EVALUATING A REGIONAL INTERDEPENDENCE APPROACH FOR TREATING APPARENT HAMSTRING TIGHTNESS IN COLLEGIATE ATHLETES: 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

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by

Rick A. Loutsch

Major Professor: Russell Baker, DAT
Committee Members: Alan Nasypany, EdD; James May, DAT;
Scott Cheatham, DPT
Department Administrator: Phillip W. Scruggs, PhD

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AUTHORIZATION TO SUBMIT DISSERTATION

This dissertation of Rick Loutsch, submitted for the degree of Doctor of Athletic Training with a Major in Athletic Training and titled "Evaluating a Regional Interdependence Approach for Treating Apparent Hamstring Tightness in Collegiate Athletes: A Dissertation of Clinical Practice Improvement," has been reviewed in final form. Permission, as indicated by the signatures and dates given below, is now granted to submit final copies to the College of Graduate Studies for approval.

Major Professor: ______________________________ Date:________________
Russell T. Baker, DAT

Committee Members: ______________________________ Date:________________
Alan M. Nasypany, EdD

______________________________ Date:________________
James M. May, DAT

______________________________ Date:________________
Scott Cheatham, DPT

Chair, Movement Sciences: ______________________________ Date:________________
Philip W. Scruggs, PhD

ABSTRACT

The Dissertation of Clinical Practice Improvement (DoCPI) was developed to illustrate evidence of each Doctor of Athletic Training (DAT) student's progress towards advancing their clinical practice. The DoCPI contains a narrative summary which details the personal growth and change that has occurred as a result of the student's experiences in the DAT program. Evidence of clinical practice improvement will also be demonstrated through analysis of and reflection on patient outcomes collected during the student's clinical residency. The adoption of a regionally interdependent approach to patient care became the focus of my clinical practice improvement and is illustrated throughout this DoCPI. Finally, the DoCPI will demonstrate scholarly growth through the presentation of a manuscript documenting the use of a novel approach to evaluate and treat apparent hamstring tightness, along with a manuscript reporting on the results of a multisite research study investigating the effects of Total Motion Release® on participants who present with apparent hamstring tightness.

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DEDICATION

To my wife, Courtney, thank you for your endless support and encouragement throughout my journey in the DAT program. I am forever grateful for the sacrifices you have made as I completed my DAT degree. I love you!

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CHAPTER 1

NARRATIVE SUMMARY

In the fall of 2010, I transitioned from a clinical staff position to an AT faculty position at Northwestern College. Moving to a faculty position caused me to contemplate my options for advancing my education. I considered several traditional doctor of philosophy (PhD) and doctor of education (EdD) programs; however, I struggled to find a program that would help me to advance as both a clinician and an educator. Upon learning about the doctor of athletic training (DAT) program at the University of Idaho, I felt that I had found a program that would meet my needs and allow me to grow in my professional practice. I enrolled in the DAT program during the summer of 2014. During my time in the program, my understanding of advanced practice and its importance to the athletic training (AT) profession has deepened. I now understand that advanced, scholarly practitioners are invaluable to the AT profession, because they add to the profession's body of knowledge by studying their clinical practice and disseminating the results of their studies. When such individuals educate athletic training students, they influence athletic training education and strengthen the profession as a whole. I believe that the DAT program has allowed me to discover and develop the knowledge and skills necessary to become an advanced, scholarly practitioner. I am committed to incorporating those principles into my clinical practice and into the AT program at my institution, Northwestern College.

In 2015, the AT Strategic Alliance announced the change that the profession would move from allowing professional education to occur at either the bachelor's degree or master's degree level, to establishing the master's degree to be the level of education required for entry into the AT profession(Strategic Alliance, 2015). The AT profession is entering a new phase of post-professional education as a result of the recently announced changes in the professional degree requirement. In a recent review of doctoral education among healthcare professionals, it was proposed that the AT profession should reserve the DAT degree as its advanced practice degree, which would ensure a standard and organized route for professional and post-professional education in AT (Seegmiller, Nasypany, Kahanov, Seegmiller, & Baker, 2015). In 2011, prior to the recent changes in AT education, the University of Idaho created the first DAT program and became a leader in establishing an advanced practice degree in AT.

The University of Idaho's DAT program was designed to prepare athletic trainers to become scholarly professionals who possessed the knowledge, skills, and abilities required to advance their clinical practice. The DAT program is a professional practice doctorate (PPD), or a doctoral program that incorporates academic coursework and a clinical residency that is focused on the utilization of an action research (AR) philosophy to solve problems in patient care. Action research, also known as participatory action research, is commonly used in healthcare (Koshy, Waterman, & Koshy, 2011; Meyer, 2000). Action research is designed to generate solutions to practical problems and often involves the practitioner studying his or her own clinical practice (Meyer, 2000). Students in the DAT program develop a Dissertation of Clinical Practice Improvement (DoCPI), which is a document that highlights the student's academic and clinical growth and his or her progress toward becoming an advanced, scholarly practitioner.

Historically, professional practice doctorates have focused on preparing students to advance their professional practice in their respective field. The PPD programs have also often emphasized integration of education within the clinical or professional setting (Willis &

Valenti, 2010). Prior to the DAT program's creation, athletic trainers lacked a viable PPD option that would advance their clinical skills as an athletic trainer. Therefore, most athletic trainers who had completed their terminal degree chose to pursue either a more traditional PhD degree or an EdD (Hertel, West, Buckley, & Denegar, 2001). Although both the PhD and EdD degrees can prepare athletic trainers for positions in academia, these degrees are not specifically designed to advance the clinical skills of athletic trainers. As a result, the profession is at risk of retaining a limited number of scholarly practitioners who have both the education and experience to add to the profession's body of knowledge in patient care. In addition, the profession may lack a sufficient number of scholarly practitioners to adequately educate future athletic trainers. Through the creation of the DAT degree, athletic trainers now have a terminal degree option that focuses primarily on developing advanced, scholarly practitioners. The creation of the DAT degree also reflects the common trend of clinical doctorates becoming the new educational standard among health care professions (Seegmiller et al., 2015). The DAT degree option will increase the number of advanced, scholarly practitioners in the AT profession, which will enhance the profession's body of knowledge and improve the educational opportunities available for future athletic trainers.

While students in the DAT program work toward becoming advanced, scholarly practitioners, they must also develop a firm understanding of the AR philosophy and begin incorporating the principles of AR into their clinical practice. The University of Idaho's DAT program encourages students to study and reflect on their clinical practice using an AR lens. For example, the program exposes students to a variety of new treatment paradigms, any of which can be incorporated into their clinical practices. By adopting an AR philosophy toward clinical practice, students will participate in the continuous cycle of reflecting on and analyzing their clinical practice, making changes in their clinical practice based on their reflection, studying changes made in their clinical practice, and generating new knowledge that leads to further reflection and changes in clinical practice. As a result of this continuous cycle, students' clinical practices can improve and, ultimately, lead to advanced, scholarly practice.

Upon entering the DAT program, I had limited knowledge of and no experience with conducting AR or incorporating the principles of AR into my clinical practice. Following the introduction to AR, which explained how the DAT program incorporates an AR philosophy into the clinical residency component of the program, I was excited to begin studying my own clinical practice. Through my early experiences in the DAT program, I became aware of the weaknesses in my patient care; specifically, I realized that there was a lack of effective treatments and an absence of meaningful patient outcomes in my practice. The DAT program introduced me to several new treatment paradigms, which I began to incorporate into my clinical practice; however, to improve as a clinician and fully understand the effectiveness of the new treatments I was utilizing, I began to study and reflect on my patient care through the collection of patient outcome measures. As my commitment to improving my clinical practice and my desire to develop into an advanced, scholarly practitioner continued to grow, I found myself embracing the AR principles of studying and reflecting on my clinical practice. This led to significant improvements in my clinical practice.

As my philosophy toward patient care continued to evolve, so did my perspective on research in AT. Historically, a majority of the research conducted in AT has taken place outside of the clinical setting on non-patient populations (Sauers, McLeod, & Bay, 2012) and has focused on disease-oriented evidence (DOE) as opposed to patient-oriented evidence

(POE) (Snyder et al., 2008). Therefore, a significant portion of the research conducted in the AT profession is not being translated to clinical practice (Sauers et al., 2012). One method that the DAT program has adopted to overcome this barrier is to encourage students to participate in translational research.

Translational research is a form of clinical research that has been defined as "investigations that apply the results from basic science to the care of patients" (Hurley, Denegar, & Hertel, 2011). Often referred to as "bench-to-bedside" research, translational research provides an important link between research and clinical practice, and it provides an opportunity for high-quality POE to be implemented into clinical practice (Hurley et al., 2011; Sauers et al., 2012). As I began to embrace the principles of the AR philosophy in my own clinical practice, I began to see the connections between AR and translational research. Adopting the principles of AR was necessary to promote change and growth within my clinical practice, and participating in translational research will help me to identify the effect of those changes on my clinical practice as well as how those results may translate to the clinical practice of other athletic trainers. During my time in the DAT program, I began to recognize that incorporating principles of the AR philosophy and translational research into my clinical practice would lead me toward my goal of becoming an advanced, scholarly practitioner.

My journey toward becoming an advanced, scholarly practitioner began when I first reflected on my clinical practice. As I began to incorporate the AR philosophy and translational research into my clinical practice, I began to identify the weaknesses in my practice. I committed myself to improving the care with which I provided my patients, and I became aware of how conducting research in my clinical setting would enhance the care I provided. Prior to entering the DAT program, I believed that research in the AT profession was only done by graduate students and faculty members at large research universities. I never imagined that the research I would conduct in my own clinical practice could make an impact on the profession. My research philosophy has since changed. I now believe that my role as a scholarly clinician is to conduct translational research that connects laboratory research to clinical research. I hope to conduct applied clinical research that will generate new theories that can then be studied in the laboratory setting. The DAT program has allowed me to begin the process of becoming a scholarly clinician.

