Alternative Approaches to the Treatment of Athletic Injuries and Shift in Clinical Practice Philosophy: A Dissertation of Clinical Practice Improvement

A Dissertation Presented in Partial Fulfillment of the Requirements for the

Degree of Doctor of Athletic Training

with a

Major in Athletic Training

in the

College of Graduate Studies

University of Idaho

by

Amy Richmond

Major Professor: Russell T. Baker, D.A.T.

Committee Members: James M. May, D.A.T.; Alan M. Nasypany, Ed.D.;

Donald K. Reordan, P.T.

Department Administrator: Phillip W. Scruggs, Ph.D.

August 2016

AUTHORIZATION TO SUBMIT DISSERTATION

This dissertation of Amy Richmond, submitted for the degree of Doctor of Athletic Training with a Major in Athletic Training and titled "Alternative Approaches to the Treatment of Athletic Injuries and Shift in Clinical Practice Philosophy: 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.

Major Professor: ________________________________ Date: _____________
Russell T. Baker, D.A.T.

Committee
Members: ________________________________ Date: _____________
James M. May, D.A.T.

________________________________ Date: _____________
Alan M. Nasypany, Ed.D.

________________________________ Date: _____________
Donald K. Reordan, P.T.

Department
Administrator: ________________________________ Date: _____________
Phillip W. Scruggs, Ph.D.

ABSTRACT

This Dissertation of Clinical Practice Improvement (DoCPI) is both the culmination and summation of the clinical development required for achieving advanced practice in athletic training. The DoCPI is the final analysis of all aspects of clinical practice as developed during the Doctor of Athletic Training (DAT) program at the University of Idaho (UI). The DAT program at UI has not only influenced my clinical practice philosophy, my values as a clinician, but my sense of self and view of the world around us. This DoCPI will present reflections on clinical practice development, highlight independent research, present patient outcomes, and conclude with the complete literature review and manuscript for a high-impact, multi-site, randomized sham-controlled trial for the treatment of meniscal tears as a demonstration of the clinical practice growth necessary for advanced practice.

ACKNOWLEDGEMENTS

Great individuals who have had significant impacts in my life made the path to advanced clinical practice and the Dissertation of Clinical Practice Improvement DoCPI possible.

Dr. Russell Baker: Thank you for your constant support and your consistent push for excellence; you have been one of the greatest mentors of my life. You have taught me invaluable lessons in scholarship, research, and clinical practice. Without you, none of this would be possible; your vision and drive not only made Team Meniscus possible, but successful. There is not a way to portray my endless gratitude.

Dr. James May: Thank you for your support, wisdom, and encouragement. Your unique perspective challenged my thought process and encouraged me to grow as a writer and a clinician. Your willingness to help truly made this process better.

Dr. Alan Nasypany: Thank you for your personal wisdom, guidance in clinical practice, and instructions in treatment paradigms. You taught me to view both clinical practice and the world in different ways. You challenged who I thought I was as a person, my perspective on life, and caused me to reevaluate my priorities for the better. I am so grateful.

Don Reordan: Thank you for your guidance in the Mulligan Concept. You have had significant positive impacts in my clinical skills that have helped mold me into a better clinician. Your guidance made our research study possible and I am truly grateful.

Team Meniscus: You have become my friends and my family. I honestly could not have survived this journey without you by my side. Thank you for countless hours of hard work, laughter, and support. I will miss our midnight video conferences and trips to Patty's.

DEDICATION

This Dissertation of Clinical Practice Improvement is dedicated to my incredibly hardworking mother. She has sacrificed her entire life to give me a wonderful life and to make sure that I never wanted for anything. My mother has endlessly supported my dreams, no matter how outlandish, including encouraging me to embark on this endeavor. She gave me a place to live and work, assisted with my responsibilities, and tolerated my all-night writing sessions. Nothing in my life would be possible without her and I will be eternally grateful for all she has done.

In loving memory of my father Norman Richmond, who was my first friend and is my guardian angel.

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CHAPTER 1

NARRATIVE SUMMARY

Introduction

Fate is an interesting concept to embrace, because accepting it also implies accepting the universe or some greater power having control over the direction we, as humans, are meant to follow in life. In the years after graduating from college, I did not give the universe much thought; I just simply kept on the path that made the most sense for my goals. I applied to the Doctor of Athletic Training program at the University of Idaho (UI) on a whim in my first year of clinical practice, without significant inquiry into the program. However, it was as if the universe was guiding me to what I was not aware that I desperately needed. Carolyn Myss (1996) once wrote, "Just let go. Let go of how you thought your life should be, and embrace the life that is trying to work its way into your consciousness;" that statement, while poignant and applicable to many aspects of life, is also the summation of my journey through the DAT program. The DAT program at UI was everything I needed to learn about clinical practice in athletic training to develop as a clinician, but nothing like what I had anticipated, in the best possible way.

Overall, it is generally accepted that post-professional education in athletic training is a necessity to develop the skills to progress from novice clinician to expert in advanced clinical practice (Neibert, 2009). Pursuit of post-professional education in athletic training has been associated as a significant positive indicator of dedication to professional growth and perception of lifelong career commitment (Mazerolle & Dodge, 2012). I have noticed a profound impact on my athletic training career as a result of participating in the DAT program at UI. My perspective on clinical practice philosophy, patient care, the role of a clinician, and the theories surrounding pain, injury, and healing have completely evolved. My patient outcomes have improved substantially, and I have been forced to confront and overcome many personal fears and self-imposed barriers. Participating in the DAT program has also greatly influenced my sense of self and self-efficacy. The DAT program at UI has been an integral part in my development - not only as an academic, a researcher, and a clinician, but also as a person - and is evident in my Dissertation of Clinical Practice Improvement (DoCPI).

Path to Advanced Practice

Advanced practice in athletic training is difficult to define because it holds a unique meaning for every clinician. Prior to the first semester of the DAT, I believed that my role as an athletic trainer was to "fix" athletic injuries and that the DAT would provide the insight I would need to accomplish that task. I learned quickly that, as a clinician and medical professional, my role was to facilitate healing whenever possible. Facilitating healing, however, involved much more than simply implementing the indicated treatment paradigm, and can seem impossible. Facilitating healing requires believing in the impossible, in knowing that spontaneous healing is possible because of the divine forces that drive human physiology, forces greater and more complicated than most can fathom and relate to the mind, body, and spirit (Myss, 2007). Myss (2009) often equates healing to the impossible and warns that, "Achieving the impossible requires that you outwit your voice of reason and access the whimsical part of your nature that inherently delights in the possibilities of the imagination." The road to healing entails awareness and acceptance of the unknown before healing can truly begin.

Moreover, the DAT program has fostered an environment where emotional intelligence (EI) can mature. Defined as the skill of accurately comprehending and appropriately responding to human emotion, EI is a requirement for advanced practice (Eberman & Kahanov, 2011). Inherent in some, learned in others, EI gives the clinician the ability to make decisions based on individual patient needs as opposed to a one-size-fits-all plan of care (Eberman & Kahanov, 2011). A leading reason for EI to become an integral part of advanced practice is the documented need for ATs to address the psychosocial aspects of pain and injury (Clement, Granquist, & Arvin-Barrow, 2013). Along with correctly interpreting the psychosocial influences specifically relating to each patient's injury, but also select the accurate psychosocial intervention to facilitate healing through holistic healthcare (Clemet et al., 2013).

Developing advanced practitioners, through autonomy in the clinical residency settings and experiential learning, has been another significant focus of the DAT program at UI. Autonomy in clinical residency sites is an integral aspect to developing advanced practitioners because it allows the clinician's patient care philosophy to mature through experiences rather than being influenced by another clinician's rigid philosophy (Gardin, Middlemas, and Mensch, 2011). Along with a change to my perspective on injuries and healing, a development of EI, and experiential learning, my path to advanced practice can be appreciated through progression in the areas of academia, research, professional development, and personal growth.

Academia

Beyond my own educational pursuits, my advancement in academia has been development as a preceptor in various athletic training education programs (ATEPs).

Prior to entering the DAT, I was not comfortable in the preceptor role. I was overwhelmed by the responsibility of clinically instructing athletic training students (ATSs) because I was insecure in regards to my own clinical competency. Moreover, I also had an inherent apprehension to the pursuit of mentorship roles in general.

A major aspect to success as a clinical preceptor (CP) is the ability to identify and exploit the elusive “teachable moment” (Rich, 2009). A “teachable moment” is defined as an authentic opportunity for learning where a student is ready and willing to accept new information (Rich, 2009). Before the DAT, most patient interactions were new experiences for me, so I was unsure of how to teach information to an ATS when I was only learning in that moment as well. Throughout the DAT I have learned that there are very few instances in which you will always know the correct answer. Part of the evaluation process and treatment based classification is trial and error in order to determine a differential diagnosis.

Furthermore, the human body is capable of healing beyond our ability to comprehend and body systems are so intertwined and interrelated that we must accept that as medical professionals, we know very little about injury, illness, and healing. As a result, the best patient care we can provide is based on what we do know to be true and an acceptance of limitless possibilities. In turn, I have become a much-improved CP because I have abandoned the fear of being wrong and turned my patient interactions into “teachable moments” about limitless possibilities for healing.

Now, I thoroughly enjoy my role in academia because I am much more confident in my ability to portray quality patient care and to articulate the theory surrounding my clinical practice without feeling pressured to define a correct diagnosis. I believe my

ATSs learn better when they understand that with every patient I am expanding my own knowledge due to the uniqueness of every patient's condition. The ATSs learn that every patient is an individual and the opportunity for a learning experience and adhering to a preset, rigid, universal protocol is doing them a disservice.

Likewise, I have also learned through my own experiences in new treatment paradigms during the DAT that mistakes are part of growth. Therefore, I am significantly more willing to allow my ATSs to make mistakes. I will allow my ATSs to determine which treatment paradigm(s) would be indicated and, as long as it is not specifically contraindicated or dangerous to the patient, I will allow them to utilize their selected treatment. Afterward, I will have them evaluate whether the treatment garnered their expected result and facilitate a discussion about adjustments that need to be made to implementation of treatments, adjustments to expectations of treatment outcomes, and/or aspects of the evaluation and treatment selection that may have been overlooked. By allowing them to make mistakes, I am also allowing my ATSs the opportunity to develop their own patient care philosophy, while increasing their clinical competency simultaneously.

Research

Prior to entering the DAT program at UI, my research background was limited to my thesis for my master's degree, which consisted of a quantitative survey analysis of behaviors of lacrosse helmet fitting across athletic trainers in the secondary school setting. The study was heavily supervised and influenced by my major professor and I had very little autonomy in the design, implementation, and analysis process. While it was an excellent introduction into the research process in general, I did not feel confident in my ability to conduct even case studies independently.

Emphasis on building a strong foundation in conducting research is an integral part of post-professional education (Neibert, 2009). Research fosters an environment in which clinicians can critically reflect because they learn not to accept outcomes at face value and to seek the truth behind the cause of the outcomes (Neibert, 2009). Research also promotes a mastery of subject matter because it allows clinicians to refine their thought process and implement interventions and decision-making strategies that are established in theory (Neibert, 2009).

Improving as a researcher has been one of the achievements of which I am the most proud. In the short time span of the DAT program, I have co-authored, designed, and implemented a variety of research studies, from case studies to a randomized, sham controlled trial. In addition, I was the lead author on a case study for an innovative treatment intervention. By conducting research, I have gained the ability to analyze my patient outcomes and my patient care in greater depth. My pattern recognition within my patient care has also improved significantly from critical reflections of my research. Finally, I have also developed the skills to disseminate my research findings by submitting my research for publication in scholarly, peer-reviewed journals and presentation at professional conferences.

Professional

Professionally, I have made a significant change directly as a result of completing the DAT program at UI. When I first enrolled, I was employed as an Assistant Athletic Trainer in a small athletic department that consisted of one other athletic trainer. The word “no” did not have a place in my vocabulary. I simply agreed to do any task that was asked of me because I thought that it was a job requirement. As a result, I was not able to maintain any sense of work-life balance. Work-life balance is difficult to achieve in athletic training in the current model because of a lack of understanding of the athletic trainers’ role in the collegiate setting and their workload ability (Pitney, 2006; Goodman, Mazerolle, & Pitney, 2015). In my situation, this was exacerbated because I was unable to advocate for myself. As a direct result of my education in the DAT, however, I have reorganized my work priorities to focus simply on good patient care (Mazerolle, Faghri, Marcinick, & Milazzo, 2010; Mazerolle, Goodman & Pitney, 2015; Mazerolle, Eason, & Trisdale, 2015) and develop healthy lifestyle changes through learning to be present, frequent meditation, and reevaluation of priorities.

Another major component of advanced clinical practice and professional improvement is development of leadership and mentorship abilities. There is a strong desire for more female role models/mentors in athletic training (Eason, Mazerolle, & Goodman, 2014). Unfortunately, women are being forced to seek out male mentors because males make up 75% of the fulltime athletic trainer positions in the collegiate setting. Furthermore, interactions with a role model can greatly influence an athletic trainer’s perception of the profession (Eason et al., 2014) and clinicians report previous experiences with role models as a significant factor contributing to their educating style as a preceptor (Mazerolle, Bowman, & Dodge, 2014). My goal has been to become a strong female leader in the collegiate athletics setting and to mentor ATSs, both in and out of the clinic, to encourage them to strive for advanced clinical practice. My greatest achievement in mentoring students has been the acceptance of one of my former ATS to the DAT cohort on 2018. In addition, he has requested that I act as his attending clinician (AC). While I hope to influence many more ATSs, I am encouraged and inspired by the impact my path towards advanced practice has had on a future generation of athletic trainers.

Personal

Over the past several semesters, I have likened my journey through the DAT to my yoga practice. The time spent on the mat meditating, practicing, and moving is all very personal because there is no right or wrong, just the current state of one's yoga practice. Yogis never focus on the end point because the journey is where real change occurs and spiritual enlightenment is found. The *Bhagavad Gita* teaches that inner peace is found when one can truly surrender attachment to expectations (Patton, 2008). Advanced practice of any kind is not a competition and there is no prize at the end because there is no end. Practice is consistent lifelong learning and advanced clinical practice should be an effort to consistently provide better patient care than the day before, not to be the best for selfish reasons.

An ancient Buddhist proverb uses the analogy of excavating a well to explain that we cannot anticipate the outcome of a journey or the quantity of obstacles necessary to overcome; however, in time and with enough perseverance, we can achieve our desired outcome (Chopra, 2007). Sri K Pattabhi Jois, guru of Ashtanga yoga, further emphasized that with practice and time "all is coming" (2008). The intent was to emphasize that inner peace is not an achievement, but rather a state of being that requires lifelong, consistent effort. Reflecting on those simple sentiments was epiphanic, because I finally recognized that like enlightenment, advanced clinical practice is also a state of being and must be respected as such.

Dissertation of Clinical Practice Improvement

The profound effects of the growth through the DAT program at UI are numerous and I will be forever positively impacted as a clinician as a result. Not only I have noted improvements in areas of clinical practice, such as research and academia, but I have also noted improvements in my overall well-being that have positively affected my professional career. The subsequent chapters of the DoCPI will embody the aforementioned new perspective on advanced clinical practice and my guiding philosophies. The DoCPI will encompass all areas of growth through the DAT program at UI, from changes in clinical practice philosophy, improved patient outcomes, personal growth as a clinician, and research into alternative treatment paradigms that may benefit the athletic training profession.

Chapter Outlines

Following this narrative summary, the DoCPI will continue with a case study manuscript of the most profound finding of my athletic training career in Chapter 2. While the outcome of this case study does not provide enough evidence to be applicable to the athletic training profession as a whole - it is limited to just one patient case - it highlights the growth and change of my perspective throughout the DAT program. In this case, I highlight a mind-body therapy used to alleviate the low back pain of one of my patients. Prior to the DAT, I only ever considered physical causes of pain and injury, never psychosocial or energetic causes. It was my opinion that anything relating to the patient's mental state should be the responsibility of a psychologist or psychiatrist;

however, I now realize my perspective was created because I was ill equipped to manage any such condition. Through significant mentoring from the DAT faculty, I have come to accept that the human body cannot be divided and treated as individual parts. Every anatomical system directly affects every other system on a physiological level. Attempting to treat a patient as if the systems were not interrelated was not only ignorant, but also impossible when attempting to provide quality and effective patient care. The only way to provide quality patient care was to treat the whole body, and not just the complaint. The case study developed as a direct result of attempting to model my clinical practice philosophy on that ideal and is particularly important to me as a clinician.

Chapter 3 details my clinical practice development through patient outcomes collected during the DAT program. In the first semester of the DAT, I collected only a few patient outcomes on a small number of treatment paradigms, some of which I had been utilizing prior to the DAT. By the final semester, however, I was able to implement more than 10 new treatment paradigms and have significantly improved outcomes in all paradigms that exceeded the national average in time lost for injuries. Chapter 3 will be a comprehensive reflection on the clinical experiences and outcomes that demonstrate evidence of advanced clinical practice and an advanced patient care philosophy.

