography scan, MRI, and arthroscopy. Allografts, however, have a failure rate of 44% (Peters & Wirth, 2003) to 49% (Vundelinckx, Vanlauwe, & Bellmans, 2014).

In regards to autografts, a multitude of possibilities are being explored for potential tissue donor sites (Makris, Hadidi, & Athanansiou, 2013). Meniscal autografts through growth of meniscal scaffolds from donor tissue are in development (Getgood & Robertson, 2010). There are no reliability or outcomes studies for meniscal autograft transplant because the autografts currently do not resemble or mimic the original meniscus (Makris et al., 2013).

A more recent theory has begun to develop over the last decade that focuses on the surgical treatment of meniscal tears. This theory argues that surgery may not be the quintessential treatment and that conservative therapy treatment paradigms should be investigated further (Hwang & Kwoh, 2014; Katz et al., 2013; Sihvonen et al., 2013; Herrlin et al., 2007) as once assumed (Belzer & Cannon, 1993; O'Donoghue, 1980). Conservative treatment can involve various manual therapy techniques and has been shown to effectively resolve symptoms and increase function (Englund et al., 1992).

The Mulligan Concept

Background

Manual therapy encompasses a wide array of techniques and theories of efficacy (Threlkeld, 1992). The history of these techniques are rooted in the studies and research of well-known scientific scholars and are used for many different musculoskeletal injuries; however, the conservative treatment of symptoms of meniscal tears using the Mulligan Concept (MC) has not been explored. The MC was developed on a mobilization with movement (MWM) theory and principles that involve compression, traction, and/or articulation (joint mobilization) of the restricted or painful joint (Hing, Hall, Rivett, Vicenzino, & Mulligan, 2015; Mulligan, 1993; Mulligan, 2004; Mulligan, 2010; Vicenzino, Hing, Rivett, & Hall, 2011). The MC interventions incorporate a sustained passive joint mobilization during the patient's active movement, which may address and correct pain and discomfort at the knee due to meniscal tears.

The Positional Fault Theory

The MC "Squeeze" technique efficacy in treating meniscal tear symptoms is based primarily in the technique's physiological correction of a theoretical positional fault of the knee joint (Mulligan, 2010). Specifically for the "Squeeze" technique, Brain Mulligan proposes a mechanical lesion called "an abnormal meniscal distortion" should be considered when patients are complaining of meniscus tear symptoms. A typically mechanism of meniscus tears of twisting of the knee while weight bearing could cause the meniscus to distort slightly in towards the periphery of the knee (Mulligan, 2010).

Mulligan's positional fault theory is based in the foundational knowledge of normal arthrokinematics of the joint and the changes that may with injury. Mulligan theorized that minor positional faults occur secondary to injury and cause joint mal-tracking, which leads to pain, stiffness, and/or weakness (Mulligan, 1993; Mulligan, 2004). The changes that occur within the joint are not just limited to the joint surface itself, but also effects connective tissue and all other associated structures within the joint. For example, after a mechanism of injury for meniscus tears occur, meniscal tissue within the joint could cause the joint to become blocked and lose motion thus leading to pain and dysfunction. Gale et al. (1999) also determined that meniscal subluxation is common in knees with OA and is correlated with the severity of joint space narrowing on plain radiographs, thus supporting a faulty mechanical component causing pain and dysfunction. If a meniscus has become dislodged or torn and flaps of the tissue are trapped within the joint, classic meniscus tear symptoms such as knee-joint locking, clicking, pain, and loss of motion could occur, along with other mechanical joint positional dysfunctions.

Although secondary faults due to injury are not typically observed via diagnostic imagining (Mulligan, 1993), evidence of joint positional faults have been reported in both clinical and laboratory settings (Hsieh-Y, Vicenzino, Yang, Hu & Yang, 2002; Hubbard & Hertal, 2008; Hubbard, Hertal & Sherbondy, 2006; Kavanagh, 1999; Fukuhara, Sakamoto, Nakazawa, & Kato, 2012). However, the positional fault theory is not universally accepted and although more evidence continues to be produced, it remains theoretical.

Hsieh-Y et al. (2002) observed a single case study where MRIs were taken of a thumb over a period of three weeks. Imaging was performed before the application of a MWM treatment, and a positional fault was observed. Follow-up imaging was performed immediately after the treatment, and the positional fault was absent; the patient also reported a resolution of symptoms. A three-week follow-up MRI revealed a return of the fault in the joint, but the patient did not report a return of the symptoms. Limiting factors in this study were a lack of statistical analysis and the utilization of one patient. Those factors provide low level evidence and an inability to make a definitive statement that all injuries lead to positional faults which MWMs are indicated to correct.

Support for the presence of a positional fault in chronic ankle instability and in acute and subacute ankle sprains is also found in the literature (Berkowitz & Kim, 2004; Hubbard & Hertal, 2006; Hubbard, Hertal, & Sherbody, 2006; Kavanagh, 1999; Vincenzio, Paungmali, & Teys, 2007). The studies are inconclusive as to whether the positional fault predisposed the participant to injury or if it was caused by the injury, even though significant differences in fibular positioning on the talus was observed in both sub-acute lateral ankle sprain and chronic ankle instability participants as compared to the uninjured ankle and matched controls. Thus, likely supporting positional fault to be the result of injury rather than the cause. The results, however, are promising and suggest that, if these faults exist, treatments such as MWMs would be effective in correcting joint positioning that has been altered due to injury. More research is needed in this area to determine if Mulligan's positional fault theory can be consistently and scientifically accepted.

One possible positional fault mechanism of the menisci within the knee joint could be supported using a physiological rationale similar to the meniscoid in the cervical spine. Hearn and Rivett (2002) explored the biomechanical reasoning for pain relief after a Sustained Natural Apophyseal Glide (SNAG) in the cervical spine. The researchers assessed the role of the meniscoid in zygopohyseal joint dysfunction. The meniscoid in the cervical spine is reminiscent of the mensci in the knee. They both have similar functions and positioning within their respective joints. Hearn and Rivett (2012) discussed the possibility of the meniscoid becoming entrapped between the cervical vertebrae or displaced on the articular surface after the vertebrae returns to the neutral position from an open packed position, much like the meniscus can cause a joint to become mechanically stuck after a patient has been sitting for extended period of time with the knee in an open packed position. The review implicates the possibility that a cervical SNAG could lead to a decrease in pain by separating the facet surfaces and releasing the meniscoid or allowing the trapped segment to return to its normal resting position and normal arthrokinematic function. Also noted is a possibility of stretching adhesions that are secondary to positional faulting of the meniscoid or to the joint capsule in the knee joint, which is attached to the meniscus and may have developed adhesions secondary to meniscal pathology.

Neurophysiological Effects

The body's ascending and descending pathways for pain perception and modulation occur along the same route to the central nervous system (Ossipov, Dusso, & Porreca, 2010). Researchers also theorize the origin of pain associated with meniscal pathology is the result of compression on the peripheral nerve supply on the outer horn of the structure (Renstrom & Johnson, 1990), where joint impingement on the nerve sends noxious signals to the spinal cord and upward to the supraspinal mechanisms of pain perception. Theoretically, chronic pain will continue to exist as long as the tissue of the meniscus is compressed and signals are continually relayed to the brain.

Multiple theories exist to explain how and why joint mobilizations contribute to pain relief in patients with painful and restrictive movement. Melzack and Wall's (1965) classic gate control theory offers insight to a possibility that passive joint movement initiates segmental inhibitory mechanisms that cause spinal mechanisms of pain control to block the noxious signal's pathway to the brain. The peripheral touch stimulated large A-Beta fibers may transmit non-painful contact stimulus faster to the central nervous system (CNS) than smaller noxious transmitting delta fibers (Vicenzino et al., 2011). Initiation of sympathetic nervous system responses were observed after a treatment of MWMs, eliciting similar responses of pain relief to those seen after spinal manipulation (Paungmali, O'Leary, Souvlis, & Vicenzino, 2003). While neurophysiological implications involving CNS hypoalgesia for most MC techniques are accepted, researchers have not concluded the mechanism by which the technique produces the hypoalgesia effect. However, Paungmali et al. (2003) suggest that the hypoalgesic effects of MWMs at the elbow to treat lateral epicondylalgia was not produced by an opioid pain-modulating mechanism and may have resulted from other mechanisms of pain control.

Many studies have been conducted which support the mechanical hypoalgesia component of the MC, but most are case studies or case series with small sample sizes concentrated on the shoulder, elbow, or ankle (Collins, Teys, & Vicenzino, 2004; Paungmali et al., 2003; Slater, Arendt-Nielson, Wright, & Graven, 2006; Teys, Bisset, & Vicenzino, 2008). Studies conducted to explore the hypoalgesic effect in the knee resulting from joint mobilization have typically involved patients with osteoarthritis. While osteoarthritis has been indicated as a secondary joint disease due to meniscal injury (Englund et al., 2009), no studies have measured pain reduction in patients with meniscal pathology exclusively. Despite this, hypoalgesia mechanisms and a physiological component are also suspected to contribute to positive outcomes of the treatment as well.

Psychological Implications

Psychological or psychosocial involvement may also contribute to positive outcomes of the MC "Squeeze" technique; supporting implications of the mechanisms of efficacy of the MC to provide a placebo effect after treatment is completed (Vincezino, Hing, Rivett, & Hall, 2011). The mechanisms by which this may occur lay in musculoskeletal interventions that affect a variety of patient components not directly related to the physical injury itself. The history of both the patient and clinician, in addition to a patient's exposure to pain, healing, and fears about treatment, play a role in how effective the treatment will be for the patient (Bialosky, Bishop, Price, Robinson, & George, 2009; 2011; Vicenzino et al., 2011).

Pain relief has physiological mechanisms by which the placebo and psychological effect takes place. Bialosky, Bishop, George, and Robinson (2011) suggested interpreting and classifying the placebo effect of manual therapy as an active ingredient in pain reduction, while Miller and Kaptchuk (2008) suggested interpreting the placebo effect as 'contextual healing' instead of an unexplained positive reaction to an intervention.

The placebo effect is typically used to determine the efficacy of an indicated therapeutic intervention and disregarded as actively contributing to positive patient outcomes. If the therapeutic intervention does not elicit considerable significant positive outcomes compared to the placebo, the treatment is classified as ineffective (Bialosky et al., 2011). As placebo hypoalgesia relates to MWMs and other treatment interventions, studies support the placebo's relationship to the central nervous system's descending pain inhibitory pathways from the supraspinal structures (Bialosky et al., 2011). Whether or not MWM's hypoalgesic effect is based in actual accepted mechanisms of pain control by correcting biomechanical and physiological faults or by way of the placebo effect is of no difference. If patients are reporting positive outcomes for pain reduction and increases in function, the treatment is successful and indicated for the patient's condition.

Teys et al. (2008) determined during a study on shoulder pain and range of motion that patients receiving a sham treatment gained increases in range of motion and decreases in pain as compared to the control group. While the MWM treatment group had the most significant gains, the study lends credit to both the efficacy of MWMs for the treatment of shoulder pain and restriction and also to the consideration of using a placebo effect as a viable and useful component of manual therapy.

Vicenzino, Paungmali, and Teys (2007) concluded that while the implications and speculations of neurophysiologic involvement elicited from the MWMs is accepted, the actual effect of the technique is much more complex and multifaceted. The implications for other psychological components along with the placebo effect involve diminishing a patient's previous perception that movement at a particular joint is painful. By applying the MWM and instructing the patient to move through the now pain-free range, the previous fearful memory may be eliminated (Vicenzino et al., 2011).

The Mulligan Concept "Squeeze" Technique Procedure

The basic treatment application for all MWMs incorporates Mulligan's rules and principles for the intervention. Mulligan advocates that his techniques be pain free during the patient's full range of motion. If at any point the movement becomes painful while the glide is applied, the clinician is to stop the movement and adjust the glide. For the treatment to be indicated, the clinician must be able to apply the correct glide to provide the patient with a pain-free range of motion. If pain-free motion is not achieved, the patient may fall within the contraindications of the technique or other principals of the treatment may have not been followed (Mulligan, 1993; Mulligan, 2004; Mulligan, 2010; Vicenzino et al., 2011; Vicenzino, 2011; Hing et al., 2015).

The MC uses the acronym "CROCKS" (contraindications, repetitions, overpressure, communication, knowledge, and skills, subtle movement, sustain, and sense) to serve as a reminder of the general principles for all its intervention ns. If all of these principles are followed, Mulligan suggests that a PILL effect (pain free, instant, long-lasting) will occur for the patient (Hing et al., 2015; Mulligan, 1993; Mulligan, 2004; Mulligan, 2010; Vicenzino et al., 2011).