Along with the shift in my research philosophy, my experiences in the DAT program have helped to foster a change in the way I view evidence-based practice (EBP) in AT. Clinicians who utilize EBP in their clinical practice use the latest research evidence to inform their patient care decisions (Hurley et al., 2011). Prior to entering the DAT program, I believed I had to rely on high-quality evidence from level-1 randomized controlled trials or level-2 prospective cohort studies to support my clinical decisions. As a result, I often dismissed evidence from lower level studies, such as case series or studies. As I learned more about translational research and the importance of connecting research to clinical practice, I began to understand the role that applied clinical research studies plays in informing clinical practice.

Conducting applied clinical research allows clinicians to disseminate clinical findings to other clinicians who can then apply those findings to their own practices. In order for research results to translate to other clinicians' work, each study has to have a balance of internal and external validity (Hurley et al., 2011). Internal validity refers to how well the experimental design of the study was controlled; external validity refers to the ability of the results of a study to be generalized by clinicians in other clinical settings (Hurley et al., 2011). In regards to applied clinical research, clinicians may not be able to control all the variables in the research design—which may result in lower internal validity. However, the external validity will be higher, because the research was performed on patients in the clinical setting and not on participants in a controlled laboratory setting. As I gained a deeper understanding of the important role applied clinical research has on generating new knowledge within the AT profession, I began to see how I can generate evidence from my own clinical practice through the collection of POE, which can then be utilized to generate practice-based evidence (PBE).

Practice-based evidence is a form of evidence generated by clinicians through the purposeful study of their clinical practice. It informs clinicians of the effectiveness of their interventions (Krzyzanowicz, May, & Nasypany, 2014). Throughout my experiences in the DAT program, I have committed myself to becoming a PBE clinician. The knowledge and understanding I have gained regarding AR, translational research, and the current state of research in AT have made me aware of the importance of generating PBE within my clinical practice. Through my clinical experiences, I have embraced the opportunity to study the effect the changes I have made in my clinical practice have had on my patient care. The PBE that I have generated has continued to inform my future clinical decisions and is allowing me to move closer to becoming an advanced, scholarly practitioner.

In addition to utilizing an AR philosophy and translational research to improve patient care, the DAT program encourages students to participate in multisite research studies. In the current state of AT research, a majority of the research conducted includes small sample sizes of non-patient participants, which limits the clinical relevance of many of the studies (Sauers et al., 2012). Another limitation of AT research is that it often is performed within the clinicians' work setting, thereby limiting the potential patient population and decreasing the external validity of the research (Sauers et al., 2012). By participating in multisite research and collaborating with other clinicians across a diverse patient population, clinicians may overcome some of these limitations.

The DAT program has embraced the concept of multisite research and offers students several opportunities to conduct translational research studies with other clinicians across the country. Students identify common local problems in their respective clinical settings, and they work together to develop multisite research studies designed to inform clinical practice and solve those local problems. Although multisite research has its advantages, it also presents challenges for clinicians. The main challenge is ensuring that all research procedures are consistent across each site. This, in turn, ensures the internal validity of the study (Arnold, Gansneder, & Perrin, 2005). The DAT program addresses this challenge by having on-campus academic sessions in the summer, which allow students to design multisite research studies, participate in reliability testing, develop consistent treatment techniques, and design scripts that each research team member will use to ensure consistent research methodology. As the AT profession continues to evolve, it is essential that more multisite research is conducted in AT.

The inclusion of key components such as translational research and multisite research in the University of Idaho's DAT program enable its students to become scholarly practitioners and leaders in the AT profession. In addition, the DAT program exposes students to new treatment paradigms, thereby providing them with the resources necessary to advance their clinical practice. Upon entering the DAT program, students are taught the skills of and foundational knowledge behind several treatment paradigms, and they are encouraged to study the effectiveness of these treatments in their own practice. The exposure to new treatment paradigms also provides students with the opportunity to develop clinical research studies, in which they investigate the effect of a treatment paradigm on a patient population. As part of this DoCPI, I will highlight some of my experiences with the new treatment paradigms that I incorporated into my clinical practice. I will also present some of the clinical research I have completed, where I examined the effect of these treatments on my patient population. I believe that this research is evidence of my growth as a clinician and of my shift toward becoming an advanced, scholarly practitioner.

Part of becoming a scholarly practitioner is adding to the profession's body of knowledge through the dissemination of clinical research results. Chapter 2 of my DoCPI contains a published case study manuscript that demonstrates the effectiveness of using a novel technique—reactive neuromuscular training (RNT)—to treat apparent hamstring tightness (AHT). Through my clinical experiences of using RNT to treat AHT and other musculoskeletal conditions, I have gained a new perspective on patient care that extends beyond the traditional pathoanatomical, or DOE, approach. The case study included in Chapter 2 highlights my newly acquired clinical reasoning skill of evaluating and treating patients through a regional interdependence (RI) approach. The RI approach to patient care is in contrast to the pathoanatomical approach and encourages clinicians to consider the interdependence between anatomical regions rather than focus their evaluation and treatment on a single region (Wainner, Whitman, Cleland, & Flynn, 2007). In addition to demonstrating my change in perspective on patient care and my shift toward an RI approach in my clinical practice, the published manuscript highlights my commitment to studying my own clinical practice and disseminating those results to the profession.

My journey toward becoming a scholarly practitioner cannot be fully demonstrated by a single case study. To illustrate my growth as a clinician and scholarly practitioner, Chapter 3 of my DoCPI includes a collection of the patient outcomes I have gathered throughout my clinical residency, along with an analysis and reflection on those outcomes. The collection and analysis of patient outcomes, and the reflection on those outcomes, should become part of a scholarly practitioner's daily practice; therefore, included in this chapter is evidence of my success and struggles with collecting patient outcomes and incorporating new treatment paradigms into my clinical practice. In addition, Chapter 3 highlights how I have adopted an AR philosophy in my clinical practice by reflecting on my practice and studying the changes I have made in my patient care. I discuss those changes in detail and focus on specific patient encounters that demonstrate significant changes in my approach to patient care.

Unlike Chapters 2 and 3 of this DoCPI, which focus on my growth as a clinician through my individual patient outcomes, Chapters 4 and 5 highlight how I have grown as a clinician and researcher through my participation in multisite research. Chapter 4 contains two critically appraised topic (CAT) manuscripts that were written in collaboration with the other members of my multisite research team. The CAT manuscripts included in this DoCPI helped to inform us of the current state of the apparent hamstring tightness (AHT) stretching literature in regards to comparing stretching to neurodynamics and comparing static stretching to proprioceptive neuromuscular facilitation (PNF) stretching. As part of the development process of the CAT manuscripts, members of our research team gained a deeper understanding of the common research methods that are described in current literature for assessing the effects of stretching and improving measures of hamstring extensibility. Our team used this information to help formulate the research questions we wanted to answer through our multisite research study on AHT, and to develop the research methods we would use for the study.

Chapter 5 contains the results of our multisite research study on the effect of Total Motion Release® on patients who present with AHT. This study was designed to enhance the AT profession's body of knowledge regarding the treatment of AHT, and the results of the study are presented in the manuscript format required to submit it for publication. My experiences during this research project have not only enhanced my understanding of AHT, they have enhanced my skills as a scholarly practitioner who is committed to improving patient care by participating in multi-site, translational research and disseminating the results of said research to other clinicians in the AT profession.

My pursuit of a DAT degree represents a turning point in my career. Possessing a doctorate in AT will allow me to become a clinician and educator who is not only a leader within this evolving profession, but who is also someone who works to prepare future leaders. Prior to beginning my journey through the DAT program, my initial reason for obtaining a doctorate was to advance my status as a faculty member at Northwestern College; however, I also wanted to obtain a terminal degree that I believed would enhance my abilities as a clinician and educator. I hoped that by enrolling in the DAT program, I would gain the knowledge and skills to become a life-long learner who is passionate about improving my patient care and clinical education. My experiences in the DAT program have allowed me to achieve this goal.

I look forward to continuing my growth as an advanced practitioner by participating in translational and multisite research throughout my career. Not only will such research enhance my patient care, it will provide opportunities for my students to learn the skills needed to conduct translational research in their future clinical practices.

Throughout my journey in the DAT program, I have not only advanced my knowledge and skills as a clinician, but I have changed my approach to clinical practice. This DoCPI illustrates my commitment to becoming an advanced, scholarly practitioner who incorporates EBP and PBE into my clinical practice and who strives to contribute to the AT profession's body of knowledge. My time in the DAT program has led me down the path towards advanced, scholarly practice. My DoCPI illustrates my commitment to scholarly practice through the reflection on my clinical practice and participation in multisite research that is designed to inform and improve patient care within the clinical setting.

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CHAPTER 2

REACTIVE NEUROMUSCULAR TRAINING RESULTS IN IMMEDIATE AND LONG TERM IMPROVEMENTS IN MEASURES OF HAMSTRING FLEXIBILITY: A CASE REPORT

Loutsch, R. A., Baker, R. T., May, J. M., & Nasypany, A. M. (2015). Reactive neuromuscular training results in immediate and long term improvements in measures of hamstring flexibility: a case report. *International Journal of Sports Physical Therapy*, *10*(3), 371-7.

Abstract

Background and Purpose

Hamstring tightness is a common complaint among active individuals and patients are traditionally classified with tight hamstrings based on commonly accepted clinical exams including the active knee extension, active straight leg raise, and passive straight leg raise tests. Apparent hamstring tightness is a condition that is present in patients who have the perception of hamstring tightness and are classified with a tissue extensibility dysfunction but demonstrate immediate gains in hamstring range of motion following an intervention that does not address a tissue length dysfunction. Reactive neuromuscular training can be used as part of the evaluative process to classify and treat patients with apparent hamstring tightness. The purpose of this case report was to identify, treat, and report the outcomes experienced when using a reactive neuromuscular training technique on a patient who was classified with hamstring inflexibility based on traditional testing methods.

Case Description

A 20 year-old female softball player presented with a chief complaint of hamstring tightness of more than four years duration. The patient tested positive for hamstring

inflexibility based on traditional testing methods. The patient was then treated using a reactive neuromuscular training technique in which the patient resisted a manual anterior to posterior force at the abdomen, sternum and across the hips while simultaneously bending forward at the hips in an attempt to touch her toes.