The last two chapters will encompass the focused research portion of my DoCPI. In Chapter 4, I worked with my multi-site research team to review the literature regarding meniscal pathology and determine a potential clinical problem we needed to address. The chapter serves as evidence of my ability to critically analyze the literature, identify a problem, and identify the necessary methodology for implementing a research study to answer our research questions. Overall, the evidence for needing to study alternative treatment for meniscal pathologies is presented.

The final chapter is the cumulative piece of evidence for my development as a scholar. In this chapter, I worked with my multi-site research team to design and implement a study assessing the effects of the Mulligan Concept (MC) "Squeeze" technique, as compared to a sham treatment, on meniscal tears. The resulting manuscript also provides evidence of my ability to conduct the analysis, interpret the results, and to prepare a scholarly manuscript to disseminate my findings. The results found in Chapter 5 describe the potential usefulness of the MC "Squeeze" technique in an athletic population.

Conclusion

The path to advanced practice is an extensive and exhaustive process of self-reflection, exploration of new treatment paradigms, and advancement of all aspects of clinical practice. The journey is unique for all clinicians and, at times, may be unclear; but, continuing to strive for greatness will lead each clinician to an end result far beyond their expectations. The DoCPI will examine my particular journey by providing evidence of advancement in research, implementation of new treatment paradigms, changes in patient care philosophy, and significant improvement in patient outcomes.

References

Chopra, D. (2007). *Buddha*. New York: Harper Luxe.

Clement, D., Granquist, M., & Arvinen-Barrow, M. (2013). Psychosocial Aspects of Athletic Injuries as Perceived by Athletic Trainers. *Journal Of Athletic Training*, *48*(4), 512-521. http://dx.doi.org/10.4085/1062-6050-48.3.21

Eason, C. M., Mazerolle, S. M., & Goodman, A. (2014). Motherhood and Work–Life Balance in the National Collegiate Athletic Association Division I Setting: Mentors and the Female Athletic Trainer. *Journal of Athletic Training*, *49*(4), 532–539. http://doi.org/10.4085/1062-6050-49.3.03

Eberman, L. & Kahanov, L. (2011). Emotional Intelligence: A Requisite for Good Clinical Practice. *Athletic Training Education Journal*, *6*(3), 127-128.

Gardin, F., Middlemas, D., & Mensch, J. (2011). A Qualitative Description of Self-Regulatory Behaviors in Male Expert and Novice Athletic Trainers in Collegiate Settings. *Athletic Training Education Journal*, *6*(3), 136-144.

Goodman, A., Mazerolle, S., & Pitney, W. (2015). Achieving Work-Life Balance in the National Collegiate Athletic Association Division I Setting, Part II: Perspectives From Head Athletic Trainers. *Journal Of Athletic Training*, *50*(1), 89-94. http://dx.doi.org/10.4085/1062-6050-49.3.87

Jois, K. (2010). *Yoga mala*. New York: North Point Press.

Mazerolle, S. M., Borland, J. F., & Burton, L. J. (2012). The Professional Socialization of Collegiate Female Athletic Trainers: Navigating Experiences of Gender Bias. *Journal of Athletic Training*, *47*(6), 694–703.

Mazerolle, S. M., Bowman, T. G., & Dodge, T. M. (2014). The Professional Socialization of the Athletic Trainer Serving as a Preceptor. *Journal of Athletic Training*, *49*(1), 75–82. http://doi.org/10.4085/1062-6050-48.6.16

Mazerolle, S., Eason, C., & Trisdale, W. (2015). Work-Life Balance Perspectives of Male NCAA Division I Athletic Trainers: Strategies and Antecedents. *Athletic Training & Sports Health Care*, *7*(2), 50-62. http://dx.doi.org/10.3928/19425864-20150216-01

Mazerolle, S., Goodman, A., & Pitney, W. (2015). Achieving Work-Life Balance in the National Collegiate Athletic Association Division I Setting, Part I: The Role of the Head Athletic Trainer. *Journal Of Athletic Training*, *50*(1), 82-88. http://dx.doi.org/10.4085/1062-6050-49.3.88

Mazzerolle, S. & Dodge, T. (2012). National Athletic Trainers' Association-Accredited Postprofessional Athletic Training Education: Attractors and Career Intentions. *Journal Of Athletic Training*, *47*(4), 467-476. http://dx.doi.org/10.4085/1062-6050-47.4.11

Myss, C. (1996). *Anatomy of the spirit*. New York: Harmony Books.

Myss, C. (1997). *Why people don't heal and how they can*. New York: Harmony Books.

Myss, C. (2009). *Defy gravity*. Carlsbad, Calif.: Hay House, Inc.

Neibert, P. (2009). Novice to Expert Practice via Postprofessional Athletic Training Education: A Grounded Theory. *Journal Of Athletic Training*, *44*(4), 378-390. http://dx.doi.org/10.4085/1062-6050-44.4.378

O'Connor, C., Grappendorf, H., Burton, L., Harmon, S., Henderson, A., & Peel, J. (2010). National Collegiate Athletic Association Division I Football Players' Perceptions of Women in the Athletic Training Room Using a Role Congruity Framework. *Journal Of Athletic Training*, *45*(4), 386-391. http://dx.doi.org/10.4085/1062-6050-45.4.386

Patton, L. (2008). *The Bhagavad Gita*. London: Penguin

Pitney, W. (2006). Organizational influences and quality-of-life issues during the professional socialization of certified athletic trainers working in the National Collegiate Athletic Association Division I setting. *Journal Of Athletic Training*, *41*(2), 189-195.

Rich, V. (2009). Clinical Instructors' and Athletic Training Students' Perceptions of Teachable Moments in an Athletic Training Clinical Education Setting. *Journal Of Athletic Training*, *44*(3), 294-303. http://dx.doi.org/10.4085/1062-6050-44.3.294

Welch, C., Hankemeier, D., Wyant, A., Hays, D., Pitney, W., & Van Lunen, B. (2014). Future Directions of Evidence-Based Practice in Athletic Training: Perceived Strategies to Enhance the Use of Evidence-Based Practice. *Journal Of Athletic Training*, *49*(2), 234-244. http://dx.doi.org/10.4085/1062-6050-49.2.15

CHAPTER 2

MINDFULNESS AND SELF-MANAGEMENT TECHNIQUES FOR THE TREATMENT OF ACUTE NON-SPECIFIC LOW BACK PAIN IN A COLLEGIATE BASKETBALL PLAYER: A CASE REPORT

(In submission to the International Journal of Sport Physical Therapy)

Abstract

Background and Purpose: Low back pain (LBP) is a potentially debilitating condition that affects most of the population in their lifetime. Description of Case: 23 year-old male collegiate basketball player complaining of intermittent LBP lasting for five days was treated using Reflexercise™, a mind-body therapy designed to regulate the autonomic nervous system (ANS). **Outcomes:** The patient reported clinically significant changes on the Numeric Pain Rating Scale (NRS) and a single-activity Patient Specific Functional Scale (PSFS) that also indicated an alleviation of symptoms. The patient also learned to use the intervention as a self-management technique to resolve remittent episodes of LBP. **Discussion:** Strong correlations have been made between LBP and psychosocial factors. Current treatment guidelines suggest that mind-body therapy should be implemented in the treatment of LBP. **Level of Evidence:** IV, case report **Keywords:** Low Back Pain, Psychosocial Interventions, Reflexercise™.

Background and Purpose

According to the World Health Organization (WHO), low back pain (LBP) is a leading cause of disability globally. [1] In the United States, disability associated with LBP costs 16 billion dollars and affects 5.4 million Americans each year.[2] The source of the high annual cost is the frequency in which LBP affects the general population. The first-time incident rate of LBP ranges from 6.3% to 15.4%, but the incidence rate escalates to as high as 94% for recurrent episodes of LBP within one year.[3,4] In a survey of elite athletes, previous researchers found that 31.3% reported at least one episode of LBP in the prior 12 months.[5]

A common symptom associated with a low back pain diagnosis is pain that is concentrated posteriorly, inferior to the rib cage and above the gluteal region.[6,7] The presence of leg pain does not affect the diagnosis.[6,7] Typical characteristics of LBP include: the absence of a traumatic event, LBP being the singular complaint, certain postures alleviate symptoms (e.g., standing), certain movements (e.g., torso flexion) exacerbate symptoms, pain that does not wake the patient up at night, pain that does not require a frequent change of position to subdue symptoms, and no change in bowel or bladder function.[5,8] An acute episode of LBP is defined as symptoms lasting less than six weeks from onset, while subacute symptoms resolve within six to 12 weeks of onset, and chronic LBP symptoms resolve after longer than three months. Typically, symptoms resolve within the acute range; however, most patients will experience symptom recurrence within their lifetime,[5,9] with many regarding to the condition as a relapsing-remitting illness as opposed to an injury.[8]

Physical causes that may affect the incidence rate of LBP are ground surfaces, prolonged periods of sitting, heavy lifting, obesity that distorts spinal alignment, and late stages of pregnancy.[5] A comprehensive medical history and physical exam are considered adequate for diagnosing acute low back pain, as long as the patient does not have any "red flag" signs/symptoms that indicate a more significant pathology (e.g., cancer) or nerve root involvement (e.g., stenosis).[9,10] "Red flag" signs/symptoms include, but are not limited to, the clinical signs of fractures, infections, tumors, and/or cauda equina syndrome.[9,10] In the absence of "red flags," additional diagnostic testing is not indicated for patients within the acute timeframe.[9,10]

While there are many suspected physical causes of LBP that can be attributed to specific pathology, the greatest predictors of LBP are level of education, gender, and marital status.[7] Only 10% of all cases of LBP have a specific, known, pathological cause, which implies that the remaining 90% come from non-specific causes and are commonly defined as non-specific low back pain (NSLBP).[6] There is a strong psychological correlation with episodes of low back pain,[5] which is so strong that opioid pain medications are contraindicated because the psychological effects can exacerbate the problem.[8]

Many treatment options for NSLBP exist, and may include activity modifications to avoid movements or positions that exacerbate symptoms, as well as low-stress aerobic exercise.[9,10] Other frequently prescribed treatments include short-term use of anti-inflammatories, patient education about movement and positioning, and cognitive behavioral therapy.[5] Mindfulness-based meditation programs have also been used for the treatment of chronic LBP with moderate success for injury perception, but no statistical significant outcome for pain reduction.[11] Treatment of NSLBP is complicated, and there is no consensus on which type of treatments or paradigms yield the best results. Despite the psychosocial implications of low back pain being well-documented,[1,4,6-8,12-18] there is a paucity of research on many therapies, such as Reflexercise™, that are theorized to address these components of LBP.

Reflexercise™ is the first of six steps or treatments in the Associative Awareness Technique (AAT) paradigm.[19] The AAT paradigm is based on the theories of the startle reflex and conditioning of the nervous system.[20] Reflexercise™ is recommended to be used once per hour, every hour, for 21-28 days to create the desired effect of down-regulation of the sympathetic branch of the ANS.[19,20] The treatment begins with establishing a "Grateful Heart," then progresses into core practice and can be taught as a home exercise program to adhere to treatment recommendations.[19] While Reflexercise™ is not specifically designed as a pain mitigating treatment, it is worth investigating whether treatment paradigms meant to affect the nervous system's response to stressful triggers, many of those, which are correlated to LBP, has an effect on the symptoms of LBP. The purpose of this case study was to patient outcomes using a mind-body therapy, Reflexercise™, in a patient with acute non-specific low back pain. If a beneficial effect was found, a secondary purpose was to determine if a longer dosage of the therapy yielded a greater effect on the patient's symptoms.

Case Description

History

The patient was a 23-year-old male, collegiate basketball player complaining of moderate intensity (NRS=5), non-specific low back pain (NSLBP) experienced for one week. The patient did not have any previous history of low back pain or a specific mechanism of injury for this occurrence; instead, he reported an unexplained gradual onset of pain with basketball activity. The pain began after the first day of basketball practice and was present throughout his entire low back region, bilaterally and inferior to the rib cage, but superior to the posterior superior iliac spine (PSIS). The patient initially sought treatment for the pain on the second day of symptoms.

Due to identified pelvic and lumbar vertebral dysfunction, the patient was initially treated for mechanical causes of LBP. Treatment interventions included Muscle Energy Technique (MET) to correct apparent pelvic girdle asymmetry (i.e., right-sided upslip, anterior rotation, and inflare with a left sacral torsion on a left oblique axis) and Mulligan Concept (MC) sustained natural apophyseal glides (SNAGS) to correct an apparent 5th lumbar vertebrae right-sided facet issue. The patient responded to treatment, reporting an immediate resolution of his pain complaint, and maintained that improvement for five days. After this period of time, however, the patient reported a return of his pain at the same intensity and without any known physical provocation (e.g., gradual onset, no defined mechanism of injury). The physical exam findings differed, however, as the patient did not present with a pelvic girdle asymmetry or 5th lumbar vertebral dysfunction when the symptoms returned.

Clinical Impression #1

The patient reported an immediate and significant decrease in pain after the first round of treatment for LBP; however, when the symptoms returned one week later, the treating clinician theorized the true cause of the acute LBP had neither been identified nor treated. In an effort to better understand the nature of the patient's condition, further evaluation was necessary to rule out other pathological causes of LBP, to identify any potential contraindications for the treatment, and to assess other causes (e.g., psychosomatic dysfunction) that could produce the patient's complaint.

Evaluation

The patient underwent an evaluation following the algorithms provided by the U.S. Department of Health and later adapted by the New Zealand Society of Physiotherapists.[10] The patient was first asked to provide a detailed history of the onset and duration of the LBP and the associated symptoms.[10] The patient was also screened for potentially significant psychosocial aspects of disability with the Disability in the Physically Active Scale.[21] The patient scored below a 23, indicating that his perception of disability was within normal limits.[21] The patient did not report significant psychosocial factors (e.g., increased stress, increased unhappiness, recent significant life event) when prompted to describe any changes to daily life. The patient was then screened for and was negative for the "red flags" (i.e., significant trauma, signs of osteoporosis, history of cancer, recent unexplained illness, signs of spinal infection, night pain, significant pain in the supine position, saddle anesthesia, recent loss of bladder and/or bowel function, neurological deficit in the lower body, and major motor control deficit).[10]

The patient then underwent a physical exam to rule out any specific pathology that may have caused the onset of LBP. The patient's posture exam was within normal limits, without any obvious asymmetries. The Stork Stance, H, and I tests were negative, indicating that a spondylolisthesis or positional fault at the facet joint was most likely not the root cause of lumbar pathology.[22,23] During a repeated motions exam, the patient did not experience any peripheralizing or centralizing of pain with any motion tests, but did report pain with lumbar flexion.[22,23] During the standing Gillete's test, the patient displayed equal and normal motion bilaterally of the pelvic girdle, indicating no pelvic girdle asymmetry.[22,23] The long-sit test, which may also indicate a pelvic girdle asymmetry and contribute to a functional leg discrepancy, was negative in both the supine and seated positions.[22,23] Finally, a negative seated flexion test also indicated that the symptoms were not likely cause by a pelvic girdle asymmetry.[22,23] Equal motion bilaterally during a sphinx test and a seated flexion test indicated that the cause of the symptoms was probably not due to the presence of sacroiliac joint dysfunction.[22,23] The patient's lower limb reflexes were within normal limits, leg circumference was equal bilaterally, lower limb manual muscle tests were equal bilaterally, and no loss of sensory function was present, indicating that there no intervertebral disc herniation or nerve root compression.[10]

Clinical Impression #2

Following the evaluation and a lack of evidence supporting a specific pathology, the clinician deemed it appropriate to diagnose the patient with NSLBP. While the patient did not have a high total score on the DPA Scale, which could indicate a significant influence of psychosocial factors, the patient did report moderate dysfunction in response to several wellness questions, indicating a disruption in his perception of the overall quality of life.[21] Because the patient's evaluation only indicated a moderate disturbance in perception of quality of life, a psychosocial factor, the clinician felt there was minimal risk to the patient in utilizing a potentially neutral treatment (neither specifically indicated nor specifically contraindicated) related to addressing psychosocial factors. The patient provided informed consent for collection and potential publication of his medical history and outcomes of this treatment intervention. The Institutional Review Board (IRB) at the XXXX and XXXX approved collection and publication of any or all de-identified medical information collected by the clinician as a result of job responsibilities.

Outcome Measures

Numeric Pain Rating Scale

The Numeric Pain Rating Scale (NRS) is a valid measure of pain.[24] The NRS was used both pre- and post-treatment to assess for changes in level of pain. Prior to treatment, the scale was used in its entirety: an average of current level of pain, best pain over the past 24 hours, and worst pain over the past 24 hours.[24] Immediately post-treatment, the patient was only able to provide the current level of pain, due to the 24-hour time constraints of the additional two dimensions. Each dimension of the NRS was reported on a scale ranging from 0 (no pain) to 10 (representing severe pain).[24] The reported minimal clinically important difference (MCID) for the NRS specifically for low back pain is a decrease of 1.5 points after one week of treatment and 2.2 points after four weeks of treatment.[25]

Patient Specific Functional Scale

The Patient Specific Functional Scale (PSFS) is a valid assessment of physical function.[26] The PSFS can assess up to five physical tasks,[26] but the patient was asked to report and assess only the most debilitating activity. The scale is reported from 0 to 10, where 10 indicates the patient is able to do the activity to the same level as before the injury, and 0 indicates the patient is unable to perform the activity in any capacity.[26] An increase of 2.5 is recognized as the minimal detectable change for the assessment of a singular activity on the scale.[27]

Intervention

Grateful Heart

The first step in Reflexercise™ is mental priming to create a “grateful heart.”[19] The patient was instructed to choose one of the three options that he identified with the most: visualizing a white light healing your body with each inhalation, focusing on something that you are grateful for and allowing the grateful sensation to be the primary focus, or focusing on a memory that brings positive emotions and allowing the positive emotions to be the primary focus.[19] Reflexercise™ is patient-driven and private,[19] so the patient was instructed to choose one option, but did not have to verbalize which option he chose or what would be the focal point of his concentration.