The technique for the MC "Squeeze" incorporates patient generated open packed positioning of the knee joint, compression of the joint space, and a minor fibio-tibial glide either posterior or anterior dependent upon flexion or extension restrictions. Minimal tibial-femoral rotation may be required if an alteration is needed to provide pain relief (Hing et al., 2015; Mulligan, 1993; Mulligan, 2010). To perform the technique correctly, the patient may be placed in a weight-bearing or supine position. The approach for treating flexion may be done either supine or standing, but treatment for extension can only be done while the patient is supine (Mulligan, 2010; Hing et al., 2015).

The clinician begins the treatment by first testing for restrictive movement and/or local pain during knee flexion or extension, depending on the primary complaint of the patient. If a restriction and/or pain is noted while the patient is supine, the treatment is performed supine;

if the restriction and/or pain is noted during a weight-bearing activity, the patient is treated during the weight-bearing activity.

To perform the technique in the supine position, the clinician will begin by palpating the medial and lateral joint line of the knee to locate an area of most tenderness. If tenderness is noted over the postero-medial or medial joint space of the right knee, the clinician will stand at the left side of the patient; however, if tenderness is noted over the lateral joint line, the clinician will stand on the same side as the patient. The clinician will place the medial border of one thumb, reinforced by the other, over the tender joint space and instruct the patient to actively and slowly flex the knee so the joint space will open. When the clinician begins to feel the joint space open beneath the thumbs, a squeeze is applied centrally. While squeezing centrally, the clinician encourages more joint flexion using the ulnar border of the hand that is over the upper end of the tibia. The patient may experience localized discomfort from the overlap grip to tolerance, but the localized discomfort should not be exacerbated with movement. The clinician maintains the squeeze and overpressure for a few seconds, repeat three times, and then reassess motion. This MC "Squeeze" technique, while effective, is uncomfortable due to the pressure caused underneath the clinician's thumb while the squeeze portion of the treatment is performed, but the movement itself should not be painful (Mulligan, 2011). Other MWMs have a pain-free requirement (Mulligan, 1993).

The same technique and hand placement is used for a weight-bearing patient. The clinician will kneel beside the patient and place the his or her thumbs over the joint margin, as indicated for the supine patient. The clinician will then instruct the patient to perform a squat during the movement, at which point the clinician will apply thumb pressure as the joint space is revealed. The patient may feel more comfortable holding on to a table or a chair for support during the weight-bearing alternative. The squeeze is held for a few seconds and then three more repetitions are done before reassessing for pain and motion (Hing et al., 2015; Mulligan, 2010).

The pressure or squeeze from the clinician occurs centrally, from the tender point (as noted in the assessment). The direction of the squeeze is important to mention because of the anatomical movement of the menisci during flexion and extension of the knee, especially if the tender point is located along the lateral joint line. The lateral meniscus is more mobile than the medial meniscus and is pulled anteriorly during knee extension via the patellomensical ligament. During the last few degrees of flexion, the menisofemoral ligament pulls the posterior horn of the lateral meniscus medially and anteriorly (Vedi, Spouse, Williams, Tennant, Hunt, & Gedroyc, 1999). Patients complaining of pain with extension and full flexion may benefit most from the squeeze technique because of the clinician's hand placement and the direction applied in the joint space during active movement.

Efficacy of Treatment of Mobilization with Movement

Hing et al. (2007) conducted a review of all relevant MWM studies and reported significant positive results with the treatment application when compared to placebo or controls. The authors found only one study that did not report notable improvements from applications of MWMs, but this study conducted by Slater et al. (2006) pertained to outcomes of lateral epicondylalgia induced by the research team.

Support exists for the mechanical correction of a theoretical positional fault. In regards to the mechanisms of pain control related to a hypoalgesic effect and psychological theories, Bialosky et al. (2009) suggested a combination of both biomechanical (e.g., positional fault) and neurophysiological (e.g., hypoalgesia) mechanisms are responsible for the efficacy of manual therapy techniques, such as MWMs, for treating musculoskeletal injuries. The MC "Squeeze" technique involves direct pressure on the tender point in the joint space which may incorporate both a mechanical correction of a displaced meniscus and a hypoalgesic effect. By applying direct pressure into the joint line, the potentially displaced tissue could be placed back into its normal anatomical position. Moreover, correcting a potential position fault could lead to a return to functioning arthrokinematics of the joint. The pressure provided by the clinician during the technique also causes minor discomfort to the patient which may elicit peripheral mechanisms of pain control such as endogenous opioids thus, contributing to a decrease in pain.

Conclusion

The MC "Squeeze" technique is a recommended option for conservative therapy of meniscal tears. The manual therapy intervention is designed to treat limited range of motion and localized joint line pain during movement (Mulligan, 2010), which are symptoms often found in the presence of meniscal tears (Lowery et al., 1996). Despite the theorized benefit of this technique with these patients, the authors of this literature review could not identify formal investigations of the efficacy of this treatment. Therefore, research is to examine the effect of the MC "Squeeze" technique in physically active patients who present with clinical symptoms of meniscal tears and meet the criteria for a clinical diagnosis of a meniscal tear.

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CHAPTER 5

Applied Clinical Research: Multi-Site Case Series

Title

Innovative Treatment of Clinically Diagnosed Meniscal Tears: A Randomized Sham-Controlled Trial of the Mulligan Concept "Squeeze" Technique

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Abstract

Background: Meniscal tears are a common injury, often leading to surgery or lengthy conservative treatment. Arthroscopic surgery is currently the gold standard for treatment; however, this option may lead to subsequent surgeries and osteoarthritis prompting a need for alternative treatment options for meniscal tears.

Purpose: To assess the effects of the Mulligan Concept (MC) "Squeeze" technique compared to a sham technique in participants presenting with a clinically diagnosed meniscal tear.

Study Design: A multi-site randomized sham-controlled trial.

Methods: Participants (n=23) were recruited as a sample of convenience in a physically active and sedentary population, ranging from 14-62 (age = 24.91 ± 12.09) years of age, who reported common symptoms of a meniscal tear. Randomization ensured equal distribution of participants into either the MC "Squeeze" technique treatment group or the sham group. A maximum of 6 treatments were applied within a 14-day period for each treatment. Patients were assessed using the Numeric Pain Rating Scale (NRS), Patient Specific Functional Scale (PSFS), the Disablement in the Physically Active (DPA) scale and the Knee Injury Osteoarthritis Outcome Score (KOOS).

Results: All participants in the MC "Squeeze" group met the discharge criteria of ≤ 2 points on the cumulative NRS, ≥ 9 points on the PSFS, and ≤ 34 points on the DPA Scale for chronic and ≤ 23 for acute injuries at the end of the treatment intervention. A significant difference was found on the changes in PSFS scores ($F(1, 21) = 4.40$, $p = .048$, partial eta squared = .17, observed power = .52) and DPA Scale scores at discharge ($F(1, 21) = 7.46$, $p = .013$, partial eta squared = .27, observed power = .74) between the two groups.

Conclusion: The results indicate the MC "Squeeze" technique had a positive effect on patient function and health-related quality of life over a period of 14 days that was clinically and statistically superior to the sham treatment.

Clinical Relevance: The MC "Squeeze" technique is an effective treatment for reducing symptoms associated with meniscal tears in a patient population meeting the criteria for a clinical diagnosis.

Key Terms: Knee Pain, Rehabilitation, Manual Therapy, Meniscal Tears

Introduction

The incidence of lower body injury, especially knee injuries, has grown[45,59] due to increased participation in recreational sports[24,53] and intercollegiate athletic competition.[27] Meniscal tears commonly occur as a result of sport participation[45] and, in a 10 year epidemiologic study on the occurrence of knee injuries, researchers found meniscus tears were the second most common knee injury.[45] Meniscal injuries are not only common in the young, athletic population; 35% of adults over the age of 50 experience degenerative tears.[34]

Injuries to the meniscus are often the result of compressive forces placed on the meniscus by the tibia and femur during flexion and rotation during weight bearing.[46] A meniscal tear can affect critical functions of the meniscus, such as joint congruency, load transmission, and shock absorption[22,38] leading to the classic signs and symptoms of a meniscal tear: catching, locking, or clicking; joint line pain; and a feeling of "giving out" or instability.[39] Despite the importance of the meniscus tissue for function, incidental findings of asymptomatic tears on magnetic resonance imaging (MRI) are relatively common,[40,62,73,70] suggesting the presence of a meniscal tear does not directly correlate to knee disability. In theory, patients with meniscal tears may not seek medical treatment if physical symptoms that would indicate injury or pathology are not being experienced. Therefore, the presence of meniscal lesions on MRI findings may not equate to the pathology being the root cause of dysfunction.[62,73]

When a meniscus tear is diagnosed, treatment options are typically categorized as surgical, involving partial meniscectomy or meniscal repair, or non-surgical, which is defined as conservative therapy.[47] Arthroscopic surgery currently remains the proposed gold standard for treatment of meniscal tears. Arthroscopic partial meniscectomy (APM) is often a more attractive surgical option for patients due to shorter post-surgery rehabilitation time-lines.[20] An APM occurs in as many as 61 per 100,000 meniscal tears[23] and approximately one-third of patients who exhaust conservative care will go on to have a meniscectomy to decrease pain and increase function.[47] Although patients elect to have APM more often, the APM procedure has inconsistent results for alleviating the symptoms of meniscal tears[54,50,41,34,63] and 50% of patients who undergo APM develop knee OA symptoms confirmed by radiographic images years after surgery.[16,17,19,20] Furthermore, the severity of symptoms and the extent of cartilage damage seen on imaging in patients who underwent APM is worse than the damage observed in cases of degenerative meniscus tears.[16,17,19,20]

Preservation of the meniscus through arthroscopic surgical repair is considered the most ideal option;[20] however, failure rates have been reported as high as 42% following those procedures[23] and the risk for subsequent surgeries is as high as 20%.[52] Consequently, patients who undergo any type of meniscal surgery are at risk for requiring subsequent surgeries,[52] which suggests clinicians should exhaust conservative care options for meniscus tears before pursuing surgical options.[26]

Recommendations for conservative therapy for meniscus tears commonly includes active exercises focused on increasing range of motion (ROM) and muscle strength while improving balance and flexibility.[26,47] Although conservative therapy protocols are recommended as an alternative to surgery,[26,34,30] lengthy timelines[47] and poor outcomes[26,34,30] may make those protocols less appealing to patients. Time commitment for conservative care has been reported to be between 8 and 10 weeks with patients performing therapeutic exercises 3 times a week or more[47] and no significant difference was found between the immediate and long-term outcomes of partial meniscectomy and conservative therapy in middle aged patients with degenerative medial meniscal tears,[26,34,30] Because reported outcomes of surgery and conservative care are similar and have inconsistent results,[26,34,30] there is a need for research into non-operative alternative treatment methods for treating the symptoms of meniscal tears.

The Mulligan Concept (MC) is a manual therapy paradigm with specific techniques theorized to address the symptoms associated with meniscal tears.[49] One of those techniques, the MC "Squeeze" technique, is designed to treat range of motion deficits and pain localized to the joint line of the knee during movement.[49] Such symptoms are often reported in the presence of meniscal tears due to altered joint mechanics and function caused secondarily by the disruption of meniscal tissue.[4] If meniscal tissue is dislodged or subluxed from its normal anatomical position after a tear, the disrupted tissue may cause increased pressure on the highly innervated periphery of the meniscus tissue and result in the commonly reported symptoms.[55,38,71,15] Conceivably, to alleviate the pain and dysfunction resulting from the tissue disruption, the abnormal pressure on the periphery of the meniscus and the pain-sensitive anterior capsular structures need to be resolved. Within the MC, it has been proposed that relocating the tissue towards the midline of the joint would reduce pain because the periphery of the menisci would no longer send pain signals.[49] The MC "Squeeze" technique may produce this benefit through the application of a therapeutic pressure to the meniscus.[49] Pressure is applied through a "squeezing" force on the meniscus at the most tender/swollen point along the joint line while the patient actively flexes and extends their knee to mobilize the tissue back to its normal anatomical position.[49]

The MC "Squeeze" technique has produced favorable patient outcomes for clinically classified meniscal tears in anecdotal reports and published *a priori* case studies.[5,29] In these reports, patients reported positive changes in pain, function, disability, and psychosocial well-being on patient reported outcome measures; however, the small sample size and lack of comparison groups necessitates the need for further investigation to determine the effectiveness of the MC "Squeeze" technique. Therefore, the purpose of this study was to assess the effects of the MC Squeeze technique compared to a sham technique in participants presenting with a clinically diagnosed meniscal tear.

Methods

Study Design

The present study was a multi-site randomized sham-controlled trial, designed to be conducted across four clinics with four clinician-researchers providing treatment. Clinical experience among the clinician-researchers ranged from 3-10 years (mean = 6.5 ± 2.89 years), but each had equal experience and training in the MC. Prior to beginning this study, the clinicians all completed two accredited MC courses together and had one year of experience in applying the MC in patient care. Additionally, a training session was conducted in-person with the four clinician-researchers to review methods prior to commencing the study. The training involved the review of all inclusion/exclusion orthopedic tests and dependent variables, and the verification of MC "Squeeze" technique application by a certified MC teacher with over 20 years of experience within the MC.