Outcomes

Following one reactive neuromuscular training treatment session the patient tested negative for hamstring inflexibility based on traditional testing methods and maintained those results at a five-week follow-up appointment.

Discussion

The subject in this case report demonstrated the effectiveness of reactive neuromuscular training in identifying and treating apparent hamstring tightness. Based on these findings, clinicians should consider using reactive neuromuscular training to properly classify and treat patients with a chief complaint of hamstring "tightness."

Level of Evidence: 4 (single case report)

Key words: Apparent hamstring tightness, patient classification, treatment based classification

Background and Purpose

Hamstring tightness is a common complaint among active individuals.[1] In the clinical setting, patients who present with limited range of motion (ROM) on the active knee extension (AKE), passive straight leg raise (PSLR), and active straight leg raise (ASLR) tests are commonly classified with tight hamstrings and treated with traditional stretching techniques.[2–5] Stretching activities are commonly used in healthcare to improve joint ROM,[6–10] and the American College of Sports Medicine recommends routine flexibility exercises to maintain and improve joint ROM.[11] The current literature on the most effective methods to improve ROM via stretching is inconsistent,[7] and recent evidence suggests increases in ROM following a stretching program may not be due to increases in tissue length, but rather, are caused by an increase in stretch tolerance.[12–14] In addition, there is evidence to suggest that some types of stretching may negatively impact muscle strength and power under specified stretching parameters.[15–17] Given the proposed effects of stretching and the current method of classifying hamstring tightness, clinicians must ensure the cause of the apparent "tightness" warrants the application of stretching interventions prior to recommending any stretching program.

Apparent hamstring tightness is a provisional classification for those patients who have been identified as having hamstring tightness using traditional measures (e.g., AKE, PSLR). The importance of a provisional classification of apparent hamstring tightness is that testing may lead to a more definitive classification of tissue extensibility dysfunction (TED), which is a dysfunction in the length or extensibility of multi-articular soft tissue structures (i.e., muscle, fascia, nervous tissue) identified through the Selective Functional Movement Assessment (SFMA).[4] However, recent clinical practice findings demonstrate that these apparent hamstring tightness or TEDs (based on special test findings) can often be resolved in a single treatment session that does not directly involve lengthening structures. If one follows the current accepted classification pathway based on exam findings (i.e., hamstring tightness or TED), then this classification would lead the clinician to a local treatment (e.g., stretching, instrument assisted soft tissue mobilization) which may or may not resolve the "tightness." The problem with assuming local tightness or TED, is that the clinician may wrongly lengthen a normal tissue (e.g. hamstrings), when the results (e.g., negative special tests) may be gained by using non-local, non-structural lengthening techniques. An alternate hypothesis is that the apparent tightness may be a low level contraction of some fibers of a muscle (e.g., non-local stability motor control dysfunction, trigger point), which presents with similar symptoms of a TED during a traditional clinical exam. In many cases, non-traditional treatment options, such as a stability motor control intervention (e.g., reactive neuromuscular training) at a proximal or distal segment, a regional interdependence approach (e.g., Total Motion Release[18]), or slacking the local tissue instead of stretching it (e.g., positional release therapy[19]), will immediately resolve the apparent tissue tightness.

One proposed method to differentially diagnose a true TED from apparent hamstring tightness is to use a treatment based classification (TBC) system to classify patients prior to treatment. One potential component of a TBC system for hamstring tightness is reactive neuromuscular training (RNT). The term RNT was first introduced by Voight and Cook[20] and is utilized to restore functional stability about the joint and enhance motor control skills. Individualized RNT techniques are thought to correct motor pattern dysfunctions by applying a light external load to exaggerate the dysfunctional movement and cause the patient to reactively correct the subconscious dysfunctional movement pattern.[4] Current literature on

RNT is lacking, but the results of one case report demonstrated a rehabilitation program utilizing RNT that consisted of exercises that focused on promoting proper body positioning and posture by having the patient react to an outside force (e.g., elastic tubing) that promotes an unwanted movement pattern quickly improved apparent strength deficits in a patient with an anterior cruciate ligament deficient knee.[21]

It is hypothesized that patients who present with hamstring tightness may be experiencing a dysfunctional motor control pattern in which the normal firing pattern of the postural (i.e., static) muscles is delayed or sub-optimal causing the hamstring muscle group to function as a stabilizer versus their normal function as a prime mover. Therefore, this alteration of the hamstring muscle group's function results in the presentation of apparent hamstring tightness. The proposed use of a specific RNT technique may help classify and correct this dysfunctional motor control pattern by reflexively inhibiting the hamstring muscle group and activating the postural stabilizers. While variations exist, the recommended application begins with the clinician applying a manual anterior-posterior (AP) force to the center of a patient's abdomen (i.e., umbilicus), sternum, and/or across the hips bilaterally at the level of the anterior superior iliac spine while instructing the patient to prevent the clinician from pushing him/her backwards. Once the patient "stops" the AP force provided by the clinician, the patient reacts simultaneously by bending forward at the hips in an attempt to "touch" his/her toes (Figure 2.1). The patient should complete five to ten reactive forward flexion bends with the clinician applying the AP force prior to each repetition. Multiple sets of this maneuver can be performed in a single treatment session and the clinician may adjust the location (superior or inferior) of the AP force throughout the treatment session. The clinician can choose to adjust the location of the AP force in an attempt to find the location that produces the greatest increase in forward flexion by producing the optimal motor control pattern for performing forward flexion.

Patients who do not have a true hamstring TED, and have a possible motor control pattern dysfunction, will quickly improve their multi-segmental forward flexion ROM during the initial RNT treatment session. As a result of this change, the patient can be classified as having apparent hamstring tightness and would not be indicated to receive a treatment protocol designed at increase tissue extensibility (e.g., stretching). The purpose of this case report was to identify, treat, and report on the patient outcomes while using this RNT technique on a patient who demonstrated hamstring inflexibility based on the traditional testing methods.

Case Description

A 20-year-old, female softball player agreed to participate after she was informed of the purpose of this case study. The patient denied any recent history of lower extremity, lumbar, or thoracic injury. She did report chronic hamstring tightness of more than four years duration despite the use of traditional warm-up and stretching techniques. The patient reported no additional health history that would have affected trunk or lower extremity ROM and was otherwise healthy.

Initial Clinical Impression

The cause of the patient's chief complaint of chronic hamstring tightness was hypothesized to be a result of apparent hamstring tightness since the patient reported no improvement following traditional warm-up and stretching interventions. Further ROM testing was performed in order to identify whether the patient could be classified with hamstring tightness based on traditional evaluation techniques.

Examination

Prior to beginning the clinical examination the patient performed a warm up which consisted of five consecutive standing toe touches in order to reduce the potential mobilizing effect from performing repetitive hip flexion measurements.[22] Immediately after the warm up, the following ROM measurements were taken: (a) ASLR, (b) PSLR, (c) AKE, (d) finger to floor distance test (FFD), (e) sit and reach (SnR), (f) modified Shober (mShober), (g) seated sacral angle (SA), and (h) standing SA. Range of motion measurements for the ASLR, PSLR, AKE, and SA were taken using an iPhone 5s with the Clinometer (Plaincode, http://www.plaincode.com/products/clinometer/) application which has previously been shown to be reliable at measuring ROM in the shoulder[23] and cervical spine.[24] The FFD, SnR and mSchober were measured using a cloth measuring tape.

Normal ROM on the ASLR and PSLR tests has been suggested as 70⁰ or more and 80⁰ or more of hip flexion respectively.[4] For the AKE test, a knee flexion angle of 20⁰ or less has been used to define normal ROM.[3] During the clinical examination, the patient's ROM measurements (Table 2.1) on the ASLR (R=60⁰, L=58⁰), PSLR (R=67⁰, L=70⁰), and AKE (R=30⁰, L=34⁰) tests all fell outside of the normal ROM limits.

Clinical Impression After Examination

Based on the ROM measurements during the clinical examination, the patient was classified as having a potential TED. The clinical examination results were consistent with the patient's chief complaint of hamstring tightness, but had remained despite regular stretching techniques applied as part of her pre-sport warm-up. As such, the use of RNT as a screening and intervention technique to identify if the patient has apparent hamstring tightness was warranted.

Intervention

The patient was treated with RNT immediately following ROM measurements. Treatment began by having the patient standing with her feet together while the clinician provided a mild AP force to the patient's abdomen. The patient resisted this force and simultaneously bent over in multi-segmental flexion while the clinician maintained application of the force. Upon completion of the repetition, the clinician re-applied the force and the process was repeated for a set of 10 repetitions with the force being re-applied prior to each repetition. The clinician then provided the AP force on the superior portion of the sternum for approximately five repetitions and an additional five to eight repetitions were performed with the clinician providing the AP force at the level of the anterior superior iliac spine on the hip. The clinician paused treatment between each set to inform the patient of the change in location of the AP force but no additional rest was given. Total treatment time was less than three minutes. Immediately following the RNT treatment, ROM measurements were repeated. After the initial treatment was complete, the patient was instructed to resume normal daily and sport activities. The patient returned to the athletic training clinic five weeks after initial treatment for follow-up testing. The patient reported she did not participate in any additional RNT treatments or additional stretching activities outside of her normal sport activities between the initial treatment session and follow-up testing.

Outcomes

All post-treatment and follow-up ROM measurements are included in Table 2.1. The patient had an increase in post-treatment ROM on the ASLR (R=15^0, L=22^0), PSLR (R=16^0, L=14^0), and AKE (R=19^0, L=16^0) from the initial treatment. At the five week follow up, the patient further increased ROM compared to initial measurements on the ASLR (R=25^0, L=32^0), PSLR (R=25^0, L=23^0), and AKE (R=30^0, L=34^0). In addition, FFD post-treatment improved 4.5 cm from the single treatment and the patient maintained that improvement at the five week follow up. Sit and reach measurements were similar to the FFD measurements with a 4 cm improvement post-treatment and a 3.5 cm improvement at the five week follow up. The patient did not demonstrate any change in the mSchober following treatment; however, her SA measurements improved (10^o sitting, 11^o standing) at the initial post-measurements, but were not maintained at the five week follow up.