Core Practice

The treatment of Reflexercise™ can be performed with the patient in lying, sitting, or standing, whichever the patient prefers or the situation dictates.[19] For the purpose of this intervention, the patient was lying supine in a quiet clinic. The patient was instructed to first close his eyes and gently bite on the tip of his (hard enough to be uncomfortable but not enough to cause damage) tongue,[19] which would inhibit the masseter muscles. Then the patient was instructed to open his arms, turn his palms towards the ceiling, spread his fingers as wide as possible in order to counteract the crossed-arms and fist grip reflex elicited during “fight or flight”.[19] The patient was also asked to curl his toes downward, opposing the dorsiflexed toe position neurologically facilitated by “fight or flight response” and maintain the full position, while performing the "grateful heart" during the breathing technique.[19] The patient was then instructed to breathe deeply and slowly four times.[19] The original principles of Reflexercise™ state that this technique should be used once an hour, varying the treatment position, in order to reduce the patient's autonomic nervous system's reaction to stress.[19]

Re-evaluation

The purpose of this case study was simply to evaluate the effect of Reflexercise™ on non-specific low back pain on this patient, so the patient did not progress on to subsequent steps. After the first intervention of Reflexercise™ core practice, the patient was then asked to assess his level of current pain. If the pain was the same or lower, the treatment would be repeated and held for as long as the patient deemed necessary. The objective was to determine if there was a measurable effect from the four-second treatment and if there was a greater effect for holding the position for as long as it took the patient to feel the "instant relief"[19] described in the Reflexercise™ manual. If the patient reported worse pain after initial treatment intervention, treatment would have been discontinued. The patient, however, reported a significant decrease in pain, so the treatment intervention was repeated. The intervention was sustained until the patient determined the desired result had been achieved - approximately 5 minutes - and was terminated at the patient's discretion.

Home Exercise Plan

While the AAT paradigm dictates that the treatment should be utilized every hour,[19] the patient was instructed that, at a minimum, he should use the treatment during and after stressful situations and any time he felt his low back pain complaint. The goal of Reflexercise is to train the nervous system's response to stressful stimuli; to produce the most robust treatment effect, it is thought necessary to be used repeatedly.[19] The patient was not taught the subsequent steps in the paradigm in order to determine the effect of this singular treatment intervention.

Outcomes

NRS

In post-treatment measurements, only current pain can be assessed on the NRS. After the initial intervention, the patient rated his pain a 3/10 pain on the NRS; the 2 point decrease was greater than the MCID for one-week of physical therapy in patients with low back pain. (1.5 points; Table 1)[25]. The second treatment occurred at the conclusion of the first treatment, on the same day. After the second treatment, the patient immediately reported a resolution of his pain complaint (Table 1), a total decrease of 5 points. On 24 hour follow-up, the patient still reported a 0/10 cumulative NRS score (Table 1). In the weeks following the treatment intervention, the patient reported connecting the onset of his low back pain to stressful situations related to sport performance. The patient regularly performed the treatment intervention (held for as long as necessary) prior to the beginning of basketball games and any time he felt any onset of pain returning. The patient was able to manage his low back pain through self-treatment using AAT. Every time the patient used the treatment intervention, he reported an immediate resolution of his current pain complaint.

PSFS

The patient indicated that torso flexion was the most debilitating activity and chose to score that activity on the PSFS. Prior to the treatment intervention, the patient reported a PSFS score of 5/10 (Table 1). Immediately following the initial treatment, the patient reported that his PSFS score had increased to a 7/10 (Table 1), indicating that his ability to do the activity was improving. The increase in the patient's ability to perform the activity fell just short of an MDC of 2.5 points.[27] After the second treatment, the patient reported a 10/10 on the PSFS (Table 1), indicating that he could perform the physical function for that specific activity at the same level as prior to injury.[26] On 24 hour follow-up, the patient still reported a 10/10 for forward flexion on the PSFS (Table 1). In the weeks following the treatment intervention, as he began the self-management techniques, the patient did have pain return, but the return of symptoms did not affect his ability to perform the PSFS activity and he reported maintained resolution of his functional complaint.

Discussion

In this case report, the patient responded positively to the treatment, experiencing not only clinically significant improvements in his symptoms, but also experiencing a resolution of the chief complaints for pain and dysfunction. In a single treatment session, the patient greatly exceeds the MCID on the NRS for patients with low back pain after four weeks of physical therapy.[25] On the PSFS, the patient reported a 5 point increase, which greatly exceeds the MDC for the scale.[26] The patient also utilized self-management techniques to address any recurrences of pain or dysfunction; the self-management techniques were useful and effective for the patient prior to basketball-related activity when the patient perceived anxiety surrounding his sport performance as the cause for his NSLBP symptoms.

Reflexercise™ was utilized in this case because it is specifically designed to abolish a chronic stress state within the patient's nervous system to prevent prolonged autonomic nervous system (ANS) activation with decreased parasympathetic activation[20] and should probably be used beyond the improvement of symptoms to truly “disconnect” the relationship between stress and specific pains. Stress states may be caused or maintained by the startle reflex, a protective mechanism that develops in utero, which allows the nervous system to protect some or all of the body from danger by preventing any sudden movements (28;29) The startle reflex occurs when the body is faced with the decision of “fight, flight, or freeze” and the muscles must preemptively tense in order to prepare for the next movement or to protect the body (30;29). Daily, these reflexes can be unintentionally activated by any stimuli, no matter how innocuous, if the nervous system deems the stimuli threatening based on past experiences (29; 20). The body’s protective mechanisms cannot differentiate between physical threats and mental stress states and primes the ANS to react similarly for all scenarios (29). Therefore, these stimuli may have a significant psychological or psychosocial effect.

Psychological or psychosocial influence on pain has been correlated to many chronic pain conditions, including LBP.[17] As a result, the current recommendation is that clinicians implement psychosocial therapies into the treatment of all patients with LBP.[15] Regarding this specific patient, the startle reflex may have been activated by a basketball-related activity, as this patient only developed symptoms around practice and games. The patient also exhibited signs of performance anxiety. Given the patient’s condition and the current literature recommendations, it was appropriate to consider the use of a treatment that is a mind-body therapy potentially affecting nervous system dysfunction.

Moreover, prolonged influence of the startle reflex may cause “up-regulation,” repetitive ANS cycling, or sensitization, which are synonymous for an increased response of the nervous system to any stimuli.[20,29] The phenomenon of "upregulation," led to the development of Reflexerise™ and AAT, which are therapies designed at decreasing over-sensitization of the nervous system.[20] The physiological responses to this over-sensitization can produce somatic symptoms, such as muscle tension and non-specific pain[20] and can lead to sensitization behavior, where a patient will develop avoidance behaviors due to a perpetual perceived threat of danger.[29] Sensitization behaviors may have been present for this patient; he would develop NSLBP symptoms prior to sport-related activity, without any known provocation or presence of new stimuli. Theoretically, this sensitization can also be identified through the presence of a pattern of an exaggerated pain response throughout the body,[31] including trigger points in the lower ribs, sacroiliac joint, and coccyx.[28,32] The trigger points can lead to biomechanical dysfunction and quick, sudden movements may become nearly impossible.[28,32] While this phenomenon affects all people, the effects can most frequently inhibit an athletic population who are required to run, jump, and change direction regularly[2] and may have limited this patient's ability to perform sport-specific activities.

Another important component for effectively treating LBP, especially in the acute stage, is the introduction and use of self-management techniques. Back pain, even in the presence of specific pathology, that is left untreated or progresses to the chronic stage has been correlated to widespread hyperalgesia, also known as central sensitization.[31,33] Central sensitization is a phenomenon in which the patient becomes more sensitive to stimuli in order to react quicker and protect the body from perceived danger, which increases their perception of pain.[31,33-34] Prolonged states of central sensitization can become pathological, because it can become autonomous[31,34] and can lead to other chronic pain conditions that may include, but are not limited to: fibromyalgia, irritable bowel syndrome, and/or migraines.[31,33-34] However, with treatment of the underlying condition, especially if no tissue damage is present, patient prognosis is positive as the condition is temporary and sensitivity levels can return to baseline.[34]

Conclusion

Reflexercise™ may be a potential treatment option in other athletic patients who exhibit symptoms related to the influence of prolonged sensitization and central sensitization because of the treatment's targeting of the central nervous system. Further investigation is necessary into the long-term effect the treatment can have on pain and what limitations exist. Further research is also required to determine whether the treatment will affect other patient populations differently. The outcome of this case study is limited to one patient, but the results provide support for considering this treatment in the management of LBP when the clinician perceives psychosomatic factors as a cause or contributing factor.

References

1. Ehrlich G. Low Back Pain. *Bulletin of the World Health Organization*. 2003;81:671-676.
2. Frymoyer J. Back Pain and Sciatica. *New England Journal of Medicine*. 1988;318:291-300.
3. Andersson G. Epidemiological features of chronic low-back pain. *The Lancet*. 1999;354(9178):581-585. Doi:10.1016/s0140-6736(99)01312-4.
4. Hoy D, Brooks P, Blyth F. The Epidemiology of Low Back Pain. *Best Practice & Research Clinical Rheumatology*. 2010;24(6):769-781.
5. Schulz S, Lenz K, Büttner-Janz K. Severe back pain in elite athletes: a cross-sectional study on 929 top athletes of Germany. *European Spine Journal*. 2015. doi:10.1007/s00586-015-4210-9.
6. Woolf A. Understanding the burden of musculoskeletal conditions. *BMJ*. 2001;322(7294):1079-1080. doi:10.1136/bmj.322.7294.1079.
7. Chevan J, Clapis P. *Physical Therapy Management Of Low Back Pain*. Burlington, MA: Jones & Bartlett Learning; 2013.
8. Hadler, NM. *Occupational musculoskeletal disorders*. Philadelphia: Lippincott Williams & Wilkins; 2005.
9. Nijs J, Apeldoorn A, Hallegraef H et al. Low Back Pain: Guidelines for the Clinical Classification of Predominant Neuropathic, Nociceptive, or Central Sensitization Pain. *Pain Physician*. 2015;18(3):E333-E346.

10. New Zealand Society of Physiotherapists. Submission on Clinical Practice Guideline, Acute Low Back Problems in Adults: Assessment and Treatment. *Journal of Manual & Manipulative Therapy*. 1996;4(3):112-125. doi:10.1179/jmt.1996.4.3.112.

11. Morone N, Rollman B, Moore C, Li Q, Weiner D. A Mind–Body Program for Older Adults with Chronic Low Back Pain: Results of a Pilot Study. *Pain Med*. 2009;10(8):1395-1407. doi:10.1111/j.1526-4637.2009.00746.x.

12. Reisbord L, Greenland S. Factors associated with self-reported back-pain prevalence: A populationdashbased study. *Journal of Chronic Diseases*. 1985;38(8):691-702. doi:10.1016/0021-9681(85)90023-2.

13. Ehrlich G, Khaltaev N. *Low Back Pain Initiative*. [Geneva?]: World Health Organization; 1999.

14. Morone N, Greco C, Weiner D. Mindfulness meditation for the treatment of chronic low back pain in older adults: A randomized controlled pilot study☆. *Pain*. 2008;134(3):310-319. doi:10.1016/j.pain.2007.04.038.

15. Foster N, Delitto A. Embedding Psychosocial Perspectives Within Clinical Management of Low Back Pain: Integration of Psychosocially Informed Management Principles Into Physical Therapist Practice--Challenges and Opportunities. *Physical Therapy*. 2011;91(5):790-803. doi:10.2522/ptj.20100326.

16. Cramer H, Haller H, Lauche R, Dobos G. Mindfulness-based stress reduction for low back pain. A systematic review. *BMC Complementary and Alternative Medicine*. 2012;12(1):162. doi:10.1186/1472-6882-12-162.

17. Jones G. Psychosocial vulnerability and early life adversity as risk factors for central sensitivity syndromes. *CRR*. 2015;12(999):1-1. doi:10.2174/1573397112666151231113438.

18. Keefe F, Porter L, Somers T, Shelby R, Wren A. Psychosocial interventions for managing pain in older adults: outcomes and clinical implications. *British Journal of Anaesthesia*. 2013;111(1):89-94. doi:10.1093/bja/aet129.

19. Musgrave S. *Reflexercise: Train Your Brain To Be LESS Reactive To Stress, Anxiety, Chronic Pain, Depression, Trauma And PTSD Right From Home*.; 2010.

20. Kasprowicz DE. Understanding the autonomic nervous system–A missing piece in the treatment of chronic pain. 2013. Retrieved from http://www.boernepti.com/media/file/340330/Understanding%20the%20ANS.pdf.

21. Vela L, Denegar C. The Disablement in the Physically Active Scale, Part II: The Psychometric Properties of an Outcomes Scale for Musculoskeletal Injuries. *Journal of Athletic Training*. 2010;45(6):630-641. Doi:10.4085/1062-6050-45.6.630.

22. Magee D. *Orthopedic Physical Assessment*. St. Louis, Mo.: Saunders Elsevier; 2008.

23. DeStefano L. *Greenman's Principles Of Manual Medicine*. 4th ed. Baltimore, MD: Lippincott, Williams, & Wilkins; 2011.

24. Downie WW, Leatham PA, Rhind VM, et al. Studies with pain rating scales. *Ann Rheum Dis*, 1978, 3:378-381.

25. Childs J, Piva S, Fritz J. Responsiveness of the Numeric Pain Rating Scale in Patients with Low Back Pain. Spine. 2005;30(11):1331-1334. doi:10.1097/01.brs.0000164099.92112.29.

26. Stratford P, Gill C, Westaway M, et al. Assessing disability and change on individual patients: a report of a patient specific measure. *Physiother Can*. 1995; 47: 258-263.

27. Chatman AB, Hyams SP, Neel JM, et al. The patient-specific functional scale: measurement properties in patients with knee dysfunction. *Phys Ther.* 1997; *77*(8), 820-829.

28. Iams J. When Reflexes Rule. *Physical Therapy and Rehab Medicine*. 2005;16(3):41.

29. Götz T, Janik V. Repeated elicitation of the acoustic startle reflex leads to sensitisation in subsequent avoidance behaviour and induces fear conditioning. *BMC Neuroscience*. 2011;12(1):30. doi:10.1186/1471-2202-12-30

30. Rothschild B. *The Body Remembers*. New York: Norton; 2000.

31. Starkweather A, Heineman A, Storey S et al. Methods to measure peripheral and central sensitization using quantitative sensory testing: A focus on individuals with low back pain. *Applied Nursing Research*. 2016;29:237-241. doi:10.1016/j.apnr.2015.03.013.

32. Fernández-de-las-Peñas CDommerholt J. Myofascial Trigger Points: Peripheral or Central Phenomenon?. *Curr Rheumatol Rep*. 2013;16(1). doi:10.1007/s11926-013-0395-2.

33. Kindler L, Jones K, Perrin N, Bennett R. Risk Factors Predicting the Development of Widespread Pain From Chronic Back or Neck Pain. *The Journal of Pain*. 2010;11(12):1320-1328. doi:10.1016/j.jpain.2010.03.007.

34. Latremoliere A, Woolf C. Central Sensitization: A Generator of Pain Hypersensitivity by Central Neural Plasticity. *The Journal of Pain*. 2009;10(9):895-926. doi:10.1016/j.jpain.2009.06.012

CHAPTER 3

RESIDENCY OUTCOMES SYNOPSIS

Over the course of the DAT program, I collected patient outcomes data to assess my clinical practice, identify areas for improvement, and analyze my clinical progress. Overall, this process posed the greatest challenge to my skills as a clinician. I find fulfillment in providing excellent patient care, investigating new alternative manual therapy treatment paradigms, and mentoring ATS in their development as clinicians. However, I found that collecting patient outcomes and data analysis were always areas that needed improvement. By developing my clinical and research skills through the first year, I was able to collect better data, conduct more meaningful analysis, and produce significantly improved outcomes in the second year. I did not choose to collect, analyze, or present patient outcomes data the same way in any two semesters. The change in focus each semester was due to varying interests in analyzing different aspects of my clinical practice. Furthermore, those interests changed as my patient care philosophy developed and my perception of what information was personally clinically relevant altered based on clinical reflection.