The Institutional Review Boards at the four clinical sites approved the application of treatment and collection of medical information from the participants in this study. Participant recruitment took place between October 2015 and March 2016. Participants signed written informed consent acknowledging possible publication of de-identified outcomes, and consent/assent forms were collected from all minors participating in this study.

Participant Selection

Participants were recruited as a sample of convenience, physically active and sedentary participants, ranging from 14-62 years of age. Any participant who reported any of the common symptoms of a meniscal tear with various mechanisms of injury or onset of symptoms (i.e., acute and chronic) was considered for participation in this study at each clinical site. Participants were screened by the clinician-researchers using an extensive medical history, common knee orthopedic tests, muscle/strength integrity, and range of motion (ROM) assessments.

Inclusion criterion were a positive finding in a minimum of three of the following: McMurray's test, pain with maximal knee flexion, pain with maximal knee extension, joint line tenderness, and a history of clicking and/or popping.[39] The preceding inclusion criteria ware formed according to the clinical composite score (CCS) developed by Lowery et al.[39] (Table 5.1). When three of the signs were present, the CCS had a specificity of 90.2% and a positive prediction value (PPV) of 76.7%;[39] in comparison, an MRI has a specificity of 69-93.3%[10,51] and a PPV of 80.4-83.2%[10] for meniscal tears. Participants were also required to present with a positive finding in a minimum of one of the following orthopedic tests: Apley's compression and distraction (specificity = 90%);[31] and Thessaly's performed at 20 degrees of knee flexion (specificity = 96-97%).[37] Exclusion criteria were the presence of knee comorbidities, such as anterior cruciate ligament (ACL) tears, knee contusion, fracture, knee dislocation, other knee ligament instability, and non-mechanical causes of pain (e.g., hyperalgesia).

Randomization

An *a priori* randomization was designed to ensure equal distribution of participants into either the MC "Squeeze" technique treatment group or the sham group. Participant numbers were randomly generated prior to the commencement of the study and assigned prior to clinical exam. Each clinician-researcher was assigned a set of participant numbers consisting of an equal distribution of participants to treatment groups. If a participant was disqualified based on the results of their clinical exam, the participant number was assigned to the next eligible participant.

Outcome Measures

Patient outcome measures were collected to track participant progress and treatment effects. Patient outcomes included the Numeric Pain Rating Scale (NRS), the Patient Specific Functional Scale (PSFS), the Disability in the Physically Active (DPA) Scale, and the Knee injury and Osteoarthritis Outcome Score (KOOS). Cumulative NRS and PSFS were collected at intake, daily pretreatment, and 24-hours after the final treatment. Current NRS and PSFS scores were also collected daily after each treatment intervention. The DPA Scale and KOOS were only collected at intake and 24-hours after the final treatment.

Numeric Rating Scale (NRS). Participant reported level of pain was measured using the NRS. The NRS is a patient-oriented scale used among various patient populations.[35] The NRS is scored on an 11-point scale, with 0 representing no pain and 10 representing severe pain.[11] Cumulative NRS is calculated as an average of the current, best, and worst pain scores over the past 24 hours. The reported minimal clinically important difference (MCID) for the NRS is a decrease of 2 points or 33%.[61]

Patient Specific Functional Scale (PSFS). Participant function was measured using the PSFS. The PSFS is a patient-oriented tool that assesses the patient's perception of their current functional ability.[64] The participant is asked to list up to three activities which are affected by their injury and rate their perceived ability to perform each activity on a scale from 0 (unable to perform the activity) to 10 (able to perform the activity at the same level as before the injury occurred). For this study, each participant was asked to identify the single activity most affected by his or her knee injury and rate it using the PSFS 11-point scale. The same activity was used to assess PSFS throughout the duration of the study. The reported minimal detectable change (MDC) is a change in 2.5 points when using an individual activity in participants with a lower limb injury.[8]

Disablement in the Physically Active (DPA) Scale. Participant physical impairment, functional limitation, disability, and health-related quality of life[68] were measured using the DPA Scale. The DPA Scale is a questionnaire in which responses are based on a scale ranging from 1 (no problem) to 5 (severe problem) across 16 items; 16 points are subtracted from the total to create a total possible score range from 0 to 64 points.[68] A normal, healthy range has been observed to be a score of less than 35, and a score of 23 or less has been observed in participants deemed ready to return to full participation after injury by an athletic trainer or physician.[68] The MCID is a decrease of 9 points for an acute injury and 6 points for a chronic injury.[68]

Knee Injury Osteoarthritis and Outcome Score (KOOS). The KOOS is a questionnaire designed for patients suffering from a knee pathology often associated with osteoarthritis, including ACL tears, meniscal tears, and chondral lesions. The tool includes questions regarding pain, symptoms, and functional limitations in activities of daily living and sport/recreation, as well as quality of life. Responses within each dimension are based on a scale ranging from 0 to 4; a total score of 100 would indicate no symptoms.[58] The MCID for each subsection is a change of 8-10 points.[58] However, an MCID value has not been established for $KOOS_{5}$,[58] which is a composite score of all five subsection scores.

Treatment Interventions

Treatment and participant position began in the same position that elicited knee symptoms during assessment, which was either supine/non-weight bearing (NWB), partial weight bearing (PWB), or full weight bearing (FWB)[49] for both treatment options.

Mulligan Concept "Squeeze" Intervention. The clinicians placed themselves in a position of biomechanical advantage based on each participant's individual treatment position. The participant actively placed the involved knee in approximately 90 degrees of flexion (allowing access to the joint line) or to the participant's pain-free limit of flexion in NWB. The clinician then placed the medial border of one thumb (i.e., the contact thumb) on the site of maximum pain and/or joint line edema (i.e., joint line tenderness), while the other thumb (i.e., the mobilizing thumb) was used to apply a force through the first thumb in an overlapping manner (Figure 5.1). Next, the participant extended their knee through their pain-free range, while the clinician maintained contact force with thumbs, releasing the force as the joint space closed in maximal knee extension (Figure 5.2). The participant then performed active knee flexion as the clinician continued to apply a "squeezing" force towards the center of the joint until maximal knee flexion was reached (Figure 5.3). The clinician held the pressure at the joint line for two seconds as the participant applied overpressure by pulling their tibia with both hands to their end range of knee flexion (Figure 5.3). If a participant could not grasp their tibia, they were given a strap to assist them into flexion (Figure 5.4). The participants returned to their end-range of knee extension, while the clinician released the force as the joint space closed. The participants were allowed to experience localized discomfort from the overlap grip, but the localized discomfort was not exacerbated with movement.

When participants were restricted in flexion, they were asked to perform active knee flexion only (Figure 5.3). Participants, who were restricted in extension, were asked to perform active knee extension only (Figure 5.2). Participants, who were restricted in both flexion and extension, were asked to perform knee flexion first, followed by knee extension. The treatment consisted of three sets of 10 repetitions with a minimum of 30 seconds of rest between each set. As the participants progressed towards full weight bearing, the participant position during treatment application also progressed from supine to partial weight bearing (Figure 5.5) to full weight bearing (Figure 5.6). Each participant was monitored for any increase in pain throughout the technique in accordance with MC treatment principles.

Sham Intervention. The "sham" treatment followed the same protocol as the MC "Squeeze" group (i.e., flexion/extension movement pattern was consistent) with the exception of the hand placement and the force. The hand placement for the sham treatment consisted of the same overlap grip of the thumbs, but the clinician applied the "squeeze" a ½ inch below the point of maximal joint line tenderness (Figure 5.7, 5.8). To provide consistent force using the sham treatment across treatment applications and participants, the clinician used only enough force to blanch the nail bed of the reinforcing thumb when applying the "sham" treatment.

Treatment Application Protocol

The protocol consisted of a maximum of 6 treatments within a 14-day period. Treatment applications were separated by a minimum of 24 hours and a maximum of 72 hours between each treatment session. If participants reached discharge criteria prior to the sixth treatment, they could be discharged successfully from the study prior to completing all 6 treatments; a minimum of 24 hours was required after the last treatment to assess a participant for discharge. Participants were not restricted from any activities of daily living and were allowed to participate as tolerated (based on clinical presentation and clinician assessment) in any specific sport activities throughout the duration of this study.

Discharge Criteria. The discharge criteria for both treatment groups included: a PSFS score of nine or higher for the reported patient-specific activity, a cumulative NRS score of two or less (with no greater than a one on current pain), and a DPA Scale score of 34 or less for persistent/chronic injuries and 23 or less for acute injuries. Participants were discharged from the study once they reached the predetermined criteria and maintained the outcomes a minimum of 24 hours post treatment.

Data Analysis

Descriptive statistics (mean ± SD) were calculated for all participant demographics. Using NRS, PSFS, DPA, and KOOS scores from a pilot study, an *a priori* power analysis using G power determined that a minimum of 16 participants would be required for this study. A series of one-way analyses of variance (ANOVAs) were performed on the NRS and PSFS scores due to the variance in baseline scores between each group (i.e., linearity and homogeneity of regression did not exist). A series of one-way analyses of covariance (ANCOVAs), with baseline scores as the covariate, were performed on DPA Scale and $KOOS_5$ scores. Patient outcomes on NRS and PSFS were used to assess the effect of each intervention after a single treatment, and NRS, PSFS, DPA, and $KOOS_5$ were used to assess the effect of each treatment intervention after final treatment. Mean differences, ± standard deviation (SD), were calculated with statistical significance set at $p \leq 0.05$, confidence intervals

(CI) at 95%, and partial eta squared values: small = 0.02, medium = 0.13, and large = 0.26.[9] All data analyses were performed using Statistical Package for the Social Sciences (SPSS Inc., Chicago, IL, USA) version 23.0.

Results

Participant Demographics

Twenty-eight participants (males = 14, females = 14) qualified for this study. Five participants elected to withdraw prior to reaching discharge criteria in the allotted 14-day period. Two participants withdrew due to the time constraints of the study (MC "Squeeze" group = 1, sham group = 1), two sustained additional injuries (sham = 2), and the last did not offer a reason (sham = 1). The remaining 23 participants (age = 24.91 ± 12.09, males = 11, females = 12) were included in the final data analysis. The MC "Squeeze" group was composed of 12 participants (acute = 6, chronic = 6) and the sham group was composed of 11 participants (acute =3, chronic = 8). Participants were generally healthy (i.e., no general medical or orthopedic comorbidities) with a mean BMI of 28.48 ± 5.35, from both athletic and general populations (MC "Squeeze" BMI = 25.98 ± 5.62, Sham BMI = 26.35 ± 5.17; Table 5.2). The results of each participant's clinical exam are presented in Table 5.3.

Numeric Rating Scale Outcomes

A univariate ANOVA was used to assess the change in current pain between the MC "Squeeze" and sham groups immediately after the first treatment. No significant difference was found ($F(1, 21) = .006$, $p = .938$, partial eta squared = .000, observed power = .051) between the two groups. The MC "Squeeze" group reported a mean reduction on current NRS of 1.56 ± 1.01 after a single treatment, while the sham group reported a mean reduction of

1.30 ± 1.51.

A univariate ANOVA revealed no significant difference in cumulative pain scores between the MC "Squeeze" and sham groups after the final treatment ($F(1,21) = 1.70$, $p = .21$, partial eta squared = .075, observed power = .24) (Table 5.1). However, the MC "Squeeze" group reported a mean reduction on cumulative NRS of 2.19 ± 1.00 effectively meeting the MCID of 2 points for NRS,[61] while the sham group only reported a mean reduction of 1.24 ± 2.31 (Table 5.4). All 12 (100%) participants in the MC "Squeeze" group met the discharge criteria of ≤ cumulative 2 points on NRS at the end of the treatment intervention, while only 4 (36%) of the 11 sham participants met the discharge criteria for NRS.

Patient Specific Functional Scale Outcomes

A univariate ANOVA was used to assess the change in PSFS scores between the MC "Squeeze" and the sham groups immediately after the first treatment. A significant difference was found ($F(1, 21) = 4.40$, $p = .048$, partial eta squared = .17, observed power = .52) between the two groups. The MC "Squeeze" group reported a mean improvement of function on PSFS of 1.58 ± 2.69 after a single treatment application, while the sham group reported a mean reduction of .46 ± 1.86. Four (33%) participants in the MC "Squeeze" group reported an MDC on the PSFS after the first treatment while no participants in the sham group reported clinically meaningful improvements in function.