Discussion

Prior to RNT treatment, ROM measurements on the ASLR, PSLR, and AKE tests would classify the patient as having had tight hamstrings resulting from a TED.[2,10,21] Following one treatment session with a RNT exercise intervention, the patient's ROM improved and were within normal ROM limits[21] on each of the above tests. At the five week follow up appointment, the patient's ROM measurements on the ASLR, PSLR, and AKE remained within the normal limits and had increased from the initial post-treatment measurements. The patient denied making any changes to her physical activity level or training program following initial treatment and did not receive any additional treatments aimed at increasing hamstring flexibility.

While only one patient, these findings indicate superior results compared to stretching studies that have assessed similar outcome measures. De Weijer, Gorniak, and Shamus[25] found patients achieved an immediate increase in ROM on the AKE test of about 13^o following a single session of 3 sets of 30 second passive static stretches; however, after 24 hours the post-stretch increase in ROM decreased to just under 8^0 and no additional follow-up testing was performed. Bandy, Irion, and Briggler[10] reported similar results following a six-week stretching program. In their study, patients in the stretching groups gained, on average, between 10.5° and 11.5° of knee extension on the AKE test. Similarly, Cipriani, et al[26] reported an 18.1° increase in ROM on the PSLR test following a four-week static stretching program, but also reported a steady decrease in ROM in the same patients during the subsequent four weeks after discontinuing the stretching program. The patient in this case study demonstrated a greater increase in ROM on the AKE test immediately following a single treatment session of RNT ($R=19^{\circ}$, $L=16^{\circ}$) without utilizing any treatment designed to directly elongate tissue. More importantly, the patient demonstrated further increases in ROM at a five-week follow up (R=30, L=34) without any additional RNT treatment sessions, as opposed to the decrease in ROM that was seen in the stretching studies.[25,26]

The gains in ROM seen in this patient immediately following RNT treatment and the increased gains in ROM at a five-week follow up meet or exceed the increases in ROM identified in traditional stretching literature.[8,10,25,26] The results may be explained by a change in motor pattern function as a result of the RNT intervention and suggests it is unlikely the patient had a hamstring length deficit prior to treatment despite the positive tests for hamstring tightness. More importantly, the results of this case study identify a potential flaw in the current thinking regarding evaluation and treatment of hamstring tightness. Current evaluation techniques may be unable to differentiate between true and apparent hamstring tightness; therefore, patients may often be incorrectly prescribed stretching interventions which may be contraindicated if the clinician is lengthening tissue that does not require tissue elongation. Clinicians should consider using treatment based assessment techniques to differentiate between true and apparent hamstring tightness. Future research needs to be conducted on a larger population in order to determine the reliability and validity of using the proposed RNT treatment as an individual treatment for apparent hamstring tightness, as well as using it as part of a more comprehensive hamstring tightness TBC system. In addition, further research needs to identify if a true change in motor control occurs with RNT, and if that change correlates with improved athletic performance and/or injury prevention.

Conclusion

The results of the case report demonstrate that the subject did not have a TED despite fitting that classification based on the use of traditional evaluation techniques to assess hamstring flexibility. The use of an RNT intervention allowed for quick identification of the apparent hamstring tightness and improved all of the patient's ROM measurements in only three minutes of treatment. The improvements were maintained at a five-week follow-up appointment without any further treatment being applied. Based on these results, clinicians should consider utilizing the described RNT intervention as a screening tool within the differential diagnostic process, and as a treatment, for patients who present with signs of hamstring tightness. The use of such interventions may lead to the development of an efficient and effective TBC system for improving outcomes in patients who present with hamstring flexibility issues.

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Figure 2.1 Reactive Neuromuscular Training (RNT) technique used to identify and treat apparent hamstring tightness. (A) Clinician applies an anterior-posterior force and (B) the patient simultaneously reacts by reaching for his/her toes.

Table 2.1. Clinical evaluation r*ange of motion measurements pre-and post- reactive neuromuscular treatment including 5 week follow-up testing and total change in range of motion.*

	Pre-Treatment	Post-Treatment	5 Week Follow-up	Total Change
ASLR Right	60º	75º	85º	25º
ASLR Left	58º	80º	90º	32º
PSLR Right	67º	83º	92º	25º
PSLR Left	70º	84º	93º	23º
AKE Right	30º	11º	0º	30º
AKE Left	34º	18º	0º	34º
SA (Standing)	60º	71º	60º	0º
SA (Seated)	75º	85º	74º	-1º
mSchober	21.25cm	21cm	22cm	0.75 cm
FFD	1cm	-3.5cm	-3.5cm	4.5cm
S&R	0cm	-4.0cm	-3.5cm	3.5cm

ASLR= Active Straight Leg Raise
PSLR= Passive Straight Leg Raise
AKE= Active Knee Extension
SA= Sacral Angle
mSchober= Modified Schober
FFD= Finger to Floor Distance
S&R= Sit and Reach

CHAPTER 3

OUTCOME SUMMARY, RESIDENCY FINDINGS, AND IMPACT

A key component of the Doctor of Athletic Training (DAT) program is the completion of a clinical residency, which begins during the first fall semester of the program. The residency provides students with the opportunity to advance their clinical skills and begin the process of becoming scholarly practitioners. Students are exposed to multiple treatment paradigms and are then encouraged to begin incorporating those paradigms into their clinical practice. Students also collect patient outcome measures, which, when reflected upon, can help to determine the success of the students' clinical practices and provide data that the students can use to help inform their future clinical decisions. In the following summary of my clinical residency, I present data from the patient outcomes I have collected. I also reflect upon and analyze those outcomes.

Embracing Change

Prior to entering the DAT program in the summer of 2014, I believed that I was a successful athletic trainer and that the treatments I provided met my patients' needs. I also felt that I was an effective educator. Shortly after beginning the DAT program, however, my opinion changed. I became aware that I had viewed my previous clinical practice through a pathoanatomical lens, in which I assumed that all pain and dysfunction was the result of a local anatomical pathology. As a result, I often treated patients with local therapeutic modalities and exercise, believing that those treatments would address the anatomical pathology that I suspected was present. I never questioned the efficacy of my treatments or the evidence that supported them. Rather, I simply accepted the treatments as "correct" without studying, through the collection of patient outcome measures, the effect the treatments had on my patients. I also failed to reflect on my clinical practice, which led to a lack of growth as a clinician and a lack of desire to pursue new treatment techniques or philosophies.

As I began my clinical residency in the fall of 2014, I quickly realized that if I were to grow as a clinician, I would have to embrace significant changes in the way I approached my clinical practice. I would need to change my philosophy of patient care and challenge the traditional beliefs I had relied on up to that point in my career.

Making these changes proved to be more difficult than making the initial decision to change. At the end of the Summer I session, I wrote the following statement in my AT610 Course Learning Analysis Assignment:

> *Returning to my clinical practice this fall, I am excited to apply the techniques we have learned and begin using them as part of my evaluation process. My concern is that I will have moments of frustration when the techniques I use don't produce the results I expect. During these times of frustration, I will have to stay present in the moment and avoid the temptation to revert back to my old treatment philosophy. If I regularly review the foundational knowledge of each treatment technique, I can have confidence in myself and my abilities to use the treatment paradigms we have learned.*

Reflecting back on this statement and on my clinical residency of the Fall I semester, I realize that I was accurate in predicting that there would be moments when I would experience frustration and become tempted to revert back to my "old treatment philosophy." I underestimated how difficult it would be to make the significant changes that were necessary to begin adopting a patient-care philosophy that would allow me to become a scholarly clinician. Therefore, I attempted to make numerous major changes in my clinical practice early in the fall semester, which led to poor implementation of my new patient care philosophy and a lack of meaningful reflection on my clinical practice.

Identifying and Overcoming Barriers

The changes I began to make in my clinical practice came as a result of experiences I had during my first summer in the DAT program, when I started to identify barriers that were preventing me from progressing as a clinician. I was excited to make changes in my practice; however, I was not ready to accept the fact that the methods I had utilized for the past 10 years were no longer good enough. As I began to incorporate new treatment paradigms into my clinical practice, I was not always successful at achieving positive results. I struggled with accepting a new approach to clinical practice, in which I would take those unsuccessful results and learn from them. Instead, I reverted back to what was more comfortable: my traditional treatment methods. When I did not get the immediate results I desired, I found myself quickly abandoning my use of the new treatment paradigms and returning to my use of modalities and strengthening exercises. Overcoming this challenge took time. It also required a significant amount of self-reflection. Through the reflection process, I began to understand that to grow as a clinician, I needed to invest my time and energy into deepening my knowledge of the treatment paradigms I was utilizing. By enhancing my knowledge of the treatment paradigms, I would gain confidence in my clinical reasoning and in my skill with using the new paradigms, which would lead to improved patient outcomes.

Another barrier I had to overcome during my clinical residency was that of understanding the purpose of collecting patient outcomes. Initially, I found myself becoming so focused on actually collecting outcomes that I forgot the purpose behind collecting the data. Collecting patient outcomes was not simply a course requirement; it was the means by which to assess my clinical practice improvement. The type of patient outcomes the DAT program expects students to collect in their clinical practice goes beyond the traditional, disease-oriented outcome measures (e.g., range of motion). Instead, the expectation is for students to collect *patient-oriented* outcome measures, which indicate how patients' injuries or illnesses affect their quality of life. An example of a patient-oriented outcome measure used by students in the DAT program is the Disablement in the Physically Active (DPA) Scale. The DPA scale is a multidimensional, patient-reported outcomes instrument that has been found to be valid, reliable, and responsive at measuring disablement in physically active patients with musculoskeletal injuries (Vela & Denegar, 2010). In addition to multidimensional, patient-centered outcomes, DAT students are also required to collect patient-oriented outcome measures that are region-specific, such as the Lower Extremity Functional Scale (LEFS). By incorporating a combination of multidimensional and regional outcome measures, DAT students are able to gain a clear understanding of their patients' conditions before beginning treatment and have a consistent method by which to evaluate the effectiveness of their treatments.