Data was collected over four semesters, but only three major perspective changes occurred from year one to year two. In the first year of the DAT program, I analyzed patient outcomes in a patient population that I was comfortable treating to develop my clinical skills in new treatment paradigms without extending far beyond my comfort zone. By the second year, I was significantly more interested in analyzing how effective I had become in providing quality patient care and how those outcomes compared to the overall collegiate athletic training populations as a whole. In the fall of the second year, I analyzed how often I used each treatment paradigm and what resulted from each treatment on every patient regardless of sport or injury. In the spring semester of the second year, I analyzed how effective my patient care was at reducing the number of injuries and time lost in one team compared to national epidemiological data.

Year One

Patient Population

In the first 18 months of the DAT program, my patient population consisted of 600 patients across a variety of sports. With a large volume of patients requiring treatment, much of the first year was spent developing an effective system for collecting, analyzing, and reflecting on patient outcomes. However, much of the data collected was incomplete (e.g., no discharge data, no follow-up data, no data collected during some treatments) or collected at inconsistent intervals. Therefore, traditional data analysis techniques (e.g., parametric statistics) were often not effective means for analyzing my patient outcomes and finding meaning; however, the process did provide ample opportunity for reflection. Unfortunately, the majority of my critical reflection focused on methods and strategies for improving the data collection process. By the end of the first year, I was able to perform a case series analysis on four patients with a complaint of anterior shoulder pain.

The four patients were overhead athletes with an insidious onset of shoulder pain in the dominant arm and a loss of cervical rotation towards the dominant arm. The patients were all classified as "Dysfunctional Non-Painful (DN) on the multi-segmental flexion during the Selective Functional Movement Assessment (SFMA). Three of the four patients also presented with a DN on the cervical rotations to the ipsilateral side, with the remaining patient presenting with a “Dysfunctional Painful” (DP) to the ipsilateral side. While most patients were not limited to those two dysfunctions, the multi-segmental flexion and right cervical rotation were the most conspicuous because those motions typically included a significant loss of motion. All of the patients had the same somatic pelvic girdle dysfunction of sacral flexion dysfunction, left on left flexion sacral torsion, right innominate upslip, right innominate anterior rotation, and right innominate inflare. Three of the four patients presented with a history of chronic low back pain and two had a history of recent (i.e. less than 12 weeks post) shoulder surgery.

Patient Outcomes

The first patient, a softball player, presented with right anterior shoulder pain when throwing. On evaluation, her most notable pain, problems, or dysfunctions were right anterior shoulder pain, loss of right cervical rotation, history of chronic low back pain, dysfunctional painful (DP) multi-segmental extension, dysfunctional non-painful (DN) multi-segmental flexion, sacral flexion dysfunction, left on left flexion sacral torsion, right innominate upslip, right innominate anterior rotation, and right innominate inflare. The patient’s treatment included Muscle Energy Technique (MET) to correct the somatic pelvic girdle dysfunction followed by and Reactive Neuromuscular Training (RNT) to retrain the neuromuscular system. The patient did not report any change in symptoms after the MET intervention, but did report a 0/10 pain after 1x10 RNT toe touches. The patient also regained full right cervical rotation as compared bilaterally after the RNT treatment interventions. The patient returned several times at varying intervals (e.g., 2-27 days) for treatment for the same symptoms, but after each treatment of both MET and RNS the patient reported a 0/10 pain on the Numeric Pain Rating Scale (NRS).

Next, a softball player presented with right anterior shoulder pain and radicular neurological symptoms in the entire posterior aspect of the arm and the fourth and fifth digits. The patient was three months post-surgery for rotational instability of the right shoulder. Her activity was limited because her physician prescribed a post-surgical protocol of active range of motion (AROM) in flexion and abduction at the time. The patient reported long periods of standing and sitting provoked her symptoms. The patient had an extensive history of chronic low back pain, but had not reported low back pain since before the shoulder surgery. The patient's primary dysfunctions, as noted on evaluation, were right arm and anterior shoulder pain, loss of right cervical rotation, pain with right cervical rotation, point tenderness over right transverse process of C6, ulnar nerve sliding dysfunction, history of chronic low back pain, DN multi-segmental flexion with a loss range of motion (ROM), sacral flexion dysfunction, left on left flexion sacral torsion, right innominate upslip, right innominate anterior rotation, and right innominate inflare. The patient's treatment included MET for somatic pelvic girdle dysfunction and 1x10 RNT toe touches. After treatment, the patient reported pain of 0/10. The patient's pain was alleviated for approximately 6 hours until she was forced to sit for several hours. The following day, the treatment was repeated and 1x10 RNT toe touches was added (i.e., 2x10 total). The patient's symptoms had not returned at 6 month follow-up.

The third patient was a baseball player who complained of right anterior shoulder pain when throwing. The patient had just returned (i.e., 2 weeks prior) to play after being completely cleared from a labral repair surgery in the same shoulder three months earlier. The patient was also three weeks post grade one medial sprain on the left ankle. The patient had not reported any previous history of ankle sprains or chronic ankle dysfunction. The patient admitted to intermittent low back pain in the past, but had never sought treatment for the symptoms. The primary dysfunctions noted on evaluation were right anterior shoulder pain, DN right cervical rotation with loss of end range ROM, DN multi-segmental flexion with a loss of ROM, sacral flexion dysfunction, left on left flexion sacral torsion, right innominate upslip, right innominate anterior rotation, right innominate inflare, and left ankle pain. The patient's treatment included MET for pelvic girdle dysfunction and 3x10 RNT toe touches. After treatment, the patient reported 0/10 pain when throwing. The shoulder pain had not returned in this patient at 6 month follow-up.

The final patient was a softball player who presented with right posterior shoulder pain and right-sided cervical pain. The patient's problem list included right posterior shoulder pain, DP right cervical rotation with significant loss of ROM (45 degree loss of motion), severe rounded shoulders and forward head posture, DN multi-segmental flexion, sacral flexion dysfunction, left on left flexion sacral torsion, right innominate upslip, right innominate anterior rotation, and right innominate inflare. The patient's treatment included MET and RNT on multiple occasions, in varying doses as the symptoms dictated. On several occasions, the use of MET alone resulted in the patient reporting a resolution of pain, while other instances required up to 3x10 sets of RNT toe touches in addition to the MET intervention to produce the same result. The patient was treated with increasing sets of 1x10 RNT toe touches, reporting NRS scores after MET and each set of RNT, until the outcome reported was 0/10 pain and cervical rotation was equal bilaterally as measured on a goniometer. This process was repeated at each reported instance of symptoms. After each treatment, the patient reported 0/10 pain, and the significant loss of cervical rotation would resolve; however, the pain and the loss of cervical rotation would return at irregular intervals. There was no consistent physical source of the symptoms for this patient and symptoms seemed to result after periods of intense stress and/or anxiety. Potential psychosocial causes of symptoms were identified and discussed with the patient, but the patient chose to continue with MET and RNT treatment without psychosocial interventions.

Reflection

The symptoms reported by the patients are not typical of those found in the research specifically for somatic pelvis dysfunction. Most often, somatic dysfunction of the pelvis is correlated to low back pain, as the dysfunction occurs in a significant number of patients with low back pain (Liccardone & Kearns, 2012; Juhl, Ippolito, Cremmin, & Russell, 2015). Some patients did have a history of back pain, but the chief complaint was pain in the shoulder, neck, and arm. While not heavily documented, early research on somatic dysfunctions also reports that is not the pathology of the dysfunction that determines the symptomology, because the response to the pathology is determined by the spinal cord (Koor, 2000). Therefore, the response to somatic dysfunction cannot be characterized by the specific somatic dysfunction classification, because the response to a somatic dysfunction is determined by the affected spinal segment (Koor, 2000). Essentially, the effect of any one type of somatic dysfunction cannot be definitively established, because one somatic dysfunction may affect different spinal segments in every person. As a result, one type of somatic dysfunction can produce different symptoms in every patient. While these patients' symptoms may be atypical of what is documented in the literature, it is possible that they could be associated with spinal segment impairment different from the majority of such injuries due to sport activity.

The American Association of Osteopathic Medicine (AAOM) suggests that somatic dysfunction in the acute stages can have symptoms like vasodilation, edema, tender points in the muscle, and trigger points in the muscle. In the chronic stages, however, symptoms can range from tenderness and itching to parathesia and fibrosis (Treffer, Ehrenfuechter, & Cymet, 2011). While the patients experienced a variety of similar symptoms, they all presented with somatic dysfunctions of the pelvic girdle. It is not unlikely that these patients could have been experiencing trigger points or tender points in the muscle as a result of acute somatic pelvic girdle dysfunction. Patient #2 had a chronic history of somatic pelvic girdle dysfunction documented for at least one year, so it is plausible that her chronic dysfunction could have lead to the neurological symptoms described by the AAOM.

Regarding my development as a clinician, this case series of patients with shoulder pain was the first population that I felt confident enough to treat. For me, there was an adjustment period within the first year in which I was unsuccessful at implementing and utilizing new treatment paradigms. First and foremost, I was studying new treatment paradigms that completely challenged my clinical philosophy. These new manual therapy treatment paradigms proposed potential effects greater than I was aware of in the published research in athletic training and physical therapy and proposed theories of efficacy not traditionally utilized in sports medicine. As a result, I was just beginning to comprehend their usage, physiological effect, and efficacy, which led to errors in treatment utilization and implementation. Furthermore, I was afraid of failure and afraid of being forced to confront my shortcomings as a clinician, so I had difficulty implementing treatment paradigms that I had the potential to use incorrectly. Therefore, I self-limited the potential success of my patient outcomes by not implementing treatment paradigms that may have been indicated, but I did not fully understand.

Another significant problem throughout the year was the patient outcomes collection process. One potential cause of the inconsistent and incomplete outcomes measures could have been poor time management on a large patient population. Another, more likely cause could have been self-sabotage because I did not feel comfortable treating patient. As a result, I did not want to be forced to report and reflect on poor patient outcomes. However, this patient population marked the first time I had been successful at repeatedly treating patients' symptoms. This specific patient population was also the first group in which I identified common signs, symptoms, and dysfunctions in order to develop a treatment protocol for the symptoms.

Year Two: Fall

Patient Population

In the first semester of the second year of the DAT program, I identified the issue of self-sabotage in patient outcomes during the first year and recognized that I had no system to analyze the effectiveness of my treatment interventions. Initially, I implemented an a priori design to collect outcomes on a larger patient population than the previous semester in hopes of collecting a larger volume of patient outcomes to analyze. The initial a priori design included patients with low back pain and consisted of a regimented course of treatments over a one-week timeframe to determine the most effective treatment for the symptoms. By mid-semester, I had not seen enough patients that fit into the a priori design, so I re-evaluated and decided to track all patients, regardless of chief complaint, sport, or length of symptoms, for a set length of time.

I analyzed a random selection of patient outcomes that were not included based on symptoms or chief complaint over the course of one week. There was a total of 18 patients, predominately male (n=14 male, n=4 female) and participating in football (n=5) or men's basketball (n=3). The patients were all NCAA division III college athletes (mean age=20.41±1.46 years). The most common injury reported was low back pain (n=4), but patients presented a variety of upper and lower extremity injuries as well. Most patients only received one treatment (n=11) and most presented with acute symptoms (n=15).

Patient Outcomes

Over the course of the semester, I analyzed which treatment paradigms I utilized most frequently and with which I found the greatest improvements in symptoms. The Mulligan Concept and Muscle Energy Technique (MET) were not only my most frequently selected treatment paradigms (n=19 and 16, respectively), but also the treatment paradigms that most often resolved the patients' symptoms (n=19 and 13, respectively). While not selected nearly as often, breathing corrections (n=8), Primal Reflex Release Technique (PRRT) (n=2), Positional Release Therapy (PRT) (n=1), SFMA (n=1), Neurodynamics (n=3), Associative Awareness Technique (AAT) (n=4), Postural Restoration Institute (PRI) (n=1), and Reactive Neuromuscular Stabilization (RNS) (n=2) all produced at least a Minimally Clinically Important Difference (MCID) on the NRS the majority of the time each was implemented. Only energy medicine (n=3) and Reflex Speed Pain Release (n=5) produced a success rate of less than 50% in my practice. Treatment sessions lasted an average of 21minutes (m=20.96±10.67) and approximately 2 treatment paradigms were implemented with each patient (m=2.16±1.29).

Regarding symptom resolution in one treatment, 58.1% of patients reported an alleviation of pain and functional limitation (NRS=0, PSFS=10) in one treatment session. Fifty percent of the patients reported a return of symptoms, irrespective of the diagnosis or the outcome of the first treatment session. Of these 18 patients, 16% of the patients required two treatments and .05% required a third. However, 4 patients had symptoms that did not resolve within the first week of treatment, determining my 1-week success rate to be 78%.

Changes in outcomes on the NRS and PSFS from pre- to post- treatment in the first day, irrespective of which treatment was implemented, were found to be significant ($p<.05$). Dependent t-tests were used to compare pre- to post- test scores on the NRS (Mean difference=3.209±1.91, $t(30)=9.337$, $p<0.001$) and the PSFS (Mean difference= -3.68±2.13, $t(30)=-9.59$, $p<.0001$). Regarding the post treatment outcomes on the NRS, a large effect size (Cohen's d=1.71) was found, indicating a large magnitude effect (Cohen, 1988). A large effect size was also found (Cohen's d=1.64; Cohen, 1988).

Reflection

I used a frequency analysis to determine that I was 78% successful in discharging patients within a one-week timeframe, regardless of condition. Ideally, I would like to be at 100%, but that is not likely; however, every patient experienced change large enough to exceed the MCID or minimal detectable change (MDC) values on both the NRS (MCID=2) (Salaffi et al. 2004) and PSFS (MCD=2) (Stratford et al., 1995) within the first treatment, with most reporting an alleviation of pain (NRS=0) and functional limitation (PSFS=10) within the first treatment. An alleviation of symptoms greater than an MCID is clinically significant when it occurs within such a short timeframe. While I was only 58% successful at ensuring symptom resolution on the first visit, I was able to ensure at least a clinically significant difference with every treatment.

As with the previous year, this the semester had similar problems with collection of patient outcomes. There was also one additional failed a priori design caused by continued self-sabotage, poor recognition of potential subjects, and poor identification of a clinical problem. Overall, there were still major flaws in my data collection, patient evaluation, and treatment implementation. Additionally, several patients reported symptoms that persisted longer than the creators of each treatment paradigm indicated (i.e., did not meet clinical expectations) and most likely were incorrectly diagnosed and/or the selected treatment paradigm(s) were implemented improperly. The small failures of beginning of the second year were still the failures of the previous two semesters.

Compared to the previous year, where I had only experienced similar success in four patients with very specific chief complaints and/or symptoms, discovering that I was now successful at treating a wide variety of complaints and/or symptoms was motivating factor in continuing to pursue advanced clinical practice. I was also able to implement a wide variety of treatment paradigms because my knowledge and competency increased. As compared to the previous semester, I felt more confident in my ability to accurately diagnose and classify each patient. As a result, I was able to select the most appropriate treatment paradigm. In just three semesters, I had the evidence to support the fact that a significant portion of my patient population was improving as a direct result of my clinical care.

Year Two: Spring

Patient Population

In the final semester of the DAT program, I made a transition to a new position as an Athletic Trainer at a different university. Because my patient population was reduced from 600 to 16, and from 22 sports teams to one, the frequency of treatments I performed were reduced drastically. In the previous semester, I began to analyze how effective I was as a clinician, but during this semester I desired to delve further into how my treatment interventions directly affected my patient population and their return to sport. Specifically, I became interested in how the patient care changes experienced by completing the DAT program had affected my patient outcomes as compared to national epidemiological data. Utilizing the NCAA's injury surveillance data, I compared my patient's injury rates and return-to-play timelines to the national averages.

The patient population was limited to the varsity men's soccer team of an NCAA Division 1 institution (n=16, mean age= 20±1.56). Any symptoms that required activity modification for sport-related activity for more than one day from the onset of symptoms were defined as a reportable injury (Kerr et al., 2014) and were tracked from the onset of symptoms until discharge. Reportable injuries were analyzed for all athlete exposures, any mandatory team-related game, practice, or training session (Kerr et al., 2014), during the spring practice season (i.e., less than 20 hours per week).

Patient Outcomes

In the time since my hire, the men's soccer team experienced 1,024 total athlete exposures with 8 reportable injuries requiring activity modification for at least one day, for an incidence rate of 0.0078. Those eight reportable injuries required activity modification of greater than one day from date of onset; however, no injuries required activity modification for greater than seven days and only two injuries resulted in any complete practice time-loss. Additionally, none of the reported injuries required surgery.

Notably, symptoms were reported 336 times and resulted only in eight reportable injuries. Furthermore, 125 patient treatments utilizing manual therapy treatment paradigms were performed in the time frame of the athlete exposures. Of the treatments performed, only 56 treatments were performed on reportable injuries. Therefore, the remaining 69 treatments were performed on patients who reported symptoms, but did not meet the definition of a reportable injury. Patients who experienced symptoms but did not meet the definition of a reportable injury (n=69) reported a resolution of pain (NRS=0) and functional limitation (PSFS=10) on the first visit and therefore did not require activity modification for that day. Treatment paradigms implemented included, but were not limited to, MET, RNS, Mulligan Concept (MC), neurodynamics, Primal Reflex Release Technique (PRRT), Reflexercise, Reflex Speed Pain Release (RSPR), Total Motion Release (TMR), Positional Release Therapy (PRT), and energy medicine. An average of 3 treatment paradigms were implemented per treatment session, per day.