A univariate ANOVA revealed a significant difference in the change in PSFS scores between the MC "Squeeze" and the sham groups after the final treatment ($F(1, 21) = 41.92$, $p < .001$, partial eta squared = .67, observed power = .10) (Table 5.4). After the final treatment, the MC "Squeeze" group reported a mean change on PSFS of 5.83 ± 1.85, twice the MDC of

2.5 for PSFS,[8] while the sham group only reported a mean change of .55 ± 2.07 (Table 5.4). All 12 (100%) participants in the MC "Squeeze" group reported a PSFS score equal or greater than 9 points after final treatment, while only 4 (36%) of the 11 sham participants reported equivalent PSFS scores, and produced a moderate effect size.[9]

Disablement in the Physically Active (DPA) Scale Outcomes

A univariate ANCOVA, with baseline scores set as the covariate ($p < .001$), revealed a significant difference in DPA Scale scores between the MC "Squeeze" and sham groups after the final treatment ($F(1, 21) = 7.46$, $p = .013$, partial eta squared = .27, observed power = .74) (Table 5.4). The mean difference in DPA Scale scores between the two groups was 8.78 ($p = .013$, 95% CI: -15.48, -2.08). After the final treatment, the MC "Squeeze" group reported a mean DPA Scale score of 9.00 ± 8.12, 14 points below the accepted "return to play" score of 23,[68] while the sham group reported a mean score of 18.55 ± 14.05 (Table 5.4). The mean change for the MC "Squeeze" group was 14.92 ± 7.68, more than twice the mean change of the sham group (mean change = 6.36 ± 8.15) (Table 5.4).

Knee Injury Osteoarthritis and Outcome Scores (KOOS)

A univariate ANCOVA, with baseline scores set as the covariate ($p < .001$), did not reveal a significant difference in $KOOS_5$ scores between the MC "Squeeze" and sham groups after the final treatment ($F(1, 21) = 2.11$, $p = .16$, partial eta squared = .095, observed power = .28) (Table 5.4). The mean difference in $KOOS_5$ scores between the two groups was 6.23 ($p = .16$, 95% CI: -2.73, 15.19). However, after final treatment, the MC "Squeeze" group reported a mean $KOOS_5$ score of 79.32 ± 15.23, while the sham group only reported a mean score of 69.84 ± 13.69 (Table 5.4). The mean change for the MC "Squeeze" group was 13.82 ± 10.94, more than the mean change of the sham group (mean change = 9.07 ± 11.13) (Table 5.4). Five

(42%) of the 12 participants in the MC "Squeeze" group reported $KOOS_5$ scores of ≥ 80/100 points by the end of the treatment intervention, while only 2 (18%) of the 11 sham participants reported equivalent scores.

Discussion

Participants among both treatment groups in this randomized sham-controlled study experienced positive effects, but the results suggest the improvements reported by the MC "Squeeze" group were superior overall. All 12 participants in the MC group met discharge criteria within the 14-day, 6 treatment restriction; whereas only 4 sham participants (n = 11) met discharge criteria within the research timeframe. Additionally, 42% (n=5) of the MC "Squeeze" participants displayed a full resolution of positive findings on a clinical exam; 58% (n=7) continued to display up to two positive findings, despite self-reporting as asymptomatic (Table 5.3). In comparison, none of the sham participants displayed a full resolution of positive findings on a clinical exam (Table 5.3).

A significant difference was not found between groups on the NRS; both groups reported a decrease in pain immediately after the first treatment and over the course of treatment. However, there is a possibility of a type II error occurring in the interpretation of this analysis. The analysis of change in pain scores yielded a low power (0.051) immediately after the first treatment and a low power (0.24) from intake to discharge. The lack of significant difference between the groups on the NRS at any point during the study may be attributed to higher intake scores and more variability in pain for the sham group. Lower mean NRS scores at intake for the MC "Squeeze" group afforded less room for improvement compared to the sham group during the course of treatment; thus, a "floor/ceiling" effect for the MC group may have limited the ability to detect a statistically significant difference between groups. A notable clinical difference, however was found between groups; after the first treatment, 50% of participants in the MC "Squeeze" group reported an MCID on the NRS, while only 36% of participants in the sham group reported equivalent results. Furthermore, 100% of the MC "Squeeze" group reported NRS scores of 1 or less at the completion of the study, as opposed to only 36% of the sham group.

Analysis of the PSFS scores revealed a statistically significant difference between the two groups, immediately after the first treatment and over the course of treatment, in favor of the MC "Squeeze" group. In addition, the MC "Squeeze" group experienced clinically significant improvements (i.e., MDC) immediately after the first treatment and over the course of treatment on the PSFS. It is possible the sham group experienced a "floor/ceiling" effect due to a smaller window for improvement with mean PSFS scores at baseline of 6.45 ± 1.57 as compared to the MC "Squeeze" group's mean baseline scores of 3.67 ± 1.72; however, further consideration of the outcomes suggests the MC group experienced superior outcomes to the sham group. For example, none of the sham patients reported an MDC on the PSFS after the first treatment, whereas 33% of the MC "Squeeze" group did. Moreover, 100% of the participants in the MC "Squeeze" group reported a PSFS score of 9 or better over the course of treatment as compared to just 36% of the sham. Thus, the differences between the MC "Squeeze" group and the sham group suggest the MC "Squeeze" technique may have had advantageous effects in alleviating the functional activity symptoms associated with clinically diagnosed meniscal tears compared to the sham intervention. In addition to improving functional activity, the MC "Squeeze" treatment also improved the group's perception of their disability as reported in their DPA Scale scores. A statistically significant difference was found between the MC "Squeeze" group and the sham group over the course of treatment.

The MC “Squeeze” group reported lower scores on the DPA Scale, with 100% of participants reporting scores of less than 23 points by the end of the treatment intervention. In contrast, only 55% of the sham participants reported scores of less than 23 points. A score below 23 is clinically relevant for the participants in this study because it is indicative of normative values reported after discharge from treatment for an acute injury and would also fall within the published normal, healthy range (0-34 points) for uninjured people.[68]

A statistically significant difference between groups was not found on the $KOOS_5$. The lack of significant difference between the MC “Squeeze” and sham groups could be due to the $KOOS_5$ inquiring about symptoms within the past week. The timeframe of this study was two weeks and the $KOOS_5$ was administered within 24 to 72 hours of the participants reporting being symptom-free or completing the 6 treatment sessions. Although a number of participants were asymptomatic (e.g., pain resolved, etc.) at the time of $KOOS_5$ administration, it is a possible that participants may have still been symptomatic within the week the final KOOS questionnaire was completed, which may have led to depressed scores. It is also worth noting that there was a moderate effect size and a low power for the $KOOS_5$ analysis; thus, it is possible a Type II error is being committed by accepting that there is no difference between groups.

One potential reason for the positive effects experienced by the MC “Squeeze” group is the treatment’s theorized effect on the meniscal tissue.[48,49] After meniscal injury, meniscal tissue can become dislodged from its normal anatomical position,[55,38,71,15] defined as meniscal derangement.[60] Tissue derangement has been theorized to contribute to approximately 42% of all knee pain.[43] In the presence of tissue derangement at the knee, pressure may be placed on the highly innervated joint line structures.[55,38,71,15] Hypothetically, the MC “Squeeze” technique repositions the deranged meniscal tissue into its normal anatomical position and therefore alleviates the symptoms commonly associated with meniscal tears.[48,49] However, these ideas remain purely theoretical, as there is a paucity of research available on the tissue derangement model in the extremities.[60]

The positive effects experienced by the sham group also cannot be ignored. Approximately 36% of the sham group experienced symptom improvement that qualified those patients for discharge from the study. Additionally, the majority of the sham group experienced some positive effects on most outcome instruments. The positive effects in the sham group could be attributed to the resemblance of our sham treatment to the repeated directional preference movements in the Mechanical Diagnosis and Therapy (MDT) paradigm. The MDT paradigm involves the classification of patients according to how their symptoms respond to repetitive or sustained unidirectional movements, the most common of which is a "derangement syndrome."[25,44,14,43,60,2] Derangement is defined as an anatomical disturbance in the normal resting position of a joint.[3,25,44,43,60] Patients with a reducible derangement will present a directional preference during the MDT evaluation.[3,25,44,43,60] While the MDT evaluation method was not followed in this study, it was possible that sham participants experienced improvements, or even complete abolishment of symptoms, due to the "sham" treatment resulting in applied repeated motion in a directional preference. Patients classified with a knee derangement have experienced significantly better outcomes in pain and function when compared to a control group.[60]

The positive effects achieved by the sham group could also be attributed to the psychological mechanisms of the placebo effect. The magnitude of the placebo effect depends largely on patient expectation.[21,33,67] The participants in this case series were blinded to the intervention that they received. As a result, patient outcomes may have improved based on the participant's expectation of being randomized into the treatment group. The positive effects reported by our sham participants are comparable to other placebo-controlled studies in which participants are told they will either receive a treatment or a placebo and results in small, but significant improvements in pain with small effects sizes.[28] Additionally, the sham participants that reached discharge criteria is not a new phenomenon; the placebo effect has been attributed to up to 50% of patients reaching discharge criteria, particularly in manual therapy.[6] While placebos may not alter the pathophysiology, they can alleviate symptoms (e.g. patient-reported pain).[33] Different types of manual therapies or therapeutic touch elicit various mechanisms of pain control associated with Central Nervous System (CNS) descending pain modulation including, but not limited to, an increase in **β**-endorphins, serotonin meditation, increases in dopamine production and oxytocin mediation.[69] Therefore, the placebo effect could explain why some participants experienced improvements in symptoms but most participants did not experience the significant improvements in functional activity and disability reported by the MC "Squeeze" group.

One limitation of this study was the inclusion of a relatively small sample size for generalization across all patient populations suffering from meniscal tears. Power was calculated based on pilot data of a 5-participant sample and, although the minimum sample size (n = 16) was surpassed in this study, a larger sample size including a more diverse patient population would allow for greater generalization to clinical practice. A larger sample size is also likely necessary in this study due to the number of scales used and is evident in the low power, but moderate effect size noted on certain outcomes measures (e.g., $KOOS_5$). Specifically regarding the KOOS, there was a limitation in study design because the final data collection was 24 hours post symptom resolution and/or sixth treatment intervention and the scale requires patients to analyze symptoms over the past week when symptoms may have still been present. Therefore, a true analysis of improvement on the KOOS may not have occurred with the study design.

Other limitations included difficulty determining a true sham/placebo (i.e., sham was similar to MDT) treatment in manual therapy, a lack of clinician blinding, a lack of arthroscopy for the confirmation of meniscal tears, and not controlling for each participants' activity during the course of treatment. Additionally, in participant recruitment of an injured population within the confines of the researcher's individual clinics, equal numbers of acute and chronic patients could not be obtained or equally distributed with the *a priori* randomization (Table 5.2). Lastly, the MC guidelines recommend applying an internal rotation accessory glide of the tibia when treating patients with general knee pain, and to then progress to medial/lateral glides of the tibia, to provide the greatest reduction in symptoms.[49] Thus, results reported in this study may have been further improved by determining which MC technique was best for each individual participant or through utilizing multiple interventions within the MC.

Future research on the effects of the MC "Squeeze" technique should include sub-classification of participants (e.g., acute versus chronic mechanism, etc.) prior to randomization. Because most of the participants included in this study were younger athletic patients with BMIs below the obesity level, additional research assessing older, sedentary individuals with higher BMIs would be advantageous because chronic degenerative meniscus tears are typically observed in populations who are older, sedentary, and overweight.[23,72] Additionally, the MC paradigm includes various other treatments for knee pain in addition to the "Squeeze" technique and contains recommendations to attempt multiple treatment interventions to match the patient to an intervention that abolishes pain during treatment as opposed to limiting rehabilitation to one technique for all patients.[47,48] Therefore, future research on the effects of the MC in the treatment of meniscal tears should be conducted by following the complete MC treatment guidelines and utilizing the full treatment paradigm; it will also be useful to compare the MC to traditional conservative rehabilitation protocols as opposed to a sham intervention. Researchers should also wait a week after the final treatment to collect the KOOS outcomes measure, as it is designed to capture patient symptoms over the course of a week. Finally, future research should include follow-up data (short-term and long term), identifying the time frames improvements are maintained following a return to sport or activities of daily living.

Conclusion

The results in this study indicate the MC "Squeeze" technique had a positive effect on patient function over a period of 14 days that was, in general, clinically and statistically superior to the sham treatment. While participants in both groups experienced a decrease in pain, only the MC "Squeeze" group reported a significant increase in functional activity and decrease in disability. The results in this study indicate that the MC "Squeeze" technique is an effective treatment for reducing symptoms associated with meniscal tears in a patient population meeting the criteria for a clinical diagnosis.