During the early portion of my clinical residency, a majority of the data I collected lacked meaning and purpose. However, as my focus shifted from understanding the process of collecting patient outcomes to understanding the purpose of their collection, the data I gathered contained more meaningful information that I was able to use to inform my future clinical decisions. Although the collection of patient outcomes helped me to gain a deeper understanding of the strengths and weaknesses of my clinical practice, I continued to struggle with overcoming the barrier of having confidence in the clinical decisions I was making. Overcoming this barrier has been a continuous process and struggle; however, I have found that as my commitment to and belief in each of the treatment paradigms I am utilizing increases, my patient outcomes improve and my confidence as a clinician grows. I believe that this has been the hardest barrier to overcome during my clinical residency; but I also believe that it has resulted in a great deal of personal growth.

The barriers I faced and overcame during my clinical residency helped shape who I have become as a clinician. I now see myself as a scholarly practitioner who has accepted the changes in my clinical practice that are necessary for my growth as a clinician. Although I have not reached the level of advanced practice that I hope to achieve in the future, I believe that my patient outcomes have improved throughout my time in the DAT program—as I will demonstrate through the following analysis of and reflection on those outcomes.

Data Analysis, Results, and Reflections

Fall I

As the Summer I on-campus immersion session in the DAT program came to a close, I felt confident in my abilities and was excited to begin a new chapter in my professional career. The coursework that I had completed during the summer session introduced me to a new philosophy of patient care that focused on treating patients through a holistic, patient-centered approach versus the pathoanatomical approach I had previously adopted. I was determined to become a scholarly clinician who studied his practice through the collection of patient outcomes and who generated and disseminated evidence that supported the changes I made in my patient care.

To begin the process of becoming the scholarly clinician I desired to become, I began, in the fall semester, to collect patient outcome measures in my clinical practice. I also began to explore new treatment paradigms that I had been exposed to over the recent on-campus summer session. I believe that one of the strengths of the DAT program is that the faculty is not only committed to educating students on how to change their clinical practice and become scholarly practitioners, they also invest resources into ensuring that students have the tools necessary to make significant changes and improvements in their clinical practice. The DAT faculty does this by exposing students to alternative treatment paradigms that are not often utilized in the athletic training profession. Students in the DAT program then have the opportunity to generate evidence on the effectiveness of these treatment paradigms by studying the effects of the treatments as they are incorporated into their clinical practices. My goal for the Fall I semester was to explore how some of these treatment paradigms would fit into my clinical practice. In particular, I wanted to focus on utilizing the Mulligan Concept (MC) (Mulligan, 2010), Positional Release Therapy (PRT) (D'Ambrogio & Roth, 1997), Total Motion Release® (TMR®), and reactive neuromuscular training (RNT) in my clinical practice.

I had the opportunity to participate in a MC course and a PRT course during my first summer in the DAT program, so I felt confident in my ability to immediately incorporate those treatments into my clinical practice. In addition to the MC and PRT, I chose to focus on incorporating TMR and RNT into my clinical practice due to the immediate, positive results I personally saw from these treatments and due to my interest in further studying the effect both TMR and RNT have on patients with apparent hamstring tightness.

The MC is a manual therapy technique that utilizes various joint mobilizations to address subtle joint misalignments, known as *positional faults* (Mulligan, 2010). When performed correctly, the MC is a pain-free treatment that results in an immediate, positive change in a patient's pain and dysfunction (Mulligan, 2010). During the MC course I participated in, I saw these immediate changes. Due to the common occurrence of patients presenting with joint pain and dysfunction within my clinical setting, I felt that the MC would have a positive impact on my clinical practice.

In addition to a significant number of patients presenting with joint pathology, I also saw a large number of patients who complained of muscle pain and tightness. After being introduced to PRT during the summer semester, and after personally experiencing the immediate relief in muscle pain and tightness following a PRT treatment, I felt that incorporating PRT into my clinical practice to address muscle, tendon, and fascia pain would benefit my patients. Treatment with PRT begins with the clinician identifying specific “trigger” or “tender” points, found through palpation in the muscle or in the fascia. The clinician then positions the body region in a position of comfort that allows the tissue to relax, resulting in a reduction in pain and/or tightness (D’Ambrogio & Roth, 1997).

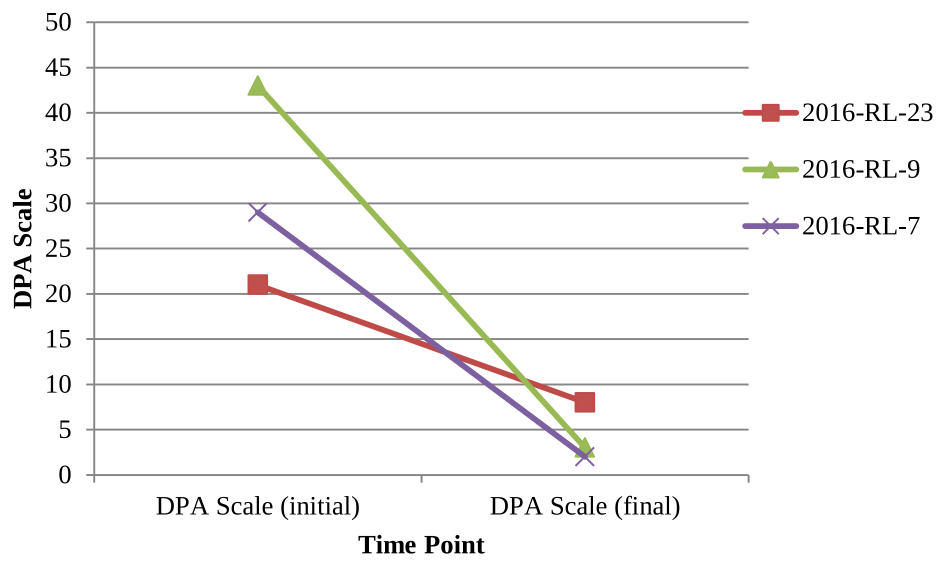
By incorporating both the MC and PRT into my clinical practice, I felt that I had found the resources necessary to treat a majority of the local pain and dysfunctions with which my patients presented. In addition to treating local pain and dysfunction in my clinical practice, I also recognized the need to include treatment paradigms that addressed dysfunctions in other body regions not directly associated with a patient’s primary complaint. I chose to focus on utilizing TMR® and RNT to address this need.

Total Motion Release® addresses dysfunctions throughout the body by evaluating and treating movement imbalances through a unique system that focuses on moving the body in directions of ease and comfort (Baker, n.d.). Reactive neuromuscular training is the process of retraining normal motor-control patterns through the introduction of purposeful, external perturbations designed to reflexively stimulate proper motor control patterns (Loutsch, Baker, May, & Nasypany, 2015; Voight & Cook, 1996). Upon incorporating each of the aforementioned treatment paradigms into my clinical practice, I was excited to see my patient care improve. Although I had had some success using each of these treatment paradigms during the Fall I semester, my lack of consistency and organization in collecting patient outcome measures early in the DAT program had limited the quality of the data I had been able to obtain and analyze during that time.

Of the new treatment paradigms I wanted to utilize during the fall semester, I believed the MC would have the greatest immediate impact on my clinical practice. One of the first patients (2016-RL-7) I recall having successfully treated using the MC in the fall semester was a women's volleyball player who sustained a grade-1 inversion ankle sprain. The patient had injured her ankle during practice the previous day, when she landed on another player's foot after executing a jumping block. The patient reported 2/10 pain at rest; the worst pain level she recalled over the previous 24 hour period was 4/10 on the Numeric Pain Rating Scale (NPRS), which is a valid and reliable measure of a patient's reported pain level on an 11-point (0-10) scale, with a score of zero being equal to "no pain" (Williamson & Hoggart, 2005). The patient reported an average score of 4.67/10 on the Patient Specific Functional Scale (PSFS) when performing the activities of running (3), jumping (4), and going up and down stairs (7). The PSFS is also an 11-point (0-10) scale (0 = "unable to perform activity"; 10 = "able to perform activity at pre-injury level"); however, where the NPRS measures pain level, the PSFS measures a patient's reported function on specific activities that they identify as being "limited" due to his or her injury (Stratford, Gill, Westaway, & Binkley, 1995). In addition, my patient reported a score of 29/64 on the DPA scale and a score of 71/100 on the LEFS.

After learning about the success other DAT students had using the MC to treat lateral ankle sprains (LAS), I chose to begin treating this patient with the MC. I chose to perform the LAS mobilization with movement (MWM) technique, which involves performing a posterior, superior, lateral glide to the distal fibula while the patient performs ankle inversion with overpressure applied by the clinician (Mulligan, 2010). I performed 3 sets of 10 repetitions with overpressure. Following treatment, the patient reported a current pain score of 0 on the NPRS. I reinforced the mobilization by performing the MC taping technique for an LAS. Over the next two days, I continued to treat the patient using the MC. By the third treatment day, the patient was pain-free and had returned to full participation in her sport. At a two-week follow-up appointment, the patient reported 0/10 pain on the NPRS, 10/10 function on the PSFS, 2/64 on the DPA scale, and 99/100 on the LEFS. Although I neglected to collect outcome data on the patient when she returned to participation in her sport, her success at returning to full participation after three treatments and only four days following injury, coupled with positive patient outcomes data at the two-week follow-up, suggests that treatment utilizing the MC was successful for this patient. Prior to my introduction to the MC, I would have expected similar outcomes following a grade-1 ankle sprain to occur over the course of one to two weeks of treatments consisting of ROM and proprioceptive exercises; however, by incorporating the MC, I was able to reduce the patient’s time away from her sport by around 50%.