Moreover, there were 56 of the aforementioned manual therapy treatments performed on patients (n=8) who suffered from a reportable injury, with an average of 7 treatments per injury. All patients reported an MCID or MDC on both the NRS (Salaffi et al., 2004) and the PSFS (Stratford et al., 1995) within the first treatment and on every subsequent treatment, until discharge. Of the eight reportable injuries, two injuries occurred in two separate patients for whom English is not a first language and a significant language barrier existed between patient and clinician. Due to communication barriers, it was difficult to obtain an accurate assessment of pain and symptoms. Cultural differences between patients and clinician also affected the evaluation and treatment process. As a result, reportable injuries were documented in these cases even when practice modification was most likely not required, but implemented as a precaution.

Finally, one patient with a reportable time loss injury of note reported symptoms that lasted for greater than 6 weeks. The patient was resistant to manual therapy treatment paradigms for approximately 5 weeks and chose anti-inflammatories and progressive resistive exercises (PREs) as recommended by the team physician to address the symptoms. The patient was able to return to play without modification in the second week of treatment, but moderate symptoms persisted for several more weeks. In the sixth week of treatment, after the symptoms had worsened slightly, the patient expressed interest in the alternative treatment paradigms. Once treatment began with the manual therapy paradigms, the patient experienced an MCID OR MDC on both the NRS (Salaffi et al., 2004) and the PSFS (Stratford et al., 1995) within the first treatment, a phenomenon he had not experienced in the past 6 weeks. Furthermore, he experienced a complete resolution of symptoms within three treatments. In summary, had the patient been receptive to manual therapy treatment paradigms initially, the patient potentially would not have suffered a significant time loss injury.

Reflection

According to the Datalys Center, the national average incidence rate for collegiate men's soccer is 8.0 (per 1,000 athlete exposures) (Kerr et al., 2015), while my incidence rate for men's soccer (7.8) was just below the national average. However, the current average for time loss injuries is between 25% and 30% for all injuries occurring during practice and competition, respectively (Kerr et.al, 2015). My average of time loss injuries was less than 1%, implying that even if injuries are occurred at close to the national average, the return to play time was significantly reduced. Furthermore, pain, functional limitations, ROM restrictions were resolved, minimizing the likelihood for the development of prolonged biomechanical dysfunctions. There is a paucity data on the average number of treatments necessary before a patient returns to full activity. However, at the rate of one treatment session per day, the results imply that most symptoms resolved within the time frame of one week, but symptoms were improved enough by the first treatment in order for the patient to practice without restrictions.

No clinician is ever perfect and there is always room for clinical practice improvement, even at the conclusion of the clinical residency requirement in the DAT program. During the semester, I continued to struggle with collecting clinically meaningful patient outcomes data. I had evidence to provide that the patients' return to sport was directly affected, but not enough data to specifically reflect on each individual patient interaction in a way that was clinically meaningful in regards to the effect of treatment interventions (e.g., outcomes scales other than the NRS and PSFS or measures other than ROM and strength) in a manner designed for peer-reviewed publication. Fear of judgment caused most of the problems in my clinical practice this semester. I had moved my clinical practice to an environment where the majority of the population was not receptive to my clinical philosophy and where collecting patient outcomes was not only discouraged, but viewed as a burden. I was self-limited to collecting data that was relevant to coaches, patients, and administrators (e.g., return to play timelines), but not necessarily to clinicians (i.e., specific patient outcomes). Moving forward, now that I have proven the worth of collecting patient outcomes data to my clinical site, it will be much easier to implement the specific patient outcomes scales that are relevant to clinicians.

By the end of the final semester of clinical residency, I had experienced enough growth in clinical practice to provide evidence that my patients were returning to play without pain, functional limitations, ROM restrictions, and strength deficits quicker than the national average and better than I previously had. Both the quality and quantity of patient outcomes collected over the course of the semester had improved significantly as compared to the first 18 months. I had progressed from inconsistently collecting patient outcomes on just a few patients every semester to collecting outcomes on every patient during every treatment session. Furthermore, I had expanded my clinical practice to not only include but increase in confidence and competence at least ten new treatment paradigms. While there was still ways to improve in clinical practice, I had finally set out to achieve my initial goal in enrolling in the DAT, be able to help alleviate my patients' symptoms and help them return to play faster.

Conclusion

Overall, completing the DAT program at UI has helped shaped my clinical practice in countless ways. I experienced significant improvements with identifying and treating patterns within a patient population, effectively evaluating and treating patients' symptoms, and helping patients return to play faster than the national averages. Prior to the DAT, I was a very hesitant and insecure clinician who was terrified of making the wrong clinical decision, had poor diagnostic accuracy, and incorrectly implemented treatment paradigms. Today, I am much more confident and effective as a clinician now and have very few reservations about clinical practice as compared to before the DAT program. I am able to more accurately diagnose and classify patients and implement the most appropriate treatment paradigm(s) with a high level of competency. I have gained significant knowledge and experience using MET, RNS, TMR, MC, PRRT, PRT RSPR, neurodynamics, and energy medicine. As a result, my patient outcomes have improved significantly from the first two semesters of the DAT clinical residency. Overall, my patients receive significantly improved patient care and as a result experience shorter return to play timelines, which is both a benefit to them and to the athletic department as a whole.

Finally, completing the DAT program at UI has helped me recognize the importance of advanced clinical practice and given me the skills to continue to grow as a clinician as I constantly and consistently strive towards scholarship and advanced clinical practice. I have completed the process for conducting a randomized, sham-controlled trial, from literature review, study design and conducting pilot study through publication. I continuously strive to pursue continuing education, conduct research in my clinic, disseminate the results of that research, and encourage other clinicians to pursue advanced clinical practice as well.

References

Cantu, R. (2008). Descriptive Epidemiology of Collegiate Men's Wrestling Injuries: National Collegiate Athletic Association Injury Surveillance System, 1988–1989 Through 2003–2004. *Yearbook Of Sports Medicine*, *2008*, 4-5. http://dx.doi.org/10.1016/s0162-0908(08)79106-2

Chatman, A., Hyams, S., Neel, J., Binkley, J., Stratford, P., Schomberg, A., & Stabler, M. (1997). The patient-specific functional scale: measurement properties in patients with knee dysfunction. *Physical Therapy*, *77*(8), 820-829.

Cohen J. *Statistical Power Analysis For The Behavioral Sciences*. Hillsdale, N.J.: L. Erlbaum

Juhl J, Ippolito Cremmin T, Russell G. Prevalence of Frontal Plane Pelvic Postural Asymmetry—Part 1. *Journal of the American Osteopathic Association*. 2015;104(10):411-421.

Kerr, Z., Dompier, T., Snook, E., Marshall, S., Klossner, D., Hainline, B., & Corlette, J. (2014). National Collegiate Athletic Association Injury Surveillance System: Review of Methods for 2004–2005 Through 2013–2014 Data Collection. *Journal Of Athletic Training*, *49*(4), 552-560. http://dx.doi.org/10.4085/1062-6050-49.3.58

Kerr, Z., Marshall, S., Dompier, T., Corlette, J., Klossner, D., & Gilchrist, J. (2015). *College Sports–Related Injuries — United States, 2009–10 Through 2013–14 Academic Years*. *Cdc.gov*. Retrieved 6 April 2016, from http://www.cdc.gov/mmwr/preview/mmwrhtml/mm6448a2.htm

Koor I. The emerging concept of the osteopathic lesion. *Journal of the American Osteopathic Association*. 2000;100(7):449-460.

Liccardone J, Kearns C. Somatic Dysfunction and Its Association With Chronic Low Back Pain, Back-Specific Functioning, and General Health: Results From the OSTEOPATHIC Trial. *Journal of American Osteopathic Association*. 2012;112(7):420-428.

Salaffi F, Stancati A, Silvestri CA, Ciapetti A, & Grassi W. Minimal clinically important changes in chronic musculoskeletal pain intensity measured on a numerical rating scale. *Eur J Pain.* 2004; *8*(4): 283–291

Stratford P, Gill C, Westaway M, Binkley J. Assessing disability and change on individual patients: a report of a patient specific measure. *Physiother Can*. 1995; 47: 258-263.

Treffer, K., Ehrenfuechter, W., & Cymet, T. (2011). *Glossary of Osteopathic Terminology*. *Aacom.org*. Retrieved 7 April 2015, from http://www.aacom.org/news-and-events/publications/glossary-of-osteopathic-terminology

Vela L, Denegar C. The Disablement in the Physically Active Scale, Part II: The Psychometric Properties of an Outcomes Scale for Musculoskeletal Injuries. *Journal of Athletic Training*. 2010;45(6):630-641. doi:10.4085/1062-6050-45.6.630

CHAPTER 4

REVIEW OF LITERATURE

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 is thought to delay the onset of osteoarthritis (OA; Getgood & Robertson, 2010). Osteoarthritis of the knee, however, 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, there was no difference when comparing the outcomes of meniscectomy to those of sham surgery (Sihvonen et al., 2013) or conservative rehabilitation (Herrlin, Hallander, Wange, Wiendenhielm, & Werner, 2007).

Researchers commonly report a recommendation to exhaust conservative treatment options prior to seeking surgical intervention (Hwang & Kwoh, 2014; Katz et al., 2012; Herrlin et al., 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 the nature of meniscal injuries, treatment options, and the research that must still be conducted to maximize patient outcomes.

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 & Webber, 1990; Renstrom & Johnson, 1990). The dry substance is 60-75% collagen (McDevitt & Webber, 1990; Renstrom & Johnson, 1990), 90% of which is type I collagen (McDevitt & 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 & Webber, 1990).

The fibers on the surface of the meniscus are organized in a multidirectional 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 et al., 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 et al., 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 et al., 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 that 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 and Biomechanics

The menisci play a functional role in (a) optimizing articular congruency (Fox et al., 2012; Lee & Fu, 2000; Masouros et al., 2008; Rath & Richmond, 2000; Renstrom & Johnson, 1990), (b) load transmission (Fox et al., 2012; Greis et al., 2002; Lee & Fu, 2000; Rath & Richmond, 2000; Renstrom & Johnson, 1990), (c) shock absorption (Fox et al., 2012; Greis et al., 2002; Lee & Fu, 2000; Masouros et al., 2008), (d) stability (Fox et al., 2012; Lee & Fu, 2000; Masouros et al., 2008; McDermott, Masouros, & Amis, 2008; Rath & Richmond, 2000); (e) proprioception (Fox et al., 2012; Greis et al., 2002), (f) joint lubrication (Fox et al., 2012; Lee & Fu, 2000; Rath & Richmond, 2000; Renstrom & Johnson, 1990), and (g) nutrition (Fox et al., 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 researchers report these functions 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 et al., 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). Researchers have reported joint line tenderness 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., 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

Researchers have classified tears 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

An experienced practitioner should use a battery of tests 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. 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). Researchers assessed the accuracy of Thessaly's test with joint line tenderness and McMurray's test, indicating that a battery of tests increases the accuracy of physical diagnosis (Konan et al., 2009). In general, the physical examination is considered essential to the diagnosis of meniscal lesions (Fowler & Lubliner, 1989; Miller, 1998; Kurosaka et al., 1999; Lowery et al., 2006).

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. Practitioners perform forced knee flexion 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). Practitioners assess joint line tenderness 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). In a 2012 meta-analysis 20 studies were included, where the overall sensitivity and specificity (without anesthesia) of the Lachman test was 81% , positive predictive value (PPV) was 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 infrapatellar 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 because it offers a dynamic element to these well-established tests (Karachalios et al., 2005).

McMurray test. Many researchers have studied the McMurray's test, 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 textbooks 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, Bell, & Frank, 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 et al., 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 described 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 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 may be essential in the clinical diagnosis of a meniscal tear because the use of a valid testing battery could improve the diagnostic accuracy of the clinical exam. Lowery et al. (2006) identified a potential testing battery utilizing the following findings: 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 of the testing battery 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. Practitioners routinely recommend magnetic resonance imaging (MRI) 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 the only diagnostic tool, which include (a) image quality affects the recurrence of false positive interpretations, (b) inexperienced scanners, (c) incorrect image parameters yield less than favorable diagnostic accuracy, (d) and 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 to 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 not to 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. Practitioners consider arthroscopy the "gold standard" for the detection of meniscal pathology, allowing a surgeon visual confirmation of an issue through a scope. Arthroscopy is a demanding procedure and dependent on the surgeon's level of experience, especially in difficult to view areas due to overlapping structures or small spaces (Nikolaou et al., 2008). Arthroscopy, however, may not be a desired diagnostic tool because of the risks involved, such as, infection, reaction to general anesthetics, and/or scarring (Nikolaou et al., 2008).

Patient Outcomes Scales and Instruments

In addition to the diagnostic assessment of meniscal lesions, practitioners should also assess the patient 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 noneffective 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 patients answer each item 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) 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. 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 as 0.85-0.93, symptoms as 0.83-0.95, activities of daily living as 0.75-0.91, sports/recreation as 0.61-0.89, and quality of life as 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 researchers designed the scale 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). Researchers found the test-retest reliability for the PSFS to be excellent, with 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

Researchers have found the Clinometer smartphone application 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

Researchers have reported the goniometric levels of intra-tester and inter-tester reliability 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 patients could sustain a tear of up to 90% in either meniscus before significant alteration of joint arthrokinematics 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). As such, researchers have embraced that surgery is only necessary if the meniscal tear interferes with normal joint motion (Englund et al., 2012). This may be a result of the significant associated risks of surgeries (Brophy & Matava, 2012), a new trend based on the arthrokinematics of the meniscus. Other researchers believe that conservative therapy should be exhausted first (Hwang & Kwoh, 2014; Katz et al., 2012; Herrlin et al., 2007; Bin et al., 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, practitioners presumed partial meniscectomy 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), however, they did acknowledge that preserving meniscal tissue was necessary to prevent OA, but suggested older patients were more likely to have OA regardless of meniscal pathology (Bin et al., 2004). Removing damaged meniscal tissue to alleviate mechanical symptoms may be the more appropriate option in this scenario because the articular cartilage may already compromised in the older patient population (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 8 weeks postsurgery and 6 months postsurgery and no significant difference in pre- and post-treatment activity level. The researchers suggested exhaustion of conservative therapy 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 6 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 6 and 12 months post treatment. While there was a 30% crossover rate from the physical therapy group to the surgery group, at 6 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 determine if the use of partial meniscectomies should be discontinued 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 has been 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). In addition, patients have a significant risk of developing OA in the long term, the exact outcome 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 techniques without 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 et al., 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 meniscectomy; 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, researchers estimated the failure rate 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 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 relatively new development in the treatment of meniscal lesions developed through an anatomic cadaveric study (Kohn & Moreno, 1995). Practitioners performed meniscal transplant surgeries 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 relatively 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 et al., 2014).

In regards to autografts, practitioners are exploring many possibilities 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, which has 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 potential efficacy of the MC "Squeeze" technique for alleviating the symptoms of meniscal tears is based primarily in the technique's mechanical correction of a theoretical positional fault of the knee joint (Mulligan, 2010). During a typical mechanism for meniscus tears (i.e., twisting of the knee while weight bearing), the meniscus could become slightly distorted towards the periphery (Mulligan, 2010). Therefore, clinicians should consider the presence of a positional fault when patients present with meniscal tear symptoms.

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 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, 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 suggesting its plausibility, it remains theoretical.

Hsieh 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 that 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 et al., 2006; Kavanagh, 1999; Vicenzio, 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, one could argue that the findings likely support the positional fault to be the result of injury, rather than the cause. In either case, the results 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 menisci 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. Researchers also noted a possibility of stretching adhesions that are secondary to positional faulting of the meniscoid or to the joint capsule in the knee joint 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). Researchers observed initiation of sympathetic nervous system responses 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, researchers also suspect hypoalgesia mechanisms and a physiological component 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 (Vicenzino et al., 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 et al. (2007) concluded that while there is acceptance of the implications and speculations of neurophysiologic involvement elicited from the MWMs, 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 practitioners follow all of these principles, 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 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 (Bedi et al., 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.

References

American Association of Orthopaedic Medicine. (2013). Cyriax System of Orthopaedic Medicine. Retrieved from: http://http://www.aaomed.org/Cyriax-System-of-Orthopaedic-Medicine on November 29, 2014.

Andrews, S., Shrive, N., & Ronsky, J. (2011). The shocking truth about meniscus. *Journal of Biomechanics*, *44*(16), 2737–2740. doi:10.1016/j.jbiomech.2011.08.026

Arnoczky, S. P., & Warren, R. F. (1982). Microvasculature of the human meniscus. *The American Journal of Sports Medicine*, *10*(2), 90–5. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/7081532

Berthiaume, M.J., Raynauld, J.P., Martel-Pelletier, J., LaBonte, F., Beaudoin, G., Bloch, D.A., Choquette, D., Haraoui, B., Altman, R.D., Hochberg, M., Meyer, J.M., Cline, G.A. & Pelletier, J.P. (2005). Meniscal tear and extrusion are strongly associated with progression of symptomatic knee osteoarthritis as assessed by quantitative magnetic resonance imaging. *Annals of the Rheumatic Diseases, 64*, 556-563. doi: 10.1136/ard.2004.023796.