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Table 5.1: Positive Findings for the Clinical Composite Score Proposed by Lowery et al. (2009) for the Detection of Meniscal Tears

	5 Positive Findings	4 Positive Findings	3 Positive Findings
Sensitivity (%)	11.2%	16.86%	30.8%
Specificity (%)	99%	96.1%	90.2%
PLR	11.45%	4.29%	3.15%
PPV	92.3%	81.8%	76.7%

Note: PLR = Positive Likelihood Ratio; PPV = Positive Predictive Value

Table 5.2: Participant Demographic Data for the MC "Squeeze" and Sham Group

Participant ID	Gender	Age	Sport/Activity	BMI	Onset (Duration of	Joint Line Point of
101	Male	45	Football Coach	35.6 BMI	Chronic	Medial
102	Male	23	Football	32.8 BMI	Chronic	Medial
103	Female	53	General Population	24.0 BMI	Chronic	Lateral
104	Male	22	Soccer	24.3BMI	Chronic	Medial
105	Male	20	Baseball	32.5 BMI	Acute	Medial
106	Male	21	Track & Field	23.6 BMI	Acute	Lateral
107	Male	14	Basketball	18.5 BMI	Acute	Medial
108	Female	18	Dance	29.9 BMI	Chronic	Lateral
109	Female	21	ROTC	24.0 BMI	Acute	Medial
110	Female	25	Swim Coach	26.8 BMI	Acute	Medial
111	Female	20	Basketball	21.30BMI	Chronic	Medial
112	Male	16	Soccer	18.5 BMI	Acute	Lateral
113*	Male	33	Football/Track	23.0 BMI	Chronic	Lateral
114*	Male	19	Baseball	25.7 BMI	Chronic	Lateral
115*	Female	20	Soccer	24.4 BMI	Chronic	Medial
116*	Female	19	Cross Country	20.4 BMI	Acute	Medial
117*	Male	23	Football	31.0 BMI	Acute	Medial
118*	Female	19	ROTC	24.1 BMI	Acute	Lateral
119*	Female	18	Recreational	21.3 BMI	Chronic	Medial
120*	Female	21	General Population	35.2 BMI	Chronic	Medial
121*	Female	62	General Population	30.4 BMI	Chronic	Posterior Lateral
122*	Male	23	General Population	33 BMI	Chronic	Lateral
123*	Female	18	Recreational	21.3 BMI	Chronic	Medial

* = Sham Treatment Group

Table 5.3: Signs and Symptoms Present Among All Participants at Intake and Discharge/After the 6 Treatments.

Sign/Symptoms	MC ‘Squeeze” Group (n=12)		Sham Group (n=11)	
	Intake	*Final Treatment*	*Intake*	*Final Treatment*
	n (%)	n (%)	n (%)	n (%)
History of Popping/Clicking	10 (83.33)	2 (16.67)	9 (81.82)	9 (81.81)
JLT	12 (100)	4 (33.33)	11 (100)	8 (72.73)
Pain in TKE	6 (50)	0 (0)	6 (54.55)	6 (54.55)
Pain in TKF	11 (91.17)	0 (0)	10 (90.90)	6 (54.55)
Positive McMurray’s Test	11 (91.17)	2 (16.67)	10 (90.90)	8 (72.73)
Positive Thessaly’s Test	10 (83.33)	0 (0)	11 (100)	6 (54.55)
Positive Apley’s Test	5 (41.67)	0 (0)	2 (18.18)	2 (18.18)
Edema	0 (0)	0 (0)	1 (9.09)	1 (9.09)
NWB/PWB	3 (25)	0 (0)	1 (9.09)	0 (0)

MC = Mulligan Concept; JLT = joint line tenderness; TKE = terminal knee extension; NWB = non weight-bearing; PWB = partial weight-bearing

Table 5.4: Analysis of Variance (ANOVA) in Outcome Measures from Intake to Final Treatment Between Groups

Outcomes	MC 'Squeeze" Group M (±SD)		Sham Group M (±SD)				
	Intake	*Final Treatment*	*Intake*	*Final Treatment*	**p**	**Effect Size**	**Power**
NRS (Avg)	2.64 (±.89)	0.44 (±.44)	3.67 (±2.50)	2.42 (±1.96)	.206	.075	.238
PSFS	3.67 (±1.72)	9.50 (±1.85)	6.45 (±1.57)	7.00 (±2.07)	.000*	.666*	1.00*
‡DPA	23.92 (±10.05)	9.00 (±8.12)	24.91 (±11.96)	18.55 (±14.05)	.013*	.272*	.739
‡$KOOS_5$	65.50 (±12.26)	79.32 (±15.22)	60.76 ±18.32)	69.84 (±13.69)	.162	.095	.282

MC = Mulligan Concept; NRS = Numeric Rating Scale for pain; Avg = average; PSFS = Patient Specific Functional Scale; DPA = Disablement in the Physically Active Scale; $KOOS_5$ = Knee injury and Osteoarthritis Outcome Score (composite score)
‡ANCOVA with baseline scores extracted as covariates
Note: statistical significance, large effect size, and high power

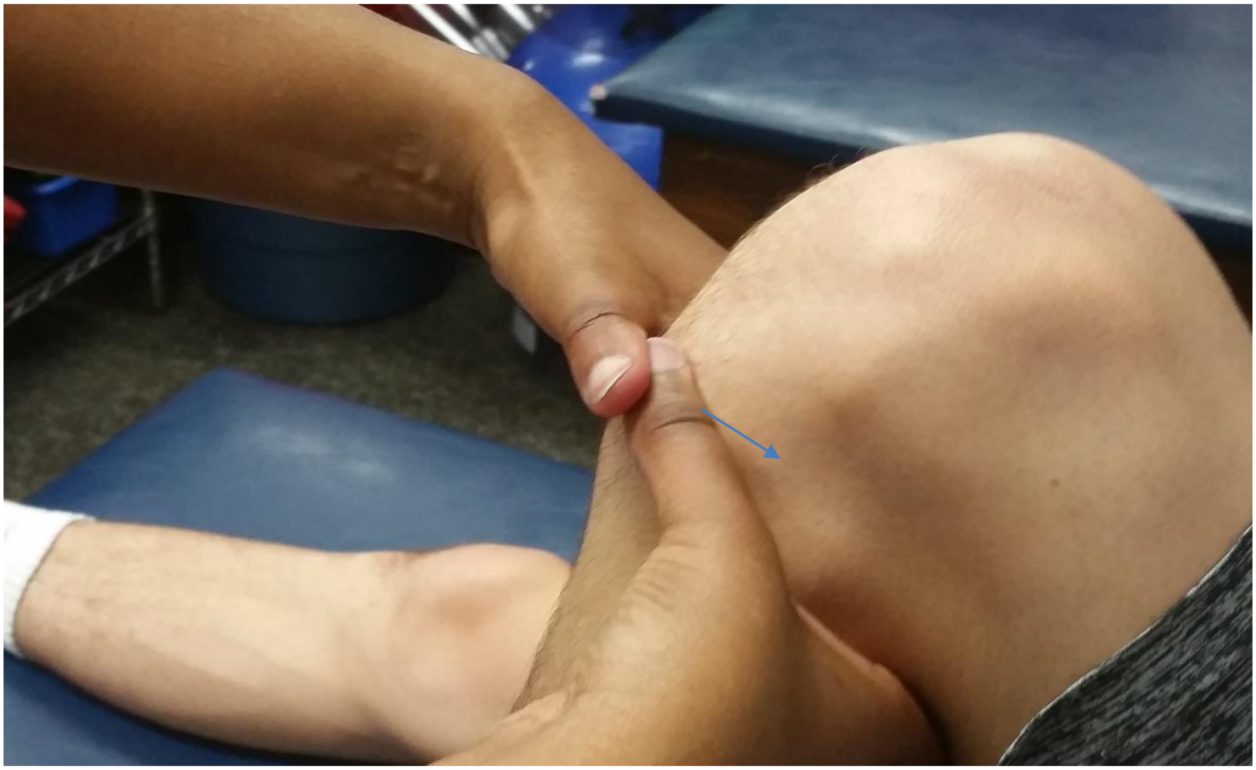

Figure 5.1: Starting hand placement showing the overlap thumb grip.
Note: Arrow in direction of force

Figure 5.2: Clinician hand placement in NWB (supine) for the MC “Squeeze” technique treatment in full knee extension with clinician alleviating pressure on the joint line.

Figure 5.3: Clinician hand placement in NWB (supine) for the MC “Squeeze” technique treatment in full knee flexion with overpressure provided by the participant.

Figure 5.4: Clinician hand placement in NWB (supine) for the MC "Squeeze" technique treatment in full knee flexion with participant using a strap to assist in providing overpressure.

A. B.

Figure 5.5: Clinician hand placement in PWB (lunge) starting (A) and ending position (B) for the MC “Squeeze” technique.

A. B.

Figure 5.6: Clinician hand placement in FWB (squat) starting (A) and ending position (B) for the MC “Squeeze” technique.

Figure 5.7: Clinician hand placement in NWB (supine) for the sham treatment in full knee flexion with clinician applying overlap thumb grip ½ inch inferior to the reported joint-line tenderness.

Note: Blue line indicates joint line. Arrow indicates ½ inch inferior to joint line.

Figure 5.8: Clinician hand placement in NWB (supine) for the sham treatment in full knee extension with clinician applying overlap thumb grip ½ inch inferior to the reported joint-line tenderness.

Note: Blue line indicates joint line. Arrow indicates ½ inch inferior to joint line.

APPENDIX A

Plan of Advanced Practice: 26 January 2016

The purpose of this document is to reflect on my chosen career path and outline meaningful goals that will assist in my development as an advanced certified athletic trainer. Specifically, a plan of advanced practice (PoAP) provides an insightful analysis of current clinical practice, strengths and weakness that effect professional and personal growth, clinical philosophies, and specific and measurable goals for professional growth. Developing a PoAP will provide a "bird's eye" view of my professional and personal experiences and a preliminary sketch of my professional future.

My current areas of advanced clinical practice include: (a) joint mobilization, specifically the Mulligan Concept; (b) treatment of acute and chronic meniscal tears using the Mulligan Concept "Squeeze" Technique; (c) treatment of acute and chronic shoulder instability using the Mulligan Concept and reactive neuromuscular training (RNT); (d) treatment of low back pain using Total Motion Release (TMR), Mulligan Concept ,and Energy Medicine; and (e) treatment of hip and groin strains using breathing techniques and primal reflex release techniques (PRRT). The treatment paradigms listed were chosen based on practice based evidence, specific to my clinical setting's current medical demands.

Reflection on Professional Experience and Development

American author and playwright James Baldwin is credited with stating, "Know from whence you came. If you know whence you came, there are absolutely no limitations to where you can go." I was exposed to the profession of athletic training during my freshman year of high school, but did not take it too seriously as I was an athlete first. After realizing that I was not a stellar athlete and sustaining many knee injuries, I decided that I should focus a little more on athletic training. I continued to play sports through my senior year, but I was always the student athlete everyone came to with their injuries, and I enjoyed the feeling of being needed. Even more, I enjoyed helping athletes get back to their beloved sports. Athletic training immediately became my top career choice, based on my high school athletic experience and the amazing athletic trainers that I met during those years.

Despite my desire to pursue my education immediately, I enlisted in the United States Air Force Reserves in June of 2001, to assist with financial obligations that I expected to encounter along my journey. After completing basic training and school specific for my military job, I attended Coastal Carolina University (CCU) for an undergraduate program in health promotion with a sports medicine option. Because this was not a Commission on Accreditation of Athletic Training Education (CAATE) program, I was not able to sit for the Board of Certification (BOC) athletic trainer's exam. As a member of the United States Air Force Reserves, my undergraduate career was interrupted; I was called to activity duty in March of 2002. During the time I spent on active duty, I travelled to portions of the world I would not likely have seen otherwise. While I don't consider any of my time serving in the military to be bad, some of my experiences were good and others were learning opportunities. During my tour at "Camp Anaconda" in Balad, Iraq, we were subjected to high-stress situations on a daily basis and immediate responses were a part of our daily existence. My natural inclination not to panic during high-stress situations was enhanced ten-fold. I witnessed injuries and experienced other situations alongside veteran soldiers who helped desensitize me and showed me how to respond so that others would feel safe and confident in my skills, which has improved my proficiency as an athletic trainer.

After completing my time on active duty, I returned to school disheartened that I was too far behind and not ready for tests again. Despite this, my desire to finish what I had started was strong. My mother stepped in and helped me center my focus back to my original plans. I completed my undergraduate degree in December of 2006, also passing the certified health education specialist (CHES) national exam. Not being able to sit for the BOC exam after graduation was frustrating, but this turned out to be a blessing in disguise, as I may not have chosen to advance my knowledge if I had been allowed to start practicing straight out of undergrad.

After working for a year outside of the profession of athletic training, I decided to pursue further education to fulfill my initial goal. I applied to and was accepted into the Masters of Athletic Training program at Texas Tech Health Sciences Center (TTUHSC). This program focused heavily on evidence-based medicine and participation in meaningful clinical rotations. I was able to experience many different clinical settings including secondary school, college, clinic, and camp settings. During my clinical rotations I began to develop as an athletic trainer, deciding what I deemed to be "good" clinical practice and "poor" clinical practice. After my first rotation in a high school setting, I knew that documentation and interpersonal skills were high on my priority list of skills that should never be compromised. During my time at TTUHSC, I held positions of leadership (president of the student athletic training association), organizing and hosting symposiums for undergraduate programs. I am grateful for the opportunity to have come through a program that valued and promoted positive athletic training education and learning experiences. I passed my state and national exams on the first attempt in May of 2010, which gave me the confidence to seek immediate employment in athletic training.