I continued to use the MC as my “treatment of choice” for LAS during the fall semester, and I treated three additional patients who were diagnosed with grade-2 lateral ankle sprains. One of the patients I treated (2016-RL-22) was non-compliant and failed to return to the AT clinic after his third treatment session; therefore, outcome data for this patient is not included in the data analysis. The average initial DPA scale score was 28.3, and the average final DPA scale score was 4.33 (Figure 3.1), resulting in an average decrease of 24 points on the DPA scale, which exceeds the minimal clinically important difference (MCID) of 9 points for acute injuries on the DPA scale (Vela & Denegar, 2010). In regards to the patients' reported function on the LEFS, the average initial score was 59.0, and the average final LEFS score was 94.3 (Figure 3.2), resulting in an average increase of 35.3 points, which also exceeds the reported MCID of 9 points on the LEFS (Binkley, Stratford, Lott, & Riddle, 1999). In addition to the positive patient-reported outcome measures, the average number of treatments (4.7) and average number of days from injury to full participation (8.33) suggest that treatment with the MC for patients with LAS was successful and exceeded the two- to four-week recovery period I had expected in my previous patient care. The results also exceed those reported in the literature, in which authors report patients return within four weeks and mechanical stability does not occur for at least six weeks following injury (Hubbard & Hicks-Little, 2008). However, my inconsistent data collection prevented me from gleaning meaningful information, such as reported levels of pain and function following a single treatment and the effect treatment had on clinical measures of strength and range-of-motion (ROM).



Key: DPA- Disablement in the Physically Active

Figure 3.1. Fall I Initial and final DPA scale scores: Treatment of LAS using the Mulligan Concept.

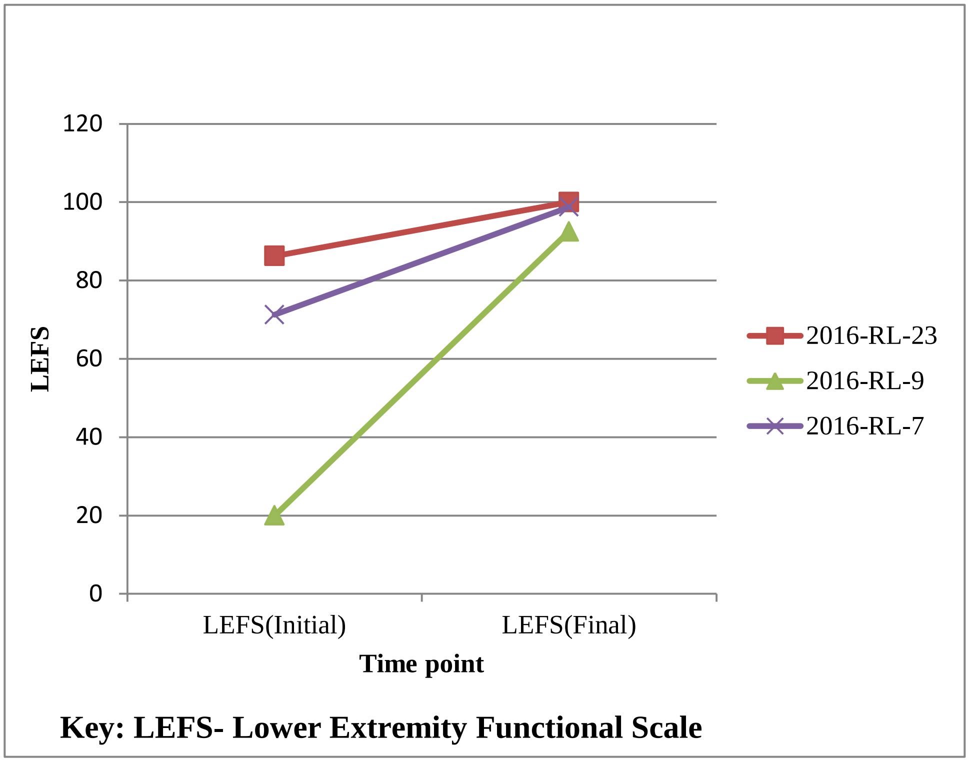


Figure 3.2. Fall I Initial and final LEFS scores: Treatment of LAS using the Mulligan Concept.

In addition to utilizing the MC in the fall semester, I also began to incorporate TMR, RNT, and PRT into my clinical practice. Unlike my experience with incorporating the MC LAS technique into my clinical practice, I struggled with understanding how and when to incorporate TMR, RNT, and PRT into my clinical practice. I found myself guessing on which treatment to use, which led to a “shotgun” approach to patient care: I would use multiple treatments at once, hoping to have success with at least one of the treatments.

One example of this haphazard approach is that of a patient of mine (2016-RL-25) who presented with a chief complaint of left hamstring pain following conditioning drills. Prior to beginning the DAT program, I would have evaluated the patient and then classified him as having a hamstring strain. However, based on his response to treatment, I classified the injury as a muscle spasm. The patient reported current pain on the NPRS of 6/10, and after one treatment session that included PRT and TMR, the patient reported 0/10 for pain. Although I was successful in resolving the patient's pain, I was unable to identify which treatment reduced his symptoms. If I would have collected post-treatment pain levels after the PRT treatment, I would have been able to identify if PRT had been successful and if TMR was necessary. Unfortunately, the results from the initial treatment did not last, and the patient reported a return of pain on his next visit. Again, I treated with PRT and TMR, and I also added RNT as a third treatment. Once more, I had success reducing the patient's pain, and the patient continued to report a reduction in pain at his next follow-up appointment; however, I was unable to identify which of the three treatments was successful. Although my patient was satisfied with the results of the treatments, my shotgun approach did not allow me to evaluate the effect each individual treatment had on the patient—which would have helped inform future clinical decisions.

During the fall semester, I also had the opportunity to begin collecting data on patients who presented with apparent hamstring tightness (AHT). This data was used to help inform a multi-site research study on AHT. I collected pre- and post-treatment ROM measurements on five patients who presented with complaints of hamstring tightness. Each patient was treated with one of the following treatment paradigms: a) RNT, b) TMR, c) MC, d) PRT, or e) neurodynamics (NDS). The immediate effect of each treatment on ROM measurements was recorded (Table 3.1). Through this experience, I learned that developing and implementing a multi-site research study requires a great deal of preparation and presents a number of challenges. One of the biggest challenges in conducting multi-site research is ensuring that the methods for the research study are clear and consistent across all research sites. Our research group identified several inconsistencies in our methods, which prevented us from analyzing the data we collected. As a result we realized the importance of conducting reliability testing to ensure reliable data across research sites. Additionally, this experience allowed me to see that in order to compile information that will help inform future clinical decisions, pre- and post-treatment data on each treatment provided must be gathered. Our study also allowed us an opportunity to reconsider the breadth of our research study, ultimately leading us to identify a narrower focus for our study as we moved forward.

During the Fall I semester, I collected patient outcome measures on a total of 30 patients; however, when I reexamine that data, it is clear that a majority of it lacked significant meaning. The first mistake I made was not taking the time to reflect on my previous clinical practice or identify a local problem that I wanted to study through the collection of patient outcome measures. By not doing this, I found myself collecting data on all of my patients, which quickly became overwhelming and led to inconsistencies in the data I collected. For example, with one patient (2016-RL-3), I collected data at an initial visit and the first follow-up appointment, which came four days later. However, I failed to collect additional patient outcome measures for another 17 days, even though the patient was treated on multiple occasions during that time. In addition, I lacked the confidence to know when to utilize new treatment paradigms in my clinical practice. Therefore, I often found myself combining multiple treatment paradigms in the same treatment session, which did not allow me to gain a deeper understanding of the effect each individual treatment had on my patients. I experienced moments of success during the fall semester, and I learned more about the treatment paradigms I was using; but because of my lack of planning and implementing the changes I wanted to make in my clinical practice, I missed several learning opportunities.

Table 3.1.

Apparent Hamstring Tightness Pilot Study Data

Patient ID		2016-RL-15	2016-RL-19	2016-RL-26	2016-RL-28	2016-RL-30
Gender		Female	Male	Male	Male	Female
Treatment		RNT	TMR®	PRT	Mulligan	NDS
FFD	Pre	1 cm	23 cm	13 cm	20 cm	17 cm
	Post	-3.5 cm	14.5 cm	10 cm	12 cm	11 cm
Right ASLR	Pre	60^o	45^o	56^o	80^o	57^o
	Post	75^o	63^o	53^o	88^o	66^o
Left ASLR	Pre	58^o	48^o	42^o	79^o	60^o
	Post	80^o	66^o	55^o	86^o	70^o
Right PSLR	Pre	67^o	57^o	52^o	85^o	60^o
	Post	83^o	68^o	64^o	96^o	66^o
Left PSLR	Pre	70^o	57^o	49^o	83^o	60^o
	Post	84^o	62^o	60^o	90^o	72^o
Right AKE	Pre	30^o	51^o	37^o	27^o	40^o
	Post	11^o	40^o	40^o	26^o	39^o
Left AKE	Pre	34^o	56^o	36^o	24^o	41^o
	Post	18^o	32^o	40^o	17^o	42^o
Right Slump	Pre	Positive	Positive	Positive	Negative	Negative
	Post	Positive	Negative	Positive	Negative	Negative
Left Slump	Pre	Positive	Positive	Positive	Positive	Positive
	Post	Positive	Negative	Positive	Negative	Negative
Sit and Reach	Pre	0 cm	26.5 cm	11.5 cm	16.5 cm	19 cm
	Post	-4 cm	16.5 cm	11 cm	13.5 cm	16 cm

Note. Patient ID – patient identification number; RNT – reactive neuromuscular training; TMR® – Total Motion Release®; NDS – neurodynamic sliders; FFD – finger-to-floor distance; ASLR – active straight leg raise; PSLR – passive straight leg raise; AKE – active knee extension

Spring I

During the Spring I semester, I continued to advance my clinical practice; however, my persistent lack of confidence in my clinical skills prevented me from making the significant improvements I had hoped to make. Over the course of the semester, I began to treat more of my patients through a regional-interdependence (RI) approach versus a more traditional, pathoanatomical approach (Sueki, Cleland, & Wainner, 2013; Wainner, Whitman, Cleland, & Flynn, 2007). An RI approach involves evaluating and treating patients who present with pain in a manner that allows the clinician to consider other areas and systems of the body that may be causing or contributing to the patient's symptoms (Sueki et al., 2013; Wainner et al., 2007).

The Selective Functional Movement Assessment (SFMA) is a system designed through an RI perspective that enables clinicians to identify movement dysfunctions which may be contributing to a patient's painful condition (Cook, 2010). Although I was introduced to the SFMA during the Summer I semester, I failed to recognize its usefulness until I attended an SFMA course at the end of the Fall I semester. I believe that attending this course increased my confidence in the SFMA, thereby prompting me to use the system in the spring. The course also helped me to be able to treat patients through an RI approach—something that I had not done in my previous clinical practice.