Bialosky, J.E., Bishop, M.D., Price, D.D., Robinson, M.E., George, S.Z. (2009). The mechanisms of manual therapy in the treatment of musculoskeletal pain: A comprehensive model. *Manual Therapy, 14* doi: 10.1016/j.math.2008.09.001.

Bialosky, J.E., Bishop, M.D., George, S.Z., & Robinson, M.E. (2011). Placebo response to manual therapy: Something out of nothing? *Journal of Manual and Manipulative Therapy*, 19 (1), 11-19. doi: 10.1179/2042618610Y.0000000001

Belzer, J. P., & Cannon, W. D. (1993). Meniscus Tears: Treatment in the Stable and Unstable Knee. *Journal of the American Academy of Orthopaedic Surgeons*, *1*(1), 41–47.

Berkowitz, M.J. & Kim, D.H. (2004). Fibular position in relation to lateral ankle instability. *Foot and Ankle International, 25*(5), 318-321.

Bin, S.-I., Kim, J.-M., & Shin, S.-J. (2004). Radial tears of the posterior horn of the medial meniscus. *Arthroscopy: The Journal of Arthroscopic & Related Surgery: Official Publication of the Arthroscopy Association of North America and the International Arthroscopy Association*, *20*(4), 373–378. doi:10.1016/j.arthro.2004.01.004

Boden, S. D., Davis, D. O., Dina, T. S., Stoller, D. W., Brown, S. D., Vailas, J. C., & Labropoulos, P. A. (1992). A prospective and blinded investigation of magnetic resonance imaging of the knee. Abnormal findings in asymptomatic subjects. *Clinical Orthopaedics and Related Research*, (282), 177-185.

Brophy, R. H., & Matava, M. J. (2012). Surgical options for meniscal replacement. *The Journal of the American Academy of Orthopaedic Surgeons*, *20*(5), 265–272. doi:10.5435/JAAOS-20-05-265

Brosseau, L., Balmer, S., Tousignant, M., O'Sullivan, J. P., Goudreault, C., Goudreault, M., & Gringras, S. (2001). Intra- and intertester reliability and criterion validity of the parallelogram and universal goniometers for measuring maximum active knee flexion and extension of patients with knee restrictions. *Archives Of Physical Medicine And Rehabilitation*, *82*(3), 396-402.

Chatman, A. B., Hyams, S. P., Neel, J. M., Binkley, J. M., Stratford, P. W., Schomberg, A., & Stabler, M. (1997). The Patient-Specific Functional Scale: measurement properties in patients with knee dysfunction. *Physical Therapy*, *77*(8), 820-829.

Chivers, M., & Howitt, S. (2009). Anatomy and physical examination of the knee menisci: a narrative review of the orthopedic literature. *The Journal of the Canadian Chiropractic Association*, *53*(4), 319-333.

Collins, N., Teys, P. & Vicenzino, B. (2004). The Initial Effects of a Mulligan's Mobilization with Movement Technique on Dorsiflexion and Pain in Subacute Ankle Sprains. *Manual Therapy, 9*(2)' 77-82. doi: 10.1016/S1356-689X(03)00101-2

Deyle, G.D., Henderson, N.E., Matekel, R.L., Ryder, M.G., Garber, M.B., & Allison, S.C. (2000). Effectiveness of Manual Physical Therapy and Exercise in Osteoarthritis of the Knee. *Annals of Internal Medicine*, 132 (3), 173-181, Retrieved from http://annals.org

Dye, S. F., Vaupel, G. L., & Dye, C. C. (1998). Conscious neurosensory mapping of the internal structures of the human knee without intraarticular anesthesia. *The American Journal of Sports Medicine*, *26*(6), 773–777.

Eck, C., Bekerom, M., Fu, F., Poolman, R., & Kerkhoffs, G. (2013). Methods to diagnose acute anterior cruciate ligament rupture: a meta-analysis of physical examinations with and without anaesthesia. *Knee Surgery, Sports Traumatology, Arthroscopy*, *21*(8), 1895-1903. doi:10.1007/s00167-012-2250-9

Englund, M., Roemer, F. W., Hayashi, D., Crema, M. D., & Guermazi, A. (2012). Meniscus pathology, osteoarthritis and the treatment controversy. *Nature Reviews Rheumatology*, *8*(7), 412–419. doi:10.1038/nrrheum.2012.69

Englund, M., Guermazi, A. & Lohmander, L.S. (2009). The Meniscus in Knee Osteoarthritis. *Rheumatic Disease Clinics of North America, 35*(3), 579-590. doi: 10.1016/j.rdc.2009.08.004

Eren, O. T. (2003). The accuracy of joint line tenderness by physical examination in the diagnosis of meniscal tears. *Arthroscopy: The Journal Of Arthroscopic & Related Surgery: Official Publication Of The Arthroscopy Association Of North America And The International Arthroscopy Association*, *19*(8), 850-854.

Evans, P. J., Bell, G. D., & Frank, C. (1993). Prospective evaluation of the McMurray test. *The American Journal Of Sports Medicine*, *21*(4), 604-608.

Exelby, L. (1996). Peripheral mobilisations with movement. *Manual Therapy 1*, 118-126: Retrieved from: http://kinex.cl/papers/Rodilla/MWMNUEVO.pdf on November 29, 2014.

Fowler, P. J., & Lubliner, J. A. (1989). The predictive value of five clinical signs in the evaluation of meniscal pathology. *Arthroscopy: The Journal of Arthroscopic & Related Surgery: Official Publication Of The Arthroscopy Association Of North America And The International Arthroscopy Association*, *5*(3), 184-186.

Fox, A. J. S., Bedi, A., & Rodeo, S. A. (2012). The basic science of human knee menisci: structure, composition, and function. *Sports Health*, *4*(4), 340–51. doi:10.1177/1941738111429419

Fox, M. G. (2007). MR imaging of the meniscus: Review, current trends, and clinical implications. *Radiologic Clinics of North America*, *45*(6), 1033–1053. doi:10.1016/j.rcl.2007.08.009

Fukuhara, T., Sakamoto M., Nakazawa R., & Kato K. (2012) Anterior positional fault of the fibula after sub-acute anterior talofibular ligament injury. *Journal of Physical Therapy Science*, 24(1), 115-117. http://doi.org/10.1589/jpts.24.115

Gale, D.R., Chaisson, C.E., Totterman, S.M.S., Schwartz, R.K., Gale, M.E., Felson, D. (1999). Meniscal subluxation: association with osteoarthritis joint space narrowing. *Osteoarthritis and Cartilage,* 7 (6), 526-532. doi: 10.1053/joca.1999.0256

Garratt, A., Brealey, S., & Gillespie, W. (2004). Patient-assessed health instruments for the knee: a structured review. *Rheumatology (Oxford, England)*, *43*(11), 1414-1423.

Getgood, A., & Robertson, A. (2010). (v) Meniscal tears, repairs and replacement – a current concepts review. *Orthopaedics and Trauma*, *24*(2), 121–128. doi:10.1016/j.mporth.2010.03.01

Good, M., Stiller, C., Zauszniewski, J.A., Anderson, G.C., Stanton-Hicks, M., Grass, J.A. (2001). Sensation and distress of pain scales: Reliability, validity, and sensitivity. *Journal of Nursing Measurements*, 9(3), 219-238.

Greis, P. E., Bardana, D. D., Holmstrom, M. C., & Burks, R. T. (2002). Meniscal injury: I. basic science and evaluation. *The Journal of the American Academy of Orthopaedic Surgeons*, *10*(3), 168–176. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/12041938

Harper, K. W., Helms, C. A., Lambert, H. S., & Higgins, L. D. (2005). Radial meniscal tears: Significance, incidence, and MR appearance. *American Journal of Roentgenology*, *185*(6), 1429–34. doi:10.2214/AJR.04.1024

Harrison, B., Abell, B., & Gibson, T. (2009). The Thessaly test for detection of meniscal tears: validation of a new physical examination technique for primary care medicine. *Clinical Journal of Sport Medicine: Official Journal of the Canadian Academy of Sport Medicine*, *19*(1), 9-12. doi:10.1097/JSM.0b013e31818f1689

Hearn, A & Rivett, A. (2002). Cervical SNAGs: a biomechanical analysis. *Manual Therapy,* 7 (2), 71-79, doi: 10.1054/math.2002.0440.

Herr, K.A., Spratt, K., Mobily, P.R., Richardson, G. (2004). Pain intensity assessment in older adults: Use of experimental pain to compare psychometric properties and usability a selected pain scales with younger adults. *The Clinical Journal of Pain.* 20(4), 207-219).

Herrlin, S., Hållander, M., Wange, P., Weidenhielm, L., & Werner, S. (2007). Arthroscopic or conservative treatment of degenerative medial meniscal tears: a prospective randomised trial. *Knee Surgery, Sports Traumatology, Arthroscopy*, *15*(4), 393–401. doi:10.1007/s00167-006-0243-2

Hing, W., Bigelow, R. & Bremner, T. (2007). Mulligan's Mobilization with Movement: A Systematic Review. *The Journal of Manual & Manipulative Therapy, 17*(2),39-66

Hing, W., White, S., Reid, D., & Marshall, R. (2009). Validity of the McMurray's Test and Modified Versions of the Test: A Systematic Literature Review. *The Journal of Manual & Manipulative Therapy*, *17*(1), 22-35.

Hing, W., Hall, T., Rivett, D., Vicenzino, B. & Mulligan, B. (2015). The Mulligan Concept of Manual Therapy Textbook of Techniques. Chatswood, Australia: Elsevier.

Howe, T., Dawson, L., Syme, G., Duncan, L., & Reid, J. (2012). Evaluation of outcome measures for use in clinical practice for adults with musculoskeletal conditions of the knee: a systematic review. *Manual Therapy*, *17*(2), 100-118. doi:10.1016/j.math.2011.07.002

Howell, J., & Handoll, H. (1996). Surgical treatment for meniscal injuries of the knee in adults. In *Cochrane Database of Systematic Reviews*. John Wiley & Sons, Ltd. Retrieved from http://onlinelibrary.wiley.com/doi/10.1002/14651858.CD001353/

Hsieh C.Y., Vicenzino, B., Yang, C.H., Hu, M.H., Yang, C. (2002). Mulligan's mobilization with movement for the thumb: A single case report using magnetic resonance imaging to evaluate the positional fault hypothesis. *Manual Therapy, 7* (1), 44-49 doi:10.1054/math.2001.0434

Hubbard, T.J. & Hertel, J. (2008). Anterior positional fault of the fibula after sub-acute lateral ankle sprains. *Manual Therapy, 13,* 63-67. doi: 10.1016/j.math.2006.09.008

Hubbard, T.J., Hertel, J., & Sherbondy, P. (2006). Fibular position in individuals with self-reported chronic ankle instability, *Journal of Orthopaedic & Sports Physical Therapy, 36* (1), 3-10.

Hwang, Y. G., & Kwoh, C. K. (2014). The METEOR trial: No rush to repair a torn meniscus. *Cleveland Clinic Journal of Medicine*, *81*(4), 226–232. doi:10.3949/ccjm.81a.13075

Jee, W., Mccauley, T. R., Kim, J., Jun, D., Lee, Y., Choi, B., & Choi, K. (2003). Meniscal tear configurations: Categorization with MR imaging. *American Journal of Roentgenology,* (180), 93–97.

Johnson, D. L., Swenson, T. M., Livesay, G. A., Aizawa, H., Fu, F. H., & Herner, C. D. (1995). Insertion-Site Anatomy of the Human Menisci: as a Basis for Meniscal Transplantation. *Arthroscopy: The Journal of Arthroscopic and Related Surgery*, *11*(4), 386–394.

Karachalios, T., Hantes, M., Zibis, A., Zachos, V., Karantanas, A., & Malizos, K. (2005). Diagnostic accuracy of a new clinical test (the Thessaly test) for early detection of meniscal tears. *The Journal of Bone and Joint Surgery. American Volume*, *87*(5), 955-962.

Kavanagh, J. (1999). Is there a positional fault at the inferior tibiofibular joint in patients with acute or chronic ankle sprains compared to normals? *Manual Therapy, 4*(1), 19-24.

Katz, J., & Fingeroth, R. (1986). The diagnostic accuracy of ruptures of the anterior cruciate ligament comparing the Lachman test, the anterior drawer sign, and the pivot shift test in acute and chronic knee injuries. *The American Journal of Sports Medicine*, 88-91.

Katz, J. N., Brophy, R. H., Chaisson, C. E., de Chaves, L., Cole, B. J., Dahm, D. L., Losina, E. (2013). Surgery versus Physical Therapy for a Meniscal Tear and Osteoarthritis. *New England Journal of Medicine*, *368*(18), 1675–1684. doi:10.1056/NEJMoa1301408

Kirkley, A., Birmingham, T. B., Litchfield, R. B., Giffin, J. R., Willits, K. R., Wong, C. J., Fowler, P. J. (2008). A Randomized Trial of Arthroscopic Surgery for Osteoarthritis of the Knee. *New England Journal of Medicine*, *359*(11), 1097–1107. doi:10.1056/NEJMoa0708333

Kohn, D., & Moreno, B. (1995). Meniscus insertion anatomy as a basis for meniscus replacement: A morphological cadaveric study. *Arthroscopy: The Journal of Arthroscopic & Related Surgery*, *11*(1), 96–103. doi:10.1016/0749-8063(95)90095-0

Kos, J., Hert, J. & Sevcik, P. (2002). Meniscoids of the intervertebral joints. *Acta Chirurgiae Orthopaedicae et Tramatologiae Cechoslovaca, 69*(3), 149-157. Retrieved from http://ncbi.nlm.nih.gov on November 27, 2014.

Krebs, E. E., Carey, T. S., & Weinberger, M. (2007). Accuracy of the pain numeric rating scale as a screening test in primary care. *Journal Of General Internal Medicine*, *22*(10), 1453-1458.

Kurosaka, M., Yagi, M., Yoshiya, S., Muratsu, H., & Mizuno, K. (1999). Efficacy of the axially loaded pivot shift test for the diagnosis of a meniscal tear. *International Orthopaedics*, *23*(5), 271-274.

Larsen, E., Jensen, P., & Jensen, P. (1999). Long-term outcome of knee and ankle injuries in elite football, 285–289.

Lee, J. M., & Fu, F. H. (2000). The Meniscus: Basic science and clinical applications. *Operative Techniques in Orthopaedics*, *10*(3), 162–168. doi:10.1053/otor.2000.5289

Lento, P. H., & Akuthota, V. (2000). Meniscal injuries: A critical review. *Journal of Back and Musculoskeletal Rehabilitation*, *15*(2), 55–62. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/22388443

Lyman, S., Hidaka, C., Valdez, A. S., Hetsroni, I., Pan, T. J., Do, H., Marx, R. G. (2013). Risk Factors for Meniscectomy After Meniscal Repair. *The American Journal of Sports Medicine*, *41*(12), 2772–2778. doi:10.1177/0363546513503444

Maitland, G. (5th ed). (1986). Vertebral Manipulations. London: Butterworths.

Makhmalbaf, H., Moradi, A., Ganji, S., & Omidi-Kashani, F. (2013). Accuracy of lachman and anterior drawer tests for anterior cruciate ligament injuries. *Archives Of Bone And Joint Surgery*, *1*(2), 94-97.

Makris, E. A., Hadidi, P., & Athanasiou, K. A. (2011). The knee meniscus: Structure–function, pathophysiology, current repair techniques, and prospects for regeneration. *Biomaterials*, *32*(30), 7411–7431. doi:10.1016/j.biomaterials.2011.06.037

Malanga, G., Andrus, S., Nadler, S., & McLean, J. (2003). Physical examination of the knee: a review of the original test description and scientific validity of common orthopedic tests. *Archives of Physical Medicine and Rehabilitation*, *84*(4), 592-603.

Mariani, P., Adriani, E., Maresca, G., & Mazzola, C. (1996). A prospective evaluation of a test for lateral meniscus tears. *Knee Surgery, Sports Traumatology, Arthroscopy: Official Journal of the ESSKA*, *4*(1), 22-26.

Mascarenhas, R., Yanke, A., Frank, R., Butty, D., & Cole, B. (2014). Meniscal Allograft Transplantation: Preoperative Assessment, Surgical Considerations, and Clinical Outcomes. *Journal of Knee Surgery*. doi:10.1055/s-0034-1382080

Masouros, S. D., Bull, A. M. J., & Amis, A. A. (2010). (i) Biomechanics of the knee joint. *Orthopaedics and Trauma*, *24*(2), 84–91. doi:10.1016/j.mporth.2010.03.005

Masouros, S. D., McDermott, I. D., Amis, A. A., & Bull, A. M. J. (2008). Biomechanics of the meniscus-meniscal ligament construct of the knee. *Knee Surgery, Sports Traumatology, Arthroscopy: Official Journal of the ESSKA*, *16*(12), 1121–32. doi:10.1007/s00167-008-0616-9

McDermott, I. D., Masouros, S. D., & Amis, A. A. (2008). Biomechanics of the menisci of the knee. *Current Orthopaedics*, *22*(3), 193–201. doi:10.1016/j.cuor.2008.04.005

McDevitt, Cahir A., & Webber, R. J. (1990). The ultrastructure and biochemistry of meniscal cartilage. *Clinical Orthopaedics and Related Research*, (252), 8–18.