I began working as the head athletic trainer for a 4-A high school in August of 2010. I went into an athletic training setting that was unorganized, under budgeted, under staffed, and lacking major resources (e.g. locked file cabinets, semi-private area for exams). I was forced to be resourceful in my early patient care. However, I was able to quickly revamp my athletic training setting, creating a safe and semi-private environment for my patients; this included turning a storage closet into an office/exam room. My initial year was so focused on developing a suitable clinic that my patient care fell to the wayside. I focused on immediate care and physical therapist driven rehabilitation sessions (cookie cutter protocols). After 3 years of doing the same treatments day after day, working 60 plus hours a week, and getting the same results, I realized I had stagnated in my profession. I began searching for a change, contemplating going to physician assistant school, getting a doctoral degree, and/or getting my massage therapy license to open my own business. After working in the profession of athletic training for 4 years, I applied for admission into the Doctorate of Athletic Training (DAT) Program at the University of Idaho.

Reflection on Current Knowledge

The DAT program has exposed me to many paradigms that I never knew existed, which has reignited my passion for the clinical aspects of athletic training. The DAT has exposed me to the “medical model”, which focuses on patient care, versus the “athletic model”, which focuses on team coverage. The medical model allows the patient to have the opportunity to be treated by the most qualified practitioner in that specific setting, unlike the athletic model, which defers to the practitioner assigned to covering that sport. My current position as the head athletic trainer at a developing, now 5-A high school has allowed for some flexibility in my treatment options, allowing me to use the medical model. I would evaluate my overall athletic training skill level as advanced at this current time, with a continued interest in the Mulligan Concept. Being recognized as an expert in a specific paradigm, such as the Mulligan Concept, which demonstrates its effectiveness in treating multiple pathologies and dysfunctions in my clinical practice, would allow me to be viewed as a professional resource at any institution/clinic. For athletic trainers such as myself, the opportunity to participate in continuing education and learn new paradigms while continuing to work in the profession is a blessing; we are able to take what we have learned and apply it immediately in the clinical setting. I continually see the advantage newly learned treatments afford my patients, as they ultimately lead to patient compliance and successful outcomes.

My clinical philosophies have changed throughout my time in the DAT and will continue to change based on my goals and chosen paths. With that disclaimer, I present my current clinical philosophies as follows:

Clinical Practice Philosophy

In my clinical practice I strive to provide patient-centered care, treating the "whole person" and not just symptoms. Through the use of thorough evaluation and classification methods, I strive to choose an intervention(s) that best suit the needs of my patient. I continue to collect and use patient outcome measures to enhance my clinical practice. My goal is to use the best available evidence based treatments, while remaining fluid in my practice, remaining open to practice based evidence. My clinical philosophy is to improve patient quality of life through open communication, objective data, and conscious reflection.

Rehabilitation Philosophy

My clinical rehabilitation philosophy is based around patient-oriented care, striving to use existing best practices while using my ongoing experience to improve as a clinician. I support this philosophy using a thorough evaluation of the patient and their history, reflection of care given and possible options, accountability to other professionals, being "present" during care, and becoming uncomfortable in my profession by being "okay" with being wrong and open to change. Using effective paradigms are important, but are subsequent and will inevitably follow my philosophy.

My evaluation process consists of a detailed history, traditional special tests, palpation, and regional interdependence paradigms. In contrast to my past philosophy, which focused on treating the area the patient associated with their pain, regional interdependence paradigms *focus on the whole patient and allow the clinician to "connect the dots" to a patient's pain. Reflection is an important aspect to my philosophy; this is where I am able to assess my patient's treatment course outside the presence of the patient, coach, or parent. I am able to evaluate the treatment chosen and the diagnosis, to see if they truly align or if there is a differential diagnosis that I may have negated. Open communication with other professionals is another way for me to reflect, as well as to be accountable for my thought process.*

Being present in patient care is an important aspect of rehabilitation, allowing myself to connect with the patient and not just going on "autopilot" while treating all patients with similar classified injuries the same. The ability to self-asses and realize when I am not present in clinic has helped me to refocus and make the choice to be present. Being uncomfortable in one's practice comes along with reflection and accountability. Realizing that I am not sure how to properly handle a patient's injury is a "blow" to my professional ego, but being uncomfortable and admitting to myself and others that I do not know what next step to take is a step in the direction of getting my patient on the right track to health. I've always prided myself on getting patients back to their sport quickly and safely, but how can I truly do this if I am too prideful to admit "that I have no idea." I am okay with knowing that I do not know everything and even more okay in knowing that there are other athletic trainers that use a different lens from me on how they view injuries, and therefore have different available treatment options.

My current rehabilitation philosophy is applying the paradigm that works best for my patients at that given time. I will continue to develop my philosophy as I develop my skills as a clinician. I now understand that I do not know or fully comprehend all the factors that can cause pain or all the potential methods to eliminate pain. The complexities of our bodies far exceed my depth of knowledge.

Low Back Pain Rehabilitation Philosophy

My current philosophy for low back pain is a subset of my clinical philosophy, which includes a detailed history, thorough clinical examination, being "present" during care and being accountable to other healthcare professionals. In the past, I would use stretching and electro-stimulation for low back pain (LBP) patients. However, I now find myself using the Mulligan Concept (MC) followed up with total motion release (TMR). Coupling these two treatment paradigms has afforded a moderate success rate in my clinical practice with acute and chronic LBP patients. If the patient is in acute disabling pain or seems highly distressed, I will start with positional release therapy (PRT) to ease trigger points, or energy medicine (EM) to relax the patient and treat the pain. My goal is to base each treatment on the patient's individual needs on a daily basis, using my initial exam and prior treatment as a foundation My clinical practice philosophies are ever changing as I learn new paradigms and begin to recognize pain patterns.

Reflection on Strengths

The strengths that I feel assist me in being a good clinician are my confidence, determination, internal and external drive, communication skills, open minded attitude, unyielding ethics, loyalty, inquisitive nature, and patient-centered philosophy of care. When I speak to my patients, they feel comfortable in the fact that I will do everything in my ability to get them back as quickly and as safely as possible. They know that I will not compromise their safety or my ethical values because their coach enjoys yelling or their parents are large contributors to the athletic program. My patients feel safe in knowing that I will stand up to their parents when they are told to "suck it up and get back out there."

However, through my communication skills the parents, coaches, and patients are able to understand the injury and the rehabilitation that will be involved. Through effective communication skills, I have been able to assist in diffusing tense situations while explaining the severity of injuries and the need to err on the side of caution. I am confident in what I know and what I do not know, am honest and upfront with my patients, and always let them know I will find either the information they are requesting or a person who knows the information. My open-minded attitude allows me to try new treatment paradigms that may be outside of my normal comfort zone.

My internal drive to get patients better and to learn my craft better so I can use the best techniques to get patients healthier allows me to push myself harder than anyone else is able to push me. The external drive stems from seeing patients successfully accomplish something that they thought was impossible. Loyalty may not seem like a strength in the athletic training profession, but being loyal to my patients means not succumbing to the outside pressures of the game or other extrinsic factors that may sway my ethical compass to that which could destroy a patient's future in athletics or in life. Having an inquisitive nature allows me to question the methods of others, ask questions, and have an answer for why I am doing the treatment I choose. I am not suggesting that the answer I give will answer all their questions or have exhausted scholarly depth, but I will provide a valid evidenced-based reason.

Patient-centered care is important in my clinical practice, as the needs of a patient may change from treatment to treatment. Patient-centered care removes the “cookie cutter” approach and places the unique needs of an individual patient at the current time at the forefront of my approach.

Reflection on Weaknesses or Areas of Improvement

Similar to my strengths, many areas of improvement in my personal life carry-over into the professional setting. However, there are very specific areas of improvement in my clinical practice that will assist me as I grow in the profession of athletic training. I believe my areas of improvement are all at or above the entry level of an athletic trainer, however in my pursuit of advancing my clinical practice I am striving for excellence in all areas.

My personal and professional traits that need improvement are my unapproachable demeanor, critical evaluation skills, insensitiveness, impatience, and stubborn disposition. I have been told on occasion that my overall presence is not inviting, and this affects patients’ feeling comfortable enough to come in to tell me about less complex injuries, that then stem into more complex injuries. Patients will sometimes visit their local physician instead of “bothering” me with their issues, which normally slows their “true” recovery time down because the physician treats the symptoms and places them on complete rest. I often make it a point to speak to my patient population outside of their injuries; just inquiring about how their day is going allows open communication.

My critical evaluation skills of scholarly works as well as case studies have improved greatly but still lack the depth that I see in others. I still find myself focusing on the areas of pain the patients point out to me. For instance, if they tell me their knee hurts, and the history given at the time reflects that of a knee injury, I tend to focus on the knee instead of considering the possibility that the pain may have been present prior to the history given or caused from an entirely different region of the body. Even with energy medicine, I will immediately go to the meridian or chakra that coincides with the area they are describing. In regards to my insensitiveness, I do not lack compassion for my patients; however, I have been known to tell them information that they may not have been mentally expecting (i.e., it is no longer safe for you to continue competition). I prefer not to coddle patients and give them a false reality; however, my reality does not have to be their reality.

The statement “patience is a virtue” has begun to surface in patient care with my high school population. I have more patience with my population, but I still have a long way to go. When patients are slacking in their rehabilitation process or come into the clinic disturbing other patients, I sometimes react negatively to gain immediate control of my environment instead of responding in a calm manner. However, I often give patients a second chance, prior to their removal. Increasing my patience and state of “presence” is important; I no longer robotically go through rehabs. Being consistent in policy is important to my personal practice; however, I do realize that the difference between being consistent and being stubborn is a fine line, and I continue to cross it daily.

A few clinical specific areas I would like to improve are: (a) my ability to produce scholarly works (b) gain a better understanding of body specific patient outcome scales (c) my ability to evaluate and treat the spine and sacroiliac joint (d) my understanding of TMR (e) my understanding of energy medicine (f) my understanding of PRRT (g) becoming an expert practitioner in the Mulligan Concept (h) my ability to mentor other athletic trainers and students interested in athletic training.

Goals for Professional Future

In my current clinical setting I am enjoying the freedoms that are afforded with being a head athletic trainer; however, I am not satisfied with the marginal salary and the lack of value placed on the sports medicine department. My professional goal is to be able to teach in an athletic training program, while still treating patients clinically. Being able to teach upcoming or certified athletic trainers will allow me to share the knowledge that I have gathered throughout my journey, as well as continue to stay current in familiar paradigms. Teaching in a program will surround me with other practitioners, from whom I will be able to acquire new knowledge, and to whom I can disseminate knowledge as well. The clinical aspect is an important aspect of continually advancing my clinical practice. If I am only teaching the foundational concepts I feel as though I may miss the opportunity to revolutionize, evolve, or create a new concept.

With my ultimate goal in my mind, I am interested in pursuing my massage therapy license not so that I can operate solely as a massage therapist, but so I can operate independently. By becoming an advanced practitioner in treatments such as the Mulligan Concept, Energy Medicine, RNT, PRRT, and TMR, I can best assist my patient population to recover quickly, limiting the amount of medications necessary and limiting their time away from their sport or activities of daily living. Working as an independent clinician would afford me the opportunity to use all of my treatment paradigms, and also give my patients the opportunity to choose me, instead of working in a setting where I am their only chose.

Gaining my massage therapy license could give me access to a different type of patient population.

The Mulligan Concept is a treatment that alleviates pain immediately and is a treatment that I plan to pursue advancement of my knowledge and skill. Specifically, shoulder injuries labeled as multi-directional instabilities are an area in which I want to become more versed. I have been able to treat the pain of these injuries with the Mulligan Concept, coupled with RNT to reduce and in some cases alleviate the subluxation that occurs or that is felt by the patient during sport. I have treated acute and chronic patients with these techniques and I look forward to seeing long term results.

I plan to advance my clinical practice by the following:

Goal	Time Frame
1. Produce scholarly works that will be shared with fellow practitioners.	2-Within a year 1-Every year post DAT graduation
2. Reflect on clinical practices and ways for improvement.	Continuous advancement
3. Acquire massage therapy certification for independence.	Within a year
4. Advance technique and use of the Mulligan Concept.	Within 2-5 years
5. Become proficient in advance techniques of Energy Medicine techniques.	Within 5-10 years
6. Advance diagnostic skills of the spine and pelvic girdle.	Continuous advancement
7. Become proficient in the Myokinesthetic Concept.	Within 2 years
8. Become proficient in PRRT.	Within 2-5 years
9. Become an educator in athletic training.	Within 2 years

Justification of Plan of Advance Practice

The justification for this plan of advance practice is the improvement of my overall patient care and the advancement of my clinical skills. This document permits transparency into my self-identified weaknesses, strengths, and future goals. My PoAP has provided the structure to accomplish many goals thus far (e.g., Mulligan lower and upper body course completion, Donna Eden's 5 day basic energy medicine course completion) and enabled me to create future plans to complete objectives in a judicious time frame. I will continually make changes to my PoAP as dictated by my growth and the needs of the profession. As I near the end of my DAT journey, my perspectives and clinical practices have evolved from that of an entry-level practitioner to an advanced clinical practitioner in select areas. I will continue to expound upon the foundation that the DAT program has provided. Throughout my educational/clinical journey I have been given the didactic tools to be an advanced scholarly practitioner in the profession of athletic training and this document outlines how I will move forward to my manifestation.