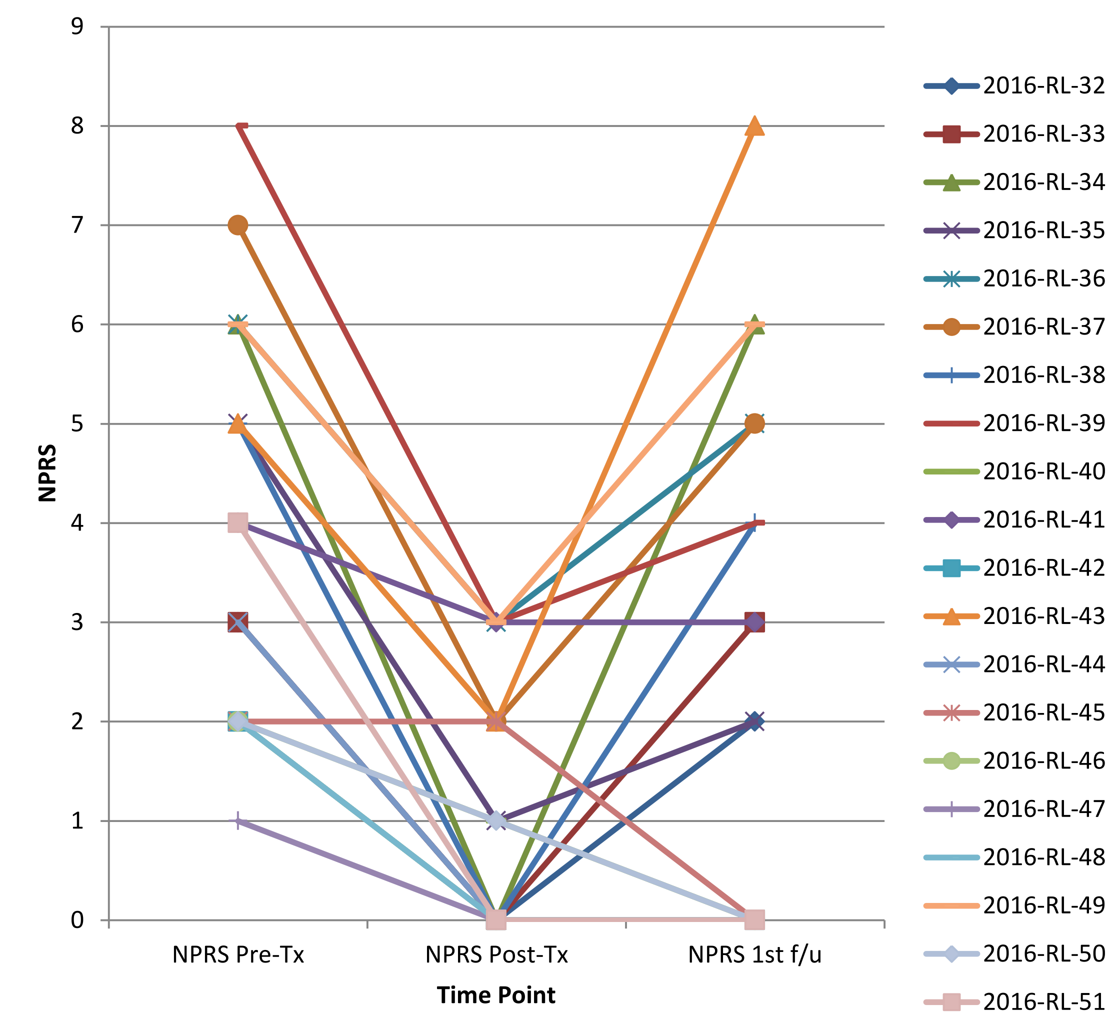
Although the use of an RI approach brought improvement to my clinical practice, I still had areas in which I lacked confidence and growth, specifically in my commitment to gaining a deeper knowledge and understanding of any one treatment paradigm. By failing to do so, I continued to move from one treatment to the next; therefore, I believe my patient outcomes were not as favorable as they could have been if I had focused on one or two treatment paradigms and had gained a better understanding of the effect each treatment had on my patients. I believe this better understanding would have allowed me to identify patient patterns and would have led to better informed treatment decisions.

An example of a successful case in which I utilized the SFMA and an RI approach involves a patient (2016-RL-48) who was seen in the clinic with a chief complaint of left (non-dominant) shoulder pain. The patient was a softball player who reported a history of posterior shoulder subluxations that occurred when batting—particularly when swinging and missing at an outside pitch. During the initial exam, the patient reported a current pain level of 2/10 on the NPRS and a function-with-swinging of 5/10 on the PSFS. The patient's clinical exam was consistent with supraspinatus tendinopathy and posterior instability. As part of the exam process, I performed the SFMA and found a glenohumeral and a core stability motor control dysfunction (SMCD). I addressed the patient's core SMCD using an RNT technique (posterior to anterior force at the abdomen). Following a single RNT treatment session, the patient reported no pain (0/10 NPRS) and normal function (10/10 PSFS) with swinging. The patient returned to normal activity and remained symptom-free at one-week and one-month follow-ups.

After reflecting on this patient's case and reviewing the literature on the topic of posterior instability when batting, I found an article that reported on a condition called "batter's shoulder," which occurs when a patient develops posterior shoulder instability, sometimes as a result of swinging and missing at outside pitches (Kang, Mahony, Harris, & Dines, 2013; Wanich, Dines, Dines, Gambardella, & Yocum, 2012). The only study that had been conducted that looked at the results of treatment on patients with batter's shoulder reported that 12 out of 14 patients failed a 10-week rehabilitation program and required surgery to repair the posterior labrum (Wanich et al., 2012). In contrast, my patient (2016-RL-48) was able to return to normal sport activity following a single treatment with RNT. I believe that this case highlights the growth and progress I made during my first year in the DAT program and illustrates the success I can achieve when incorporating an RI approach into my patient care philosophy. An RI approach allows me to identify treatments that can positively affect motor control dysfunctions along with additional dysfunctions not directly related to a patient's local complaints.

In addition to my focus on the SFMA and on incorporating an RI approach into my patient care, I also studied the effect of treating a patient's pain on the initial visit and the effectiveness of the treatment on reducing pain during the patient's first follow-up visit. My goal was to achieve a mean decrease of more than two points in reported current pain levels on the NPRS following a single treatment session, which represents an MCID on the NPRS (Farrar, Young Jr, LaMoreaux, Werth, & Poole, 2001). I collected current pain on the NPRS data for 20 patients (Figure 3.3) at 3 time points (pre-treatment, post-treatment, first follow-up), and the data collected on all patients was during the day prior to any sport participation. A repeated measures ANOVA was conducted to evaluate the effect of treatment on pain across the three time points. The results of the ANOVA indicate a significant time effect (Wilks' Lambda = 0.19, $F(2, 18) = 37.3$, $p < 0.001$, $\eta^2 = 0.81$). Follow-up comparison indicated a significant difference between pre-treatment and post-treatment pain scores (mean difference = 2.8, $p < .001$, 95% CI: 2.0, 3.6) and between pre-treatment and first follow-up pain scores (mean difference = 1.5, $p < .001$, 95% CI: 0.8, 2.2).

The significant decrease in reported pain level found between the pre-treatment reported pain level (3.9 ± 2.0) and post-treatment reported pain level (1.1 ± 1.3) suggests that the treatments provided were successful at reducing patients' pain level during the initial treatment. In addition to achieving a statistically significant mean difference score of 2.8 points, which is above the MCID of 2 points on the NPRS, the effect size (0.81) suggests that the treatment accounts for 81% of the variance in pain scores across all time points. The results also indicate a statistically significant decrease in current pain values from the pre-treatment measure on the initial visit (3.9 ± 2.0) to the pre-treatment measure on the first follow-up visit (2.4 ± 2.6). However, the decrease of 1.5 in pain scores at the first follow-up does not represent an MCID on the NPRS; therefore, it is not clinically meaningful. The analysis also revealed that the patients' reported pain level significantly increased between post-treatment and the first follow-up appointment (mean difference = -1.3, $p < 0.018$, 95% CI: -2.4, -0.2), which suggests that the treatments effect did not last.



Key: NPRS- Numeric Pain Rating Scale

Figure 3.3. Spring I change in current pain on the NPRS after first treatment session and at first follow-up appointment.

Although the data suggests that my initial treatments were effective at reducing my patients' pain, the results indicate that the treatment effects did not last, because the mean reported pain level at the first follow-up (2.4 ± 2.6) was higher than the mean reported pain level post-treatment (1.1 ± 1.3). However, further analysis indicated that a majority of the patients (N = 11) did maintain or improve in their reported pain levels on the NPRS between post-treatment and the first follow-up appointment. Further analysis also indicated that a majority of patients (N = 11) maintained an MCID of improvement between their initial NPRS score and their NPRS score at their first follow-up. Therefore, my initial treatment was successful at producing a meaningful change in 55 percent (N = 11) of my patients; but my expectations were that a greater majority of my patients would have had more meaningful change. I believe that the lack of producing meaningful change in a greater percentage of my patients was as a result of not properly classifying patients and not matching appropriate treatments to a patient's classification. As I took a closer look at the data, I saw that I had utilized three or more different treatment paradigms on a majority (N = 6) of the patients who did not achieve an MCID on current pain levels during their initial visit (N = 9). In contrast, of the patients who did achieve an MCID on current pain levels (N = 11), only one patient received treatment using three or more different treatment paradigms. Following this analysis, it became clear to me that if I were going to identify appropriate treatment interventions for my patients and avoid the "shotgun" approach to patient care, I needed to improve my evaluation skills, my approach to patient classification, and my clinical decision-making process. I also realized that I lacked confidence in my ability to achieve consistent success with utilizing only one treatment paradigm at a time. I believe that this lack of confidence was a result of not committing myself to studying the effects and deepening my understanding of a single paradigm.