McMurray, T.P., (1928). The diagnosis of internal derangements of the knee. In: The Robert Jones birthday volume. Humphrey Milford, London, pp 301-306

Melzack, R. & Wall, P.D. (1965). Pain Mechanisms: A New Theory. *Science, 150*(3699) doi: 10.1126/science.150.3699

Meserve, B., Cleland, J., & Boucher, T. (2008). A meta-analysis examining clinical test utilities for assessing meniscal injury. *Clinical Rehabilitation*, *22*(2), 143-161. doi:10.1177/0269215507080130

Metcalf, M. H., & Barrett, G. R. (2004). Prospective Evaluation of 1485 Meniscal tear patterns in patients with stable knees. *The American Journal of Sports Medicine*, *32*(3), 675–680. doi:10.1177/0095399703258743

Miller, F.G. & Kaptchuk, T.J. (2008). The power of context: reconceptualizing the placebo effect. *Journal of the Royal Society of Medicine, 101,* 222-225. doi: 10.1258/jrsm.2008.070466

Miller, G. K. (1996). A prospective study comparing the accuracy of the clinical diagnosis of meniscus tear with magnetic resonance imaging and its effect on clinical outcome. *Arthroscopy: The Journal of Arthroscopic & Related Surgery: Official Publication Of The Arthroscopy Association Of North America And The International Arthroscopy Association*, *12*(4), 406-413.

Mohan, B., & Gosal, H. (2007). Reliability of clinical diagnosis in meniscal tears. *International Orthopaedics*, *31*(1), 57-60.

Morrison, J. B. (1970). The mechanics of the knee joint in relation to normal walking. *Journal of Biomechanics*, *3*, 51–61.

Moss, P., Sluka, K., & Wright, A. (2007). The Initial Effects of Knee Joint Mobilization on Osteoarthritic Hyperalgesia. *Manual Therapy,* 12(2), 109-118. doi: 10.1016/j.math.2006.02.009

Muellner, T., Weinstabl, R., Schabus, R., Vécsei, V., & Kainberger, F. (1997). The diagnosis of meniscal tears in athletes. A comparison of clinical and magnetic resonance imaging investigations. *The American Journal of Sports Medicine*, *25*(1), 7-12.

Mulligan, B. (1993). Manual Therapy Rounds: Mobilisations with Movement (MWM's). *The Journal of Manual & Manipulative Therapy, 1*(4), 154-156.

Mulligan, B.(5th) (2004). Manual Therapy 'NAGS', 'SNAGS', 'MWMS'. Wellington, New Zealand: Plane View Services Ltd

Mulligan, B. (6th) (2010). Manual Therapy NAGS, SNAGS, MWMS etc. Wellington, New Zealand: Plane View Services Ltd

Nikolaou, V., Chronopoulos, E., Savvidou, C., Plessas, S., Giannoudis, P., Efstathopoulos, N., & Papachristou, G. (2008). MRI efficacy in diagnosing internal lesions of the knee: a retrospective analysis. *Journal of Trauma Management & Outcomes*, *2*(1), 4. doi:10.1186/1752-2897-2-4

Nepple, J. J., Dunn, W. R., & Wright, R. W. (2012). Meniscal Repair Outcomes at Greater Than Five Years. *The Journal of Bone and Joint Surgery. American Volume*, *94*(24), 2222–2227. doi:10.2106/JBJS.K.01584

O'Donoghue, D. H. (1980). Meniscectomy Indications and Management. *Physical Therapy*, *60*(12), 1617–1623.

Ossipov, M.H., Dussor, G.O. & Porreca, F. (2010). Central Modulation of Pain. *Clinical Journal of Investigation, 120*(11), 3779-3787. doi: 10.1172/JC143766

Paungmali, A., O'Leary, S., Souvlis, T. & Vicenzino, B. (2003). Hypoalgesic and Sympathoexcitatory effects of mobilization with movement for lateral epicondylalgia. *Physical Therapy, 83*, 374-383. Retrived from: http://ptjournal.apta.org on Novemenber 27, 2014.

Paungmali, A., O'Leary, S., Souvlis, T., & Vicenzino, B. (2004). Naloxone fails to antagonize initial hypoalgesic effect of manual therapy treatment for lateral epicondylalgia. *Journal of Manipulative and Physiological Therapeutics,* 27(3), 180-185.

Paungmali, A., Vicenzino, B. & Smith, M. (2003). Hypoalgesia induced by elbow manipulation in lateral epicondylalgia does not exhibit tolerance. *The Journal of Pain, 4*(8), 448-454. doi: 10.1067/S1526-5900(03)00731-4

Paxton, E. S., Stock, M. V., & Brophy, R. H. (2011). Meniscal Repair Versus Partial Meniscectomy: A Systematic Review Comparing Reoperation Rates and Clinical Outcomes. *Arthroscopy: The Journal of Arthroscopic & Related Surgery*, *27*(9), 1275–1288. doi:10.1016/j.arthro.2011.03.088

Peters, G., & Wirth, C. J. (2003). The current state of meniscal allograft transplantation and replacement. *The Knee*, *10*(1), 19–31. doi:10.1016/S0968-0160(02)00139-4

Pettman, E. (2007). A History of Manipulative Therapy. *The Journal of Manual of Manipulative Therapy, 15*(3), 165-174. Retrieved From: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2565620/pdf/jmmt0015-0165.pdf

Poynton, A. R., Javadpour, S. M., & Finegan, P. J. (1997). The meniscofemoral ligaments of the knee. *The Journal of Bone and Joint Surgery*, *79*(2), 14–17.

Prasad, V., Vandross, A., Toomey, C., Cheung, M., Rho, J., Quinn, S., Cifu, A. (2013). A Decade of Reversal: An Analysis of 146 Contradicted Medical Practices. *Mayo Clinic Proceedings*, *88*(8), 790–798. doi:10.1016/j.mayocp.2013.05.012

Pujol, N., Barbier, O., Boisrenoult, P., & Beaufils, P. (2011). Amount of Meniscal Resection After Failed Meniscal Repair. *The American Journal of Sports Medicine*, *39*(8), 1648–1652. doi:10.1177/0363546511402661

Rath, E., & Richmond, J. C. (2000). The menisci: Basic science and advances in treatment. *British Journal of Sports Medicine*, *34*(4), 252–257. Retrieved from http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=1724227&tool=pmcentrez&rendertype=abstract

Renstrom, P., Johnson, R. J. (1990). Anatomy and biomechanics of the menisci. *Clinics in Sports Medicine*, *9*(3), 523–538.

Rodkey, W. G. (2000). Basic biology of the meniscus and response to injury. *Instructional Course Lectures*, *49*, 189–193.

Roos, E. M., Roos, H. P., Ekdahl, C., & Lohmander, L. S. (1998). Knee injury and Osteoarthritis Outcome Score (KOOS)--validation of a Swedish version. *Scandinavian Journal Of Medicine & Science In Sports*, *8*(6), 439-448.

Rose, R. C. (2006). The accuracy of joint line tenderness in the diagnosis of meniscal tears. *The West Indian Medical Journal*, *55*(5), 323-326.

Scholten, R., Devillé, W., Opstelten, W., Bijl, D., van der Plas, C., & Bouter, L. (2001). The accuracy of physical diagnostic tests for assessing meniscal lesions of the knee: a meta-analysis. *The Journal of Family Practice*, *50*(11), 938-944.

Shultz, S., Nguyen, A.D., Windley, T.C., Kulas, A.S., Botic, T.L. & Bruce, D. (2006). Intratester and intertester reliability of clinical measures of lower extremity anatomic characteristics: Implication for multicenter studies. *Clinical Journal of Sport Medicine, 16*(2), 155-161.

Sihvonen, R., Paavola, M., Malmivaara, A., Itälä, A., Joukainen, A., Nurmi, H., Järvinen, T. L. N. (2013). Arthroscopic Partial Meniscectomy versus Sham Surgery for a Degenerative Meniscal Tear. *New England Journal of Medicine*, *369*(26), 2515–2524. doi:10.1056/NEJMoa1305189

Slater, H., Arendt-Nielson, L., Wright, A., & Graven, N. (2006). Effects of a manual therapy technique in experimental lateral epicondylalgia. *Manual Therapy, 11 (2).* 107-117. http://dx.doi.org/10.1016/j.math.2005.04.005:

Takasaki, H., Hall, T., & Jull, G. (2013). Immediate and short-term effects of Mulligan's Mobilization with Movement on knee pain and disability associated with knee osteoarthritis: A prospective case series. *Physiotherapy Theory and Practice,* 29(2), 87-95. doi: 10.3109/09592985.2012.702854

Teys, P., Bisset, L., & Vicenzino, B. (2008). The initial effects of a mulligan's mobilization with movement technique on range of movement and pressure pain threshold in pain-limiting shoulders. *Manual Therapy, 13(1)*, 3742. http://dx.doi.org/10.1016/j. math. 2006.07.0 11

Threlkeld, J.A. (1992). The effects of manual therapy on connective tissue. *Physical Therapy,* 72 (12), 893-902, Retrieved from: http://ptjournal.apta.org/content/72/12/893.full.pdf

Timotijevic, S., Vukasinovic, Z., & Bascarevic, Z. (2014). Correlation of clinical examination, ultrasound sonography, and magnetic resonance imaging findings with arthroscopic findings in relation to acute and chronic lateral meniscus injuries. *Journal of Orthopaedic Science: Official Journal of the Japanese Orthopaedic Association*, *19*(1), 71-76. doi:10.1007/s00776-013-0480-4

Troupis, J. M., Batt, M. J., Pasricha, S. S., & Saddik, D. (2015). Magnetic resonance imaging in knee synovitis: Clinical utility in differentiating asymptomatic and symptomatic meniscal tears. *Journal Of Medical Imaging & Radiation Oncology*, *59*(1), 1-6. doi:10.1111/1754-9485.12240

Vedi, V., Spouse, E., Williams, A., Tennant, S.J., Hunt, D.M., & Gedroyc, M.W. (1999). Meniscal movement an in-vivo study using dynamic MRI. *Journal of Bone & Joint Surgery, 81*(1), 37-41.

Vela, L. I., & Denegar, C. R. (2010). The Disablement in the Physically Active Scale, part II: the psychometric properties of an outcomes scale for musculoskeletal injuries. *Journal of Athletic Training*, *45*(6), 630-641. doi:10.4085/1062-6050-45.6.630

Vicenzino, B. (2011, June). Mulligan's Mobilisation with Movement: The science, the evidence and the art. PowerPoint Presentation presented at the 2nd International Mulligan Concept Conference, Porto, Portugal.

Vicenzino, B., Hing, W., Rivett, D. & Hall, T (2011). Mobilisation with Movement The art and the science. Australia: Elsevier Australia.

Vicenzino, B., Paungmali, A., & Teys, P. (2007). Mulligan's mobilization-with-movement, positional faults and pain relief: Current concepts from critical review of literature. *Manual Therapy*, 12 (2), 98-108, doi: 10.1016/j.math.2006.07.012

Voloshin, A. S., & Wosk, J. (1983). Shock absorption of meniscectomized and painful knees: a comparative in vivo study. *Journal of Biomedical Engineering*, *5*(2), 157–161.

Vundelinckx, B., Vanlauwe, J., & Bellemans, J. (2014). Long-term Subjective, Clinical, and Radiographic Outcome Evaluation of Meniscal Allograft Transplantation in the Knee. *The American Journal of Sports Medicine*, *42*(7), 1592–1599. doi:10.1177/0363546514530092

Wareluk, P., & Szopinski, K. (2012). Value of modern sonography in the assessment of meniscal lesions. *European Journal of Radiology*, *81*(9), 2366-2369. doi:10.1016/j.ejrad.2011.09.013

Werner, B. C., Holzgrefe, R. E., Griffin, J. W., Lyons, M. L., Cosgrove, C. T., Hart, J. M., & Brockmeier, S. F. (2014). Validation of an innovative method of shoulder range-of-motion measurement using a smartphone clinometer application. *Journal of Shoulder and Elbow Surgery*, *23*(11), e275–82. http://doi.org/10.1016/j.jse.2014.02.030

Willis, R. B. (2006). Meniscal injuries in children and adolescents. *Operative Techniques in Sports Medicine*, *14*(3), 197–202. doi:10.1053/j.otsm.2006.06.003

Wilson, A. S., Legg, P. G., & McNeur, J. C. (1969). Studies on the innervation of the medial meniscus in the human knee joint. *The Anatomical Record*, *165*(4), 485–491.

CHAPTER 5

INNOVATIVE TREATMENT OF CLINICALLY DIAGNOSED MENISCAL TEARS: A RANDOMIZED SHAM-CONTROLLED TRIAL OF THE MULLIGAN CONCEPT "SQUEEZE" TECHNIQUE

Introduction and Background

The incidence of lower body injury, especially knee injuries, has grown[44,59] due to increased participation in recreational sports[24,52] and intercollegiate athletic competition.[27] Meniscal tears commonly occur as a result of sport participation[44] and, in a 10 year epidemiologic study on the occurrence of knee injuries, researchers found meniscus tears were the second most common knee injury. [44] Meniscal injuries are not only common in the young, athletic population; 35% of adults over the age of 50 experience degenerative tears.[33]

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.[45] A meniscal tear can affect critical functions of the meniscus, such as joint congruency, load transmission, and shock absorption[22,37] 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.[38] Despite the importance of the meniscus tissue for function, incidental findings of asymptomatic tears on magnetic resonance imaging (MRI) are relatively common,[39,62,72,69] 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.[62,72]

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.[46] 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.[46] Although patients elect to have APM more often, the APM procedure has inconsistent results for alleviating the symptoms of meniscal tears[53,49,40,33,63] 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]

Thus, 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%.[51] Consequently, patients who undergo any type of meniscal surgery are at risk for requiring subsequent surgeries,[51] 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.[26,46] Although conservative therapy protocols are recommended as an alternative to surgery,[26,33,29] lengthy timelines[46] and poor outcomes[26,33,29] 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[46] 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,[26,33,29] Because reported outcomes of surgery and conservative care are similar and have inconsistent results,[26,33,29] 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.[48] 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.[48] 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 subluxated 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.[54,37,70,15,] 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 needs to be resolved. Within the MC, it has been proposed that relocating the tissue disruption towards the midline of the joint would reduce pain because the periphery of the menisci would no longer receive pain signals.[48] The MC "Squeeze" technique may produce this benefit through the application of an indirect pressure to the meniscus.[48] Indirect pressure is applied through a "squeezing" force on the meniscus at the most tender point along the joint line while the patient actively flexes and extends their knee to mobilize the tissue back to its normal anatomical position.[48]

The MC “Squeeze” technique has produced favorable patient outcomes for clinically classified meniscal tears in anecdotal reports and published a priori case studies.[5,55] 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 athletic training 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 of 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.[38] The preceding inclusion criteria ware formed according to the clinical composite score (CCS) developed by Lowery et al.[38] (Table 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%;[38] in comparison, an MRI has a specificity of 69-93.3%[10,50] 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%);[30] and Thessaly's performed at 20 degrees of knee flexion (specificity = 96-97%).[36] 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.[34] 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)[48] 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 (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 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 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 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 3). If a participant could not grasp their tibia, they were given a strap to assist them into flexion (Figure 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 3). Participants, who were restricted in extension, were asked to perform active knee extension only (Figure 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) to full weight bearing (Figure 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 7, 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 a minimum of 16 participants would be required for this study. A series of one-way analyses of variance (ANOVAs) was 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, was 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 2). The results of each participant's clinical exam are presented in Table 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 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 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 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 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 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 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 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 4).

Knee Injury Osteoarthritis and Outcome Scores

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 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 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 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% of the MC "Squeeze" participants displayed a full resolution of positive findings on a clinical exam; 58% continued to display up to two positive findings, despite self-reporting as asymptomatic (Table 3). In comparison, 18% of sham participants displayed a full resolution of positive findings on a clinical exam; 82% continued to display up to five positive findings, with 63% self-reporting as continuing to be symptomatic (Table 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. 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 as compared to the MC "Squeeze" group on the PSFS; 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 different 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.[47,48] After meniscal injury, meniscal tissue can become dislodged from its normal anatomical position,[54,37,70,15] defined as meniscal derangement.[60] Tissue derangement has been theorized to contribute to approximately 42% of all knee pain.[42] In the presence of tissue derangement at the knee, pressure may be placed on the highly innervated joint line structures.[54,37,70,15] 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.[47,48] 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."[25,43,14,42,60,2] Derangement is defined as an anatomical disturbance in the normal resting position of a joint.[3,25,43,42,60] Patients with a reducible derangement will present a directional preference during the MDT evaluation.[3,25,43,42,60] 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.[21,31,67] 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;[32] 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-particpant 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 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.[48] 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.[23,71]

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.[46,47] 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.