APPENDIX B

Applied Clinical Research-Pilot Study

Title

An Alternative Approach to the Treatment of Meniscal Pathologies: A Case Series Analysis of the Mulligan Concept "Squeeze" Technique.

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Abstract

Background: Partial meniscectomy does not consistently produce the desired positive outcomes intended for meniscal tears lesions; therefore, a need exists for research into alternatives for treating symptoms of meniscal tears. The purpose of this case series was to examine the effect of the Mulligan Concept (MC) "Squeeze" technique in physically active participants who presented with clinical symptoms of meniscal tears.

Description of Cases: The MC "Squeeze" technique was applied in five cases of clinically diagnosed meniscal tears in a physically active population. The Numeric Pain Rating Scale (NRS), the Patient Specific Functional Scale (PSFS), the Disability in the Physically Active (DPA) Scale, and the Knee injury and Osteoarthritis Outcomes Score (KOOS) were administered to assess participant pain level and function.

Outcomes: Statistically significant improvements were found on cumulative NRS ($p \leq .001$), current NRS ($p \leq .002$), PSFS ($p \leq .003$), DPA ($p \leq 0.019$), and KOOS ($p \leq 0.002$) scores across all five participants. All participants exceeded the minimal clinically important difference (MCID) on the first treatment and reported an NRS score and current pain score of 1 point or less at discharge. The MC "Squeeze" technique produced statistically and clinically significant changes across all outcome measures in all five participants.

Discussion: The use of the MC "Squeeze" technique in this case series indicated positive outcomes in five participants who presented with meniscal tear symptoms. Of importance to the athletic population, each of the participants continued to engage in sport activity as tolerated unless otherwise required during the treatment period. The outcomes reported in this case series exceed those reported when using traditional conservative therapy and the return to play timelines for meniscal tears treated with partial meniscectomies.

Level of Evidence: Level 4; Case series focusing on innovative intervention

Key Words: Knee pain, meniscus, mobilization with movement

Introduction

Meniscal tears are the second most common knee injury in sport,[1] contributing to significant time loss for athletes.[2,3] Common symptoms of meniscal tears include: clicking, catching or locking, joint line tenderness, a feeling of "giving out" or instability, pain with squatting or pivoting motions, pain at end range of flexion and/or extension, and a loss of range of motion.[4,5] Sustaining a meniscal tear is thought to lead to knee joint space narrowing and altered joint biomechanics,[6] which if not addressed, may lead to osteoarthritis (OA).[7]

Arthroscopic surgery is the "gold standard" for diagnosing meniscal tears,[8] but the most frequently used advanced diagnostic tool is magnetic resonance imaging (MRI);[9] MRI has been found to have a specificity of 76%, sensitivity of 96%, and a diagnostic accuracy of 88%.[10] Meniscal tears are also commonly diagnosed clinically using a battery of special tests.

McMurray's (specificity 95%, Sensitivity 21%),[11] Apley's (Specificity 90%, Sensitivity 13%)[12] and Thessaly's test (Specificity 97.7%, Sensitivity 90.3%)[13] are the most commonly used special tests for clinical diagnosis,[14] with Thessaly's test having the highest diagnostic accuracy (94-96%) when performed at 20 degrees of knee flexion.[15] Clinicians can also expect high diagnostic accuracies (>88%) from McMurray's and Apley's tests; when used as a testing battery, McMurray's and Apley's tests are comparable to MRI findings alone.[16-18]

One method for improving the accuracy of the clinical exam is to create a more detailed clinical testing battery. Lowery et al.[11] identified five components of a standard clinical examination which, when used as a battery, yielded a clinical composite score (CCS) superior to the accuracy of MRI for the detection of meniscal tears. The battery included: a history of catching or locking in the knee, pain with passive terminal knee flexion, pain with passive terminal knee extension, joint line tenderness and a positive McMurray's test. When all five signs were present in patients, a positive predictive value (PPV) of 92.3%, a specificity of 99% and a sensitivity of 11.2% were identified for the detection of meniscal tears (Table 1).[11] The PPV and specificity decreased to 81.8% and 96.1% respectively, while sensitivity increased to 17% in the presence of four signs.[11] When three of the five signs were present, the PPV was 76.7%, specificity 90.2%, and sensitivity 30.8%; even with only three signs present, accuracy remained comparable to that of MRI findings.[11] Despite the frequent use of MRI for diagnosing meniscal tears, a detailed patient history combined with a battery of reliable special tests can produce a diagnostic accuracy of 90%,[18] slightly superior to the diagnostic accuracy of MRI alone.[11,18] Accurate diagnosis of meniscal tears is the gateway to producing quality outcomes in patients with meniscal tear symptoms. However, following up an accurate diagnosis with the proper course of treatment should be the primary focus of any experienced practitioner.

The standard of care for partial tears in the non-vascular portion of the meniscus is arthroscopic partial meniscectomy;[19] this surgical procedure accounts for as many as 50% of all orthopedic surgeries in the United States.[20] Partial meniscectomy is said to provide symptom relief, correct biomechanical dysfunction that occurs as a result of the injury,[21] and delay the onset of OA.[5,22] However, partial meniscectomies do not correct biomechanical dysfunction, and have actually been identified as the leading cause of OA in the knee.[21-24] Furthermore, post-surgical outcomes have only reported limited success in radial tears of the posterior medial horn.[25] Despite its prevalent use, partial meniscectomy patient outcomes have been found to be no different to those of patients who receive a sham surgery.[26] Patient-reported symptoms 12-months after surgery and the number of patients requiring follow-up surgery were not significantly different between the two groups.[26]

When indicated, meniscal repair surgery is a preferred alternative to partial meniscectomy due to the preservation of the meniscus, which is thought to enhanced joint stability.[27] However, reported failure rates for meniscal repair procedures can range from 8.9%[25] up to 42%,[5] and depending on the location of the tear, a repair may not be indicated in patients without a concomitant anterior cruciate ligament (ACL) tear.[19] Additionally, the risk for follow-up surgery is higher for meniscal repair, 20.7%, than meniscectomy, 3.9%.[28] In light of the evidence, it is important for clinicians to exhaust conservative treatment options prior to surgery in the management of meniscal tears.

The Mulligan Concept (MC) “Squeeze” technique is a manual therapy intervention designed to treat limited range of motion and localized joint line pain,[29] which are symptoms often found in the presence of meniscal tears.[4,5,11] Despite the theorized benefit of this technique in patients with meniscal tears symptoms, limited formal investigations of the efficacy of this treatment exist and the mechanism of action is unknown.[30] Therefore, the purpose of this case series was to examine the effect of the MC "Squeeze" technique in symptomatic, physically active patients who met the criteria for a clinical diagnosis of a meniscal tear.

Case Series Description

A multi-site *a priori* study was designed by four clinicians (mean clinical experience = 6 years ± 2.94 SD) to treat patients presenting with meniscal tear symptoms. Five participants (age = 19.6 ± 3.2, four males and one females) actively competing in a variety of sports at either high school or collegiate levels (Table 2) presented with clinical symptoms of meniscal tears. All participants were treated with the MC "Squeeze" technique until they reached discharge criteria; outcome measures were collected throughout the course of treatment. No other treatment intervention was applied and participant activity-level was not modified during the course of treatment. The Institutional Review Boards at all four data collection sites approved the collection of medical information from the participants in this study. Participants signed written informed consent acknowledging possible publication of their outcomes.

Clinical Impression #1

Participants were included in the case series if they presented with at least three of the following: positive McMurray's test, pain with terminal knee flexion, pain with terminal knee extension, joint line tenderness, and a history of clicking and/or popping; yielding a high CCS.[11] Participants were excluded if they had a potential ACL injury, indicated by a positive

Lachman's test, because ACL tears have been found to reduce the diagnostic accuracy of the meniscal clinical composite score.[11] In addition to the CCS, two tests involving a rotational force, Thessaly's at 20 degrees and Apley's compression and distraction test, were used because they have been identified to accurately assist in the clinical diagnosis of meniscal tears.[12] Participants were required to present with a positive finding in at least one of these rotational special tests. Participants were also excluded if they presented with the following conditions during the initial exam: knee contusions, fractures, knee dislocations, increased pain with manual therapy, knee ligament instability, and non-mechanical causes of pain (e.g., hyperalgesia). The co-morbidities were considered precautions to manual therapy for the purpose of this study.

Examination

Examination included a thorough history and a comprehensive clinical exam relating to the chief complaint. The participants reported the following signs that met the inclusion criteria of: history of clicking and popping (n=2), joint line pain (n=5), pain with terminal knee flexion (n=5), pain with terminal knee extension (n=4), positive McMurray's test (n=4), positive. Thessaly's test at 20 degrees of knee flexion (n=4), and/or positive Apley's compression/distraction test (n=3; Table 3). Based on the evidence supporting the diagnostic accuracy of Thessaly's test[15] and a battery of special tests,[16-19] participants who met the inclusion criteria were provisionally diagnosed with meniscal tears.

Clinical Impression #2

Once participants were included in the study based on the clinical exam (Table 3), all five were treated with the MC "Squeeze" technique. The number of treatments (mean = 5 ±1.73) and the duration of treatment in days (mean=14.2 ± 5.68 days) were not standardized.

Participants were treated until they reported a Patient Specific Functional Scale (PSFS) score of 10, a Numeric Pain Rating Scale (NRS) score of one or less, and a DPA scale score below 23 (Table 4). Participants were also progressively released to participate in physical activity as tolerated based on the clinician's individual sport-specific return to play criteria, which did not necessarily correlate to being discharged from the study. The participant could remain in the study after returning to sport activity until they reached the standardized discharge criteria.

Outcome Measures

The following outcomes were collected at intake: Numeric Pain Rating Scale (NRS), the Patient Specific Functional Scale (PSFS), the Disablement in the Physically Active Scale (DPA), and the Knee injury and Osteoarthritis Outcomes Score (KOOS). The NRS and PSFS were collected pre- and post- each treatment, while the DPA and KOOS were only collected at intake and discharge. All outcomes scales were found to be internally and externally valid, as well as reliable.[31-36]

The NRS was used to quantify participant reported pain. The NRS score was conducted verbally and documented as an average (cumulative NRS) of current pain, best pain within 24 hours, and worst pain within 24 hours at intake, pre-treatment, and discharge.[31] Immediate post-treatment pain changes (current NRS) were recorded using participant reported current pain post-treatment. The NRS scale was scored on an 11-point scale, with 0 representing no pain and 10 representing severe pain.[31] The reported minimal clinically important difference (MCID) for the NRS is a decrease of 2 points or 33%.[32]

The PSFS was used to quantify functional ability. The PSFS score was documented during intake, pre- and post-treatment, and after discharge. The participant was asked to identify a single activity to perform in the clinic that was limited due to injury. After identifying the activity, the participant verbally rated the severity of the limitation on an 11-point scale, with 0 representing being unable to perform the activity and 10 representing being able to perform the activity at the level before injury.[32] The reported minimal detectable change (MDC) is a change in 2.5 points when using an individual activity in patients with a lower limb injury.[34]

The DPA scale was used to quantify disablement across impairment, functional limitation, disability, and health-related quality of life.[35] The DPA was collected at intake and discharge. Responses on the DPA are based on a scale ranging from 1 (no problem) to 5 (severe problem) across 16 items; total possible scores range from 0 to 64 points.[35] A normal, healthy score is less than or equal to 34.[35] An MCID is a decrease of 9 points for an acute injury and 6 points for a chronic injury.[35]

The KOOS, was used to assess five dimensions: pain, symptoms, activities of daily living, sport and recreational function, and knee-related quality of life.[36] The KOOS was collected at intake and discharge. Responses within each dimension of the KOOS are based on a scale ranging from 0 to 4; a total score of 100 indicates no symptoms present. Each dimension of the KOOS was scored separately and a composite score of the average of all 5 categories ($KOOS_5$) was used in the analysis of the data presented in this case series.[36] An MCID for each subsection is a change of 8-10 points,[36] however, an MCID value has not been established for the $KOOS_5$ composite score.

Intervention

The MC "Squeeze" technique was administered according to Mulligan Concept principles.[29] All treatment started with the participant supine and the involved knee in 90 degrees of flexion, or flexed to the participant's pain-free limit, for better access to the joint line. The clinician placed the medial border of one thumb over the site of maximum joint line pain and swelling, and with the other thumb reinforced the first to create an overlap grip position (Figure 1).[29] Next, the participant extended their knee to their maximal pain-free range, while the clinician maintained hand position, releasing the grip force on the joint line as the joint space closed (Figure 2). After maximal knee extension was reached, the participant actively returned their knee towards full flexion as the clinician increased the force with the overlapping thumb towards the center of the joint.[29] The clinician continued to hold the pressure at the joint line for two seconds as the participant applied overpressure by pulling the tibia with both hands to their end range of knee flexion (Figure 3).[29]

The participants were allowed to experience localized discomfort from the overlap grip to tolerance, but the localized discomfort was not to be exacerbated with movement.[29] Each treatment consisted of three sets of ten repetitions of the MC “Squeeze” technique. All participants were treated until discharged. The discharge criteria consisted of a PSFS score of 10, an NRS score of one or less, and a DPA scale score below 23. No additional care was provided beyond the MC “Squeeze” technique. Participants were not restricted from any activities of daily living, and those deemed able by the clinician (based on clinical presentation) were allowed to participate as tolerated in their specific sport activity.

Outcomes

Data Analysis

Paired t-tests were performed on the cumulative NRS score, current NRS pain score, PSFS, DPA Scale, each dimension of the KOOS, and $KOOS_5$ (an average of all dimension scores) to determine the effect of the interventions from initial exam to discharge. Mean differences from the initial visit scores and 95% confidence intervals (CIs) were calculated for all outcomes measures. Cohen's *d* was calculated to determine the effect size, or maximum likelihood, of each outcome measure. For Cohen's *d*, an effect size of 0.2 to 0.3 was considered a "small" effect, 0.5 a "medium" effect, and 0.8 to infinity a "large" effect.[37] All data was analyzed using SPSS version 23.0 (SPSS Inc., Chicago, IL, USA).

NRS

The use of the MC "Squeeze" technique produced a statistically significant improvement in cumulative NRS scores ($t(4) = 10.796$, $p \leq .001$,95% CI: 3.21 to 5.43, Cohen's $d = 4.39$) from initial exam to discharge. A statistically significant improvement in current NRS pain scores ($t(4)=7.303$, $p \leq .002$, 95% CI= 2.48 to 5.52, Cohen's $d = 3.07$) was also found from initial exam to discharge, 14.2 ± 5.68 days after initial exam (Table 5). The Cohen's *d* values resulted in a large effect size,[37] indicating the change in NRS scores can very likely be attributed to the treatment intervention. All five participants reported a decrease in pain immediately after a single treatment; four participants met or exceeded the MCID (decrease of 2 points or 50%)[32] on the NRS after the first treatment (mean change = 3.75 ±1.89). All participants also reported a cumulative NRS score of less than 1 by discharge. Four participants reported cumulative NRS scores of 0, while one participant reported a cumulative score of 0.33 at discharge.

PSFS

The use of the MC "Squeeze" technique produced a statistically significant positive change in PSFS scores ($t(4) = -6.74$, $p \leq .003$ 95% CI= -9.32 to -3.88, Cohen's $d = 3.01$) from initial exam to discharge 14.2 ± 5.68 days after initial exam (Table 5). The Cohen's *d* value resulted in a large effect size,[37] indicating the change in PSFS scores can likely be attributed to the treatment intervention. Of particular importance, all participants reported an increase of at least 3-points by discharge, meeting the MDC for PSFS.[34] All participants reported a PSFS score of 10 by discharge, indicating a complete restoration of function (Table 4).

DPA Scale

The use of the MC "Squeeze" technique produced a statistically significant improvement in DPA Scale scores ($t(4)= 3.817$, $p \leq 0.019$, 95% CI= 4.96 to 31.44, Cohen's $d = 1.44$) from initial exam to discharge, 14.2 ± 5.68 days after initial exam (Table 5). While only three participants reported a score that met the MCID for acute injuries (9 points),[35] the other two participants began with scores below 23, which is within the normal range. The two participants who did not meet the MCID still improved by 7 and 8 points respectively. All participants' scores on the DPA Scale were below 23 at discharge, which indicated that their perception of disability had likely returned to their pre-injury state (mean change = 18.2 ± 10.66; Table 4).

KOOS

The use of the MC "Squeeze" technique produced statistically significant improvement in $KOOS_5$ ($t(4)= -7.342$, $p \leq 0.002$, 95% CI= -39.36 to -17.62, Cohen's $d = 1.36$) scores in each of the five dimensions, along with large effect sizes, from initial exam to discharge 14.2 ± 5.68 days after initial exam (Table 6). Of particular importance, all participants reported a minimum of 8-10 point increase on each of the five dimensions of the KOOS, meeting the MCID[36]. There is currently no published MCID values for the $KOOS_5$, but the mean change was a total increase of 28.56 ± 8.7 points for each participant on the $KOOS_5$ from initial exam to discharge.

Discussion

The results of this case series indicate improved patient outcomes when utilizing the MC "Squeeze" technique in participants who were classified as having a meniscal tear based on the meniscal pathology clinical composite score.[11] Meniscal tear diagnosis was determined by a clinical evaluation consisting of a thorough history and a comprehensive clinical assessment relating to the chief complaint. The criteria for clinical diagnosis was determined to be accurate based on the evidence supporting the diagnostic accuracy of Thessaly's test[15] and a battery of special tests.[16-19] A clinical examination has been determined to have a similar, and in some cases better, diagnostic accuracy than MRI alone, concluding that MRI is only necessary in cases lacking a definitive clinical diagnosis.[11,18,38-40]

The treatment timelines in this case series varied due to each participant's availability, however, all participants were discharged within six treatments (Table 4) delivered over an average of 14.2 days (± 5.68 SD). Additionally, the improvements reported by each participant were found to be statistically and clinically significant across all outcomes measures used in this case series. The use of the MC "Squeeze" technique also produced immediate benefits for the participants, as four of the five participants reported experiencing clinically significant improvements in pain after the first treatment (Table 4). Of particular importance to the athletic population, each of the participants continued to engage in sport activity as tolerated during the treatment period. Participants #1 and #4 returned from non-weight bearing status to limited activity after just one treatment and returned to full activity by the third treatment. Participant #2 returned to full activity after two treatments. Participants #3 and #5 maintained full activity for the duration of treatment.

The outcomes reported in this case series exceed those reported in the use of traditional conservative therapy. The use of progressive resistive exercises (PREs) and non-steroidal anti-inflammatory drugs for treating meniscal pathology typically require more treatment sessions over a longer period of time (i.e., 12 weeks).[40] The outcomes of this case series also surpass the return-to-play timelines for meniscal tears treated with partial meniscectomies. In a previous study, only 80% of participants who underwent partial meniscectomy returned to full sport activity after six months of rehabilitation.[40] Despite less than desirable outcomes in many cases, the "gold standard" of care continues to be partial meniscectomy;[5,14,25-26,28,42-45] however, there are also recommendations to exhaust conservative treatment options prior to considering surgery.[25,43-45] While more research is still needed, the positive results reported in this case series provide support for the MC "Squeeze" technique as an alternative non-operative treatment option for patients with presenting with meniscal pathology.

Several limitations exist in this case series, beginning with not controlling for each participants' activity during the course of treatment and the lack of arthroscopy for the confirmation of meniscal tears; however, given that most diagnoses are not made with arthroscopy and rely on clinical diagnosis, it is important to study the treatment of meniscal pathology patients who are classified through a clinical exam. Other limitations include the lack of a control or comparison treatment group and the collection of long-term (e.g., 6-months post-discharge) outcome measures. Additionally, according to the Mulligan Concept, it is common to first apply an internal rotation accessory glide of the tibia when treating patients with general knee pain, and to progress to medial/lateral glides of the tibia, to provide the greatest reduction in symptoms.[29] Thus, the patient outcomes reported in this case series may have been further improved by determining which MC technique was best for each individual participant. However, as the MC "Squeeze" technique is recommended for the management of meniscal tear symptoms.[29] Finally, while the outcomes using the MC "Squeeze" technique were positive, the application of the technique was provided by clinicians who were novices in utilizing this specific technique. Expert MC practitioners could have possibly exceeded the clinical outcomes produced in this study; the impressive results produced by novices, however, provides evidence for the potential efficacy of using this technique. Future research is needed to compare the MC "Squeeze" technique to other interventions for short- and long-term benefit. If the technique is found to be beneficial, investigation would also be needed to better understand the underlying physiological mechanism of the treatment.

Conclusion

Meniscectomy and meniscal repair surgery are currently common practice;[24] however in this case series, use of the Mulligan Concept "Squeeze" technique produced statistically and clinically significant improvements in participants who were clinically diagnosed with a meniscal tear. The MC "Squeeze" technique may produce positive results in an athletic population seeking conservative treatment of meniscal pathology. The use of this manual therapy technique may also satisfy recommendations to exhaust conservative treatment interventions before seeking surgical intervention. Further research is needed to determine physiological mechanism and long-term effect of the treatment.

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Table B.1: Clinical Composite Score Findings for the Detection of Meniscal Tears. (Lowery et al., 2006)

	5 tests	≥4 tests	≥3 tests
% Sensitivity	11.2	16.86	30.8
% Specificity	99	96.1	90.2
% PLR	11.45	4.29	3.15
% PPV	92.3	81.8	76.7

Table B.2: Demographic Data for Participants

Participant	Age	Sex	Sport	Onset of Symptoms
1	15	Male	Football	Acute
2	20	Male	Track	Acute
3	20	Female	Lacrosse	Acute
4	24	Male	Basketball	Acute
5	19	Male	Football	Acute

Table B.3: Inclusion Criteria for All Participants with Descriptions of Positive Special Tests on Clinical Exam

Sign/Symptom	Participant 1	Participant 2	Participant 3	Participant 4	Participant 5
History of Popping or Clicking	Positive	Positive	Negative	Negative	Negative
Joint Line Tenderness	Positive	Positive	Positive	Positive	Positive
Terminal Knee Extension	Positive	Negative	Positive	Positive	Positive
Terminal Knee Flexion	Positive	Positive	Positive	Positive	Positive
McMurray's Test	Positive	Positive	Positive	Positive	Positive
Thessaly's Test (@ 20˚)	Not Performed	Positive	Positive	Positive	Positive
Apley's Compression Test	Positive	Negative	Positive	Positive	Positive
Other Initial Exam Symptoms	Edema, ROM Restriction, unable to weight bear	Edema and ROM Restriction	ROM Restriction	Edema and ROM Restriction	ROM Restriction

Table B.4: Treatment Data for Duration of Treatment from Intake to Discharge Including when Participants Achieved MCIDs

			Average NRS		Current NRS		PSFS		DPA		$KOOS_5$	
s	Total Treatments	Days to Discharge	Intake	Discharge	Intake	Discharge	Intake	Discharge	Intake	Discharge	Intake	Discharge
1	5	21	3	0*	2	0*	0	10**	35	4**	43.29	86.60**
2	6	18	5.33	0*	5	0*	6	10**	11***	3	66.69	87.54**
3	6	9	4	0*	4	0*	4	10**	42	16**	47.81	74.99**
4	6	21	5.33	0.33*	5	1*	3	10**	19***	0**	63.31	91.03**
5	2	2	4.33	0*	5	0*	4	10**	21***	14	65.85	89.60**

*MCID Achieved in first treatment
**MCID Achieved by discharge
***Normal range prior to treatment

Table B.5: Statistical and Clinical Significance for Pain, Function, and Disability Scales

Outcomes Scales	Mean Change	Significance (*p*)	95% Confidence Interval	Cohen's d
NRS- Average	4.32	0.00*	3.21 to 5.43	4.39
NRS-Current	4	0.002*	2.48 to 5.52	3.07
PSFS	6.6	0.003*	-9.32 to -3.88	3.01
DPA	18.2	0.019*	4.96 to 31.44	1.44

*Statistically significant

Table B.6: Statistical and Clinical Significance for All Subsections of the KOOS

KOOS Sub Scale	Mean Change	Significance (*p*)	95% Confidence Interval	Cohen's *d*
Symptoms	27.06	0.036*	-51.98 to -2.93	2.89
Pain	32.22	0.013*	-53.06 to -11.39	1.89
ADL's	23.22	0.014*	-38.94 to -7.72	1.93
Sports	49	0.014*	-81.38 to -16.62	1.77
QOL	11.2	0.037*	-21.31 to -1.09	0.79
Composite	28.56	0.002*	-39.36 to -17.76	1.36

KOOS – Knee injury and Osteoarthritis Outcomes Score; ADL – Activities of Daily Living; QOL – Quality of Life
*Statistically significant

Figure B.1: Starting hand placement for the MC “Squeeze” technique with participant’s knee at approximately 90 degrees of flexion.

Note: Hand placement was found in a pain-free range of motion.

Figure B.2: Clinician hand placement as participant moves through active knee extension.

Note: The pressure from the mobilizing thumb is released when the joint space closes, and reapplied when it opens with knee flexion

Figure B.3: Clinician providing the compression on the tender portion of the joint line as participant performs active knee flexion with overpressure.