References

1. Acebes C, Romero F, Contreras M, Mahillo, Herrero-Beaumont G. Dynamic ultrasound assessment of medial meniscal subluxation in knee osteoarthritis. *Rheumatol*. 2013;52(8): 1443-1447. http://dx.doi.org/10.1093/rheumatology/ket110

2. Apeldoorn AT, Helvoirt H, Meihuizen H, Tempelman H, Vandeput D, Knol DL, … Ostelo RW. The influence of centralization and directional preference on spinal control in patients with nonspecific low back pain. *J Ortho Sports Phys Ther*. 2016;46(4): 258–269. http://doi.org/10.2519/jospt.2016.6158

3. Aytona MC, Dudley K. Rapid resolution of chronic shoulder pain classified as derangement using the McKenzie method: A case series. *J Man Manip Ther*. 2013;21(4): 207–212. http://doi.org/10.1179/2042618613Y.0000000034

4. Bedi A, Kelly NH, Baad M, Fox AJS, Brophy RH, Warren RF, Maher SA. Dynamic contact mechanics of the medial meniscus as a function of radial tear, repair, and partial meniscectomy. *J Bone Joint Surg Br.* 2010;92(6): 1398-1408. http://doi.org/10.2106/JBJS.I.00539

5. Brody K, Baker R, Nasypany A, Seegmiller J. Meniscal lesions: The physical examination and evidence for conservative treatment. *Int J Athl Ther Train.* 2015;20(5): 35-38.

6. Chaibi A, Benth JS, Russell MB. Validation of placebo in a manual therapy randomized controlled trial. *Sci Rep*. 2015;5(11774): 1-8. http://dx.doi.org/10.1038/srep11774

7. Chakravarty E, Hubert H, Lingala V, Zatarain E, Fries J. Long distance running and knee osteoarthritis. *Am J Prev Med*. 2008;35(2): 133-138. doi:10.1016/j.amepre.2008.03.032.

8. Chatman AB, Hyams SP, Neel JM, Binkley JM, Stratford PW, Schomberg A, Stabler M. The patient-specific functional scale: Measurement properties in patients with knee dysfunction. *Phys Ther.* 1999;77(8): 820-829.

9. Cohen J. Statistical power analysis and research results. *Am Educ Res J.* 1973;10(3): 225. http://dx.doi.org/10.2307/1161884

10. Crawford R, Walley G, Bridgman S, Maffulli N. Magnetic resonance imaging versus arthroscopy in the diagnosis of knee pathology, concentrating on meniscal lesions and ACL tears: A systematic review. *Brit Med J*. 2007;84(1): 5–23. http://doi.org/10.1093/bmb/ldm022

11. Downie WW, Leatham PA, Rhind VM, Wright V, Branco JA, Anderson JA. Studies with pain rating scales. *Ann Rheum Dis.* 1978;37(4): 378-381.

12. Drawer S. Propensity for osteoarthritis and lower limb joint pain in retired professional soccer players. *Brit J Sports Med.* 2001;35(6): 402-408. doi:10.1136/bjsm.35.6.402.

13. Drosos GI, Pozo JL. The causes and mechanisms of meniscal injuries in the sporting and non-sporting environment in an unselected population. *Knee*. 2004;11(2): 143-149. http://doi.org/10.1016/S0968-0160

14. Dunsford A, Kumar S, Clarke S. Integrating evidence into practice: Use of Mckenzie-based treatment for mechanical low back pain. *J Multidisc Healthc*. 2011;4: 393–402. http://doi.org/10.2147/JMDH.S24733

15. Dye SF, Vaupel G, Dye CC. Conscious neurosensory mapping of the internal structures of the human knee without intraarticular anesthesia. *Am J Sports Med*. 1998;26(6): 773-777.

16. Englund M, Roos EM, Roos, HP, Lohmander LS. Patient-relevant outcomes fourteen years after meniscetomy. Influnce of type of meniscal tear and size of resection. *Rheumatology*. 2001;40: 631-639.

17. Englund M, Roos EM, Lohmander LS. Impact of type of meniscal tear on radiographic and symptomatic knee osteoarthritis: A 16-year follow-up of meniscetomy with matched controls. *Arthritis Rheum*. 2003;48: 2178-2187.

18. Englund M, Lohmander LS. Risk factors for symptomatic knee osteoarthritis fifteen to twenty-two years after meniscectomy. *Arthritis Rheum*. 2004;50(9): 2811-2819. http://doi.org/10.1002/art.20489

19. Englund M, Paradowski, P, Lohmander LS. Radiographic hand osteoarthritis is associated with radiographic knee osteoarthis after meniscetomy. *Arthritis Rheum.* 2004;50: 469-475.

20. Englund M, Guermazi A, Lohmander LS. The Meniscus in knee osteoarthritis. *Rheum Dis Clin North Am*. 2009;35(3): 579-590. doi: 10.1016/j.rdc.2009.08.004

21. Ernst E. Does spinal manipulation have specific treatment effects? *J Fam Pract.* 2000;17: 554-556.

22. Fox AJS, Bedi A, Rodeo SA. The basic science of human knee menisci: Structure, composition, and function. *Sports Health*. 2012;4(4): 340-351. http://doi.org/10.1177/1941738111429419

23. Getgood A, Robertson A. (v) Meniscal tears, repairs and replacement – A current concepts review. *Orthop Trauma*. 2010;24(2): 121-128. doi:10.1016/j.mporth.2010.03.01

24. Hanney WJ, Kolber MJ, Pabian P, Cheatham SW, Schoenfeld BJ, Salamh PA. Endurance times of the thoracolumbar musculature: Reference values for female recreational resistance training participants. *J Strength Cond Res.* 2015;30(2): 588-594.

25. Hefford, C. McKenize classification of mechanical spinal pain: Profile of syndromes and directions of preference. *Man Ther*. 2008;13: 75–81. http://doi.org/10.1016/j.math.2006.08.005

26. Herrlin S, Hållander M, Wange P, Weidenhielm L, Werner S. Arthroscopic or conservative treatment of degenerative medial meniscal tears: a prospective randomised trial. *Knee Surg Sports Traumatol Arthrosc*. 2007;15(4): 393–401. doi:10.1007/s00167-006-0243-2

27. Hootman JM, Dick R, Agel J. Epidemiology of collegiate injuries for 15 sports: Summary and recommendations for injury prevention initiatives. *J Athl Train*. 2007;42(2): 311-319.)

28. Hrobjartsson A, Gotzsche PC. Is the placebo powerless? An analysis of clinical trials comparing placebo with no treatment. *N Engl J Med*. 2001;44: 1594-1602.

29. Hwang YG, Kwoh CK. The METEOR trial: No rush to repair a torn meniscus. *Cleve Clin J Med*. 2014;81(4): 226-232. doi:10.3949/ccjm.81a.13075

30. Karachalios T, Hantes M, Zibis A, Zachos V, Karantanas A, Malizos K. Diagnostic accuracy of a new clinical test (the Thessaly test) for early detection of meniscal tears. *J Bone Joint Surg Am.* 2005;87(5): 955-962.

31. Kaptchuk TJ. The placebo effect in alternative medicine: can the performance of a healing ritual have clinical significance? *Ann Intern Med.* 2002;136: 817-825.

32. Kaptchuk T, Miller F. Placebo effects in medicine. *N Engl J Med*. 2015;373(1): 8-9. http://dx.doi.org/10.1056/nejmp1504023
33. Katz JN, Brophy RH, Chaisson CE, de Chaves L, Cole BJ, Dahm DL, Losina E. Surgery versus physical therapy for a meniscal tear and osteoarthritis. *N Engl J Med*. 2013;368(18): 1675-1684. doi:10.1056/NEJMoa1301408
34. Krebs EE, Carey TS, Weinberger M. Accuracy of the pain numeric rating scale as a screening test in primary care. *J Gen Intern Med.* 2007;22(10): 1453-1458.
35. Kujala UM, Kettunen J, Paananen H, Aalto T, Battie MC, Impivaara O, . . . Sarna S. Knee osteoarthritis in former runners, soccer players, weight lifters, and shooters. *Arthritis Rheum.* 1995; 38(4): 539-546. doi:10.1002/art.1780380413.
36. Kurosaka M, Yagi M, Yoshiya S, Muratsu H, Mizuno K. Efficacy of the axially loaded pivot shift test for the diagnosis of a meniscal tear. *Int Orthop*. 1999; 23(5): 271-274.
37. Lee JM, Fu FH. The Meniscus: Basic science and clincal applications. *Oper Tech Orthop.* 2000; 10(3): 162-168. http://doi.org/10.1053/otor.2000.5289
38. Lowery DJ, Farley TD, Wing DW, Sterett WI, Steadman RJ. A clinical composite score accurately detects meniscal pathology. *Arthroscopy*. 2006; 22(11): 1174-1179. http://doi.org/10.1016/j.arthro.2006.06.014
39. Ludman CN, Hough DO, Cooper TG, Gottschalk A. Silent meniscal abnormalities in athletes: magnetic resonance imaging of asymptomatic competitive gymnasts. *Br J Sports Med.* 1999; *33*(6): 414-416.
40. Lyman S, Hidaka C, Valdez AS, Hetsroni I, Pan TJ, Do H, … Marx RG. Risk factors for meniscectomy after meniscal repair. *Am J Sports Med. 2013;* 41(12): 2772–2778. http://doi.org/10.1177/0363546513503444

41. May S, Aina A. Centralization and directional preference: A systematic review. *Man Ther*. 2012; 17(6): 497–506. http://doi.org/10.1016/j.math.2012.05.003
42. May S, Rosedale R. A survey of the McKenzie classification system in the extremities: Prevalence of mechanical syndromes and preferred loading strategies. *Phys Ther*. 2012; 92(9): 1175-1186. http://dx.doi.org/10.2522/ptj.20110371
43. May S, Ross J. The McKenzie classification system in the extremities: A reliability study using Mckenzie assessment forms and experienced clinicians. *J Manipulative and Physiol Ther. 2009;* 32(7): 556–563. http://doi.org/10.1016/j.jmpt.2009.08.007
44. Majewski M, Susanne H, Klaus S. Epidemiology of athletic knee injuries: A 10-year study. *Knee, 2006;* 13(3): 184-188.
45. McDermott ID. (ii) Meniscal tears. *Current Orthop*. 2006; 20(2): 85-94. http://doi.org/10.1016/j.cuor.2006.02.010
46. Mordecai SC, Al-Hadithy N, Ware HE, Gupte CM. Treatment of meniscal tears: An evidence based approach. *World J Orthop*. 2014; 5(3): 233-241. doi:10.5312/wjo.v5.i3.233.
47. Mulligan, B. Manual therapy rounds: Mobilisations with movement (MWM's). *J Man Manip Ther. 1*993; 1(4): 154-156.
48. Mulligan BR. *Manual therapy NAGS, SNAGS, MWMs etc.* (6th ed.). Wellington, New Zealand: Plan View Services Ltd; 2010.
49. Nepple JJ, Dunn WR, Wright RW. Meniscal repair outcomes at greater than five years. *J Bone Joint Surg Am. 2012;* 94(24): 2222–2227. http://doi.org/10.2106/JBJS.K.01584

50. Nikolaou V, Chronopoulos E, Savvidou C, Plessas S, Giannoudis P, Efstathopoulos N, Papachristou G. MRI efficacy in diagnosing internal lesions of the knee: A retrospective analysis. *J Trauma Manag Outcomes*. 2008; *2*(1): 4. doi:10.1186/1752-2897-2-4

51. Paxton ES, Stock MV, Brophy RH. Meniscal repair versus partial meniscectomy: A systematic review comparing reoperation rates and clinical outcomes. *Arthroscopy.* 2011; 27(9): 1275-1288.

52. There are no sources in the current document. 53. Pujol N, Barbier O, Boisrenoult P, Beaufils P. Amount of meniscal resection after failed meniscal repair. *Am J Sports Med*. 2011; 39(8): 1648–1652. http://doi.org/10.1177/0363546511402661

54. Renstrom P, Johnson RJ. Anatomy and biomechanics of the menisci. *Clin SPorts Med.* 1990; 9(3): 523-538.

55. Rhinehart, AJ. Effective Treatment of an Apparent Meniscal Injury Using the Mulligan Concept. *J Sports Med Allied Health Sci.* 2015; 1(2): Article 4.

56. Roemer F, Jarraya M, Niu J, Silva J, Frobell R, Guermazi A. Increased risk for radiographic osteoarthritis features in young active athletes: A cross-sectional matched case control study. *Osteoarthr and Cartil.* 2015; 23(2): 239-243. doi:10.1016/j.joca.2014.11.011.

57. Roos H, Lindberg H, Gardsell P, Lohmander L, Wingstrand H. The prevalence of gonarthrosis and its relation to meniscectomy in former soccer players. *Am J Sports Med*. 1994; 22(2): 219-222. doi:10.1177/036354659402200211.

58. Roos EM, Roos HP, Ekdahl C, Lohmander LS. Knee injury and osteoarthritis outcome score (KOOS) - Validation of a Swedish version. *Scand J Med Sci Sports;* 1998; 8(6): 439-448.

59. Roos KG, Marshall SW, Kerr ZY, Golightly YM, Kucera KL, Myers JB, ... Comstock RD. Epidemiology of overuse injuries in collegiate and high school athletics in the United States. *Am J Sports Med*. 2015; 42(7): 1790-1797. 0363546515580790.

60. Rosedale R, Rastogi R, May S, Chesworth BM, Filice F, Willis S, … Robbins SM. Efficacy of exercise intervention as determined by the McKenzie System of Mechanical Diagnosis and Therapy for knee osteoarthritis: A randomized controlled trial. *J Orthop and Sports Phys Ther*. 2014; 44(3): 173–181. http://doi.org/10.2519/jospt.2014.4791

61. Salaffi F, Stancati A, Silvestri CA, Ciapetti A, Grassi W. Minimal clinically important changes in chronic musculoskeletal pain intensity measured on a numerical rating scale. *Eur J Pain.* 2004; 8(4): 283–291.

62. Shellock FG, Hiller WDB, Ainge GR, Brown DW, Dierenfield L. Knees of Ironman triathletes: Magnetic resonance imaging assessment of older (> 35 years old) competitors. *J Magn Reson Imaging*. 2003; 17(1): 122-130.

63. Sihvonen R, Paavola M, Malmivaara A, Itälä A, Joukainen A, Nurmi H, . . . Järvinen TL. Arthroscopic partial meniscectomy versus sham surgery for a degenerative meniscal tear. *N Engl J Med.* 2013; 369(26): 2515-2524.

64. Stratford P, Gill C, Westaway M, Binkley J. Assessing disability and change on individual patients: A report of a patient specific measure. *Physiother Can.* 1995; 47(4): 258-263.

65. Takeda H, Nakagawa T, Nakamura K, Engebretsen L. Prevention and management of knee osteoarthritis and knee cartilage injury in sports. *Br. J. Sports Med.* 2011; 45(4): 304-309. doi:10.1136/bjsm.2010.082321.

66. Turner A. Long term health impact of playing professional football in the United Kingdom. *Br. J. Sports Med*. 2000; 34(5): 332-336. doi:10.1136/bjsm.34.5.332.

67. Vase L, Petersen GL, Riley JL 3rd, Price DD. Factors contributing to large analgesic effects in placebo mechanism studies conducted between 2002 and 2007. *Pain.* 2009; 145: 36-44.

68. Vela LI, Denegar CR. The disablement in the physically active scale, part II: The psychometric properties of an outcomes scale for musculoskeletal injuries. *J Athl Train*. 2010; 45(6): 630-641. doi:10.4085/1062-6050-45.6.630.

69. Walczak BE, McCulloch PC, Kang RW, Zelazny A, Tedeschi F, Cole BJ. Abnormal findings on knee magnetic resonance imaging in a asymptomatic NBA players. *Am J Knee Surg.* 2008; 21(1): 27-33.

70. Wilson AS, Legg PG, McNeur JC. Studies on the innervation of the medial meniscus in the human knee joint. *Anat Rec*. 1969; 165(4): 485-491.

71. Yeh PC, Starkey C, Lombardo S, Vitti G, Kharrazi FD. Epidemiology of isolated meniscal injury and its effect on performance in athletes from the National Basketball Association. *Am J Sports Med.* 2012; 40(3): 589-594 http://doi.org/10.1177/03635465114286.

72. Zanetti M, Pfirmann CWA, Schmid MR, Romero J, Seifert B, Hodler J. Patients with suspected meniscus tears: Prevalence of abnormalities seen on MRI of 100 symptomatic and contralateral asymptomatic knees. *Am J Roentgenol*. 2003;181: 635-64.1

Tables

Table 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 2. Participant demographic data for the MC "Squeeze" and sham group

Participant ID #	Gender	Age	Sport/Activity	BMI	Onset (Duration of Symptoms)	Joint Line Point of Treatment
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 Coach	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 Basketball	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 Basketball	21.3 BMI	Chronic	Medial

*= Sham Treatment Group