A specific example of my lack of commitment to a specific paradigm can be seen in my treatment of a patient (RL-2016-45) who presented with a chief complaint of hamstring pain and tightness. During the initial treatment session, I used four different treatment paradigms (PRT, TMR, NDS, RNT) to reduce the patient's chief complaints. At the first follow-up visit, I continued to treat the patient using multiple treatment paradigms but achieved limited success. While in the process of writing a blog post regarding my experience with this patient and reflecting on the care I had been providing, I began to see that my failure to identify a specific treatment for this patient was based on not having completed a thorough patient evaluation or classification. On the third visit with this patient, one week following the initial treatment session, I re-evaluated the patient. Due to the positive results of his NDS test, I focused treatment and home exercises on the use of NDS sliders. Five days later, the patient's symptoms completely resolved and his ROM was equal, bilaterally. Unfortunately, because I had not properly classified this patient during his first treatment session, I was unable to identify an appropriate treatment intervention. This, in turn, led to poor clinical decision-making. This realization, which came as a result of this patient experience, represents a turning point in my time in the DAT program.

Following this turning point, I was presented with two additional patients who complained of hamstring tightness (RL-2016-46, RL-2016-51). I treated both of these patients with TMR; however, based on their clinical presentations and evaluations, each patient was treated with a different TMR hamstring technique.

The first patient (RL-2016-46) presented with a chief complaint of pain and weakness in his left hamstring. His clinical evaluation revealed decreased hamstring strength on his left side, but equal ROM when compared bilaterally. Patient-reported outcome measures that were collected included current pain on the NPRS (2/10), function using the PSFS (6/10), and disablement using the DPA scale (30/64). Because the patient did not have complaints of tightness, I began his TMR® evaluation by determining if there was a difference between his right and left legs on the Modified TMR® Mulligan (Dalonzo-Baker, n.d.). I found a 30% difference between sides. The patient performed 3 sets of 10 repetitions of the Modified TMR® Mulligan movement. Following this treatment, the patient reported no difference between sides, and his hamstring strength was equal, bilaterally. The patient performed this technique at home once each day for the next four days. When he returned to the clinic for his first follow-up visit, he reported no pain on the NPRS (0/10), normal function on the PSFS (10/10), and decreased disablement on the DPA scale (6/64). Based on these outcomes, the patient was discharged and returned to full sport participation without a return of symptoms.

The second patient (2016-RL-51) was also treated with TMR; however, based on his chief complaint and clinical presentation of hamstring tightness, he was treated with the TMR forward-flexion trunk-twist technique for hamstring tightness. Following the TMR treatment, the patient's ROM measurements improved and was nearly equal, bilaterally (Figures 3.4, 3.5, 3.6). The patient performed the TMR technique once each day on his own until he returned to the clinic for his first follow-up visit, four days later. At this time, he reported 0/10 pain on the NPRS, and all ROM measurements improved and exceeded his contralateral limb (Figures 3.4, 3.5, 3.6). Similar to the first patient, this second patient was able to return to full sport participation, and his symptoms did not return.

I believe that these two patient encounters demonstrate my growth as a clinician and illustrate the success that can be achieved when a patient is matched with an appropriate treatment. I was successful at identifying a single treatment intervention to use. Doing so allowed me to study the effect the treatment had on my patients while providing me with data to inform future patient care.

As the spring semester came to a close and the second on-campus summer semester approached, it was clear to me that my clinical practice had improved over the past year. However, I knew that there were still areas in my practice in which I needed to improve if I were going to become an advanced practitioner. In particular, I needed to invest my time in advancing my knowledge and skills in one or two specific treatment paradigms. With this in mind, my goal for the upcoming summer and fall semesters was to focus on the MC. I hoped to gain a deeper knowledge of the paradigm by attending an MC continuing-education course during the summer, and I planned to study the effect that the MC had on my patient care during my upcoming clinical residency.

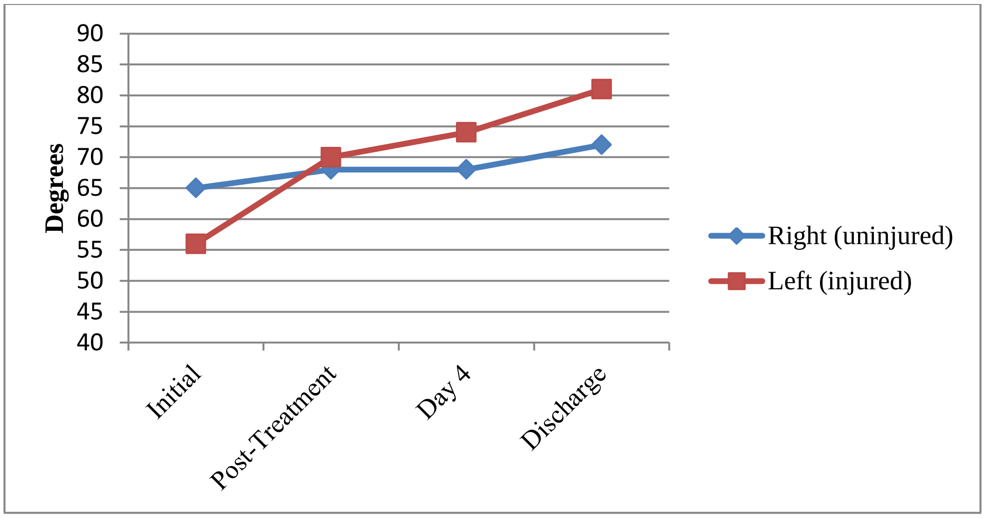


Figure 3.4. Spring I Patient #2016-RL-51: Active straight leg raise range-of-motion measures following TMR treatment.

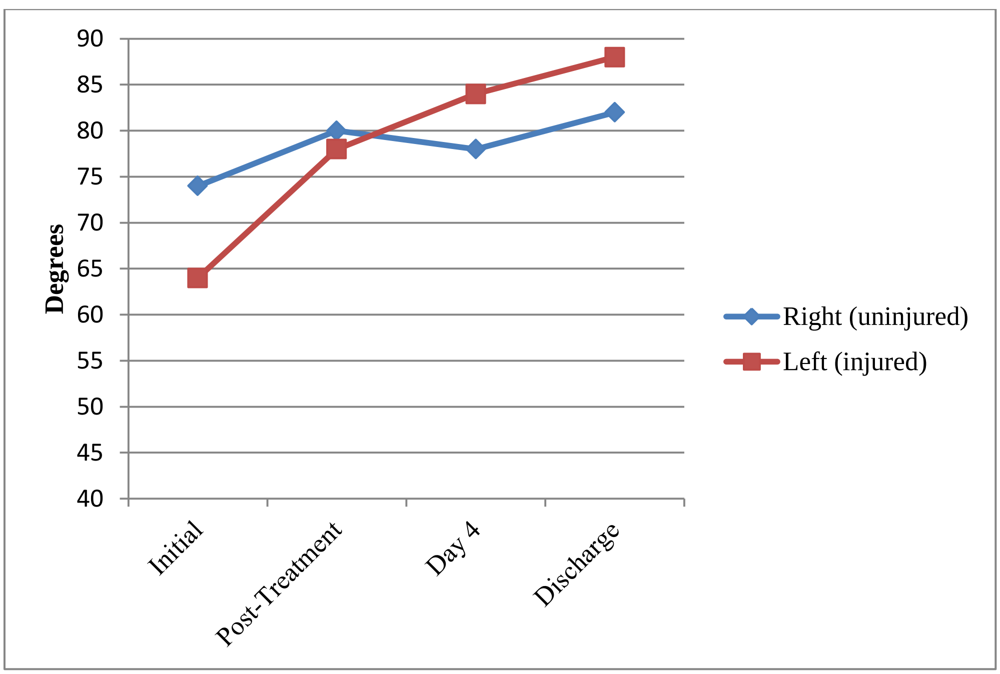


Figure 3.5. Spring I Patient #2016-RL-51: Passive straight leg raise range-of-motion measures following TMR treatment.

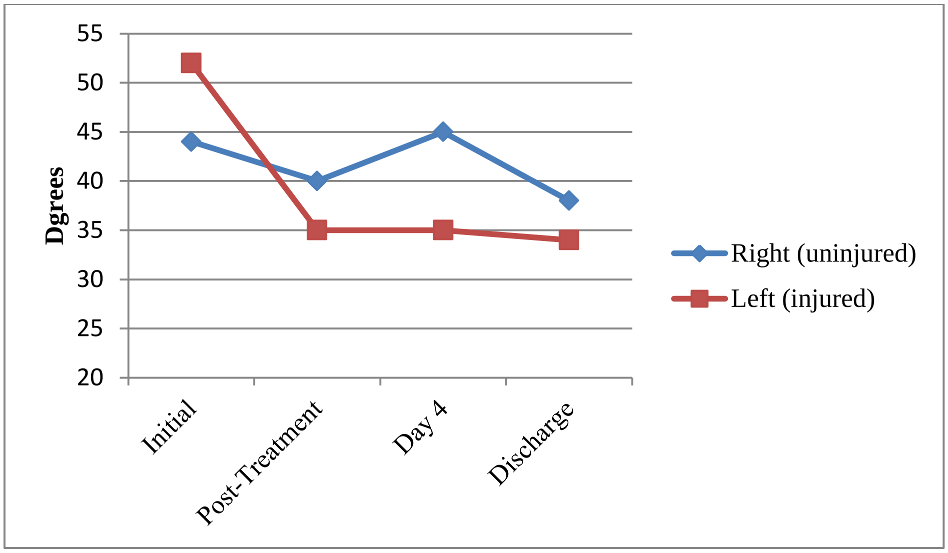


Figure 3.6. Spring I Patient #2016-RL-51: Active knee extension range-of-motion measures following TMR treatment.

Fall II

As the Summer II semester came to a close and I prepared to return to my clinical residency for the Fall II semester, I felt that my focus had been on obtaining a breadth of knowledge in many different areas. As I prepared to begin my second year, I knew I needed to focus on understanding each of the paradigms at a deeper level. I was motivated to make continued progress toward becoming a scholarly practitioner. To that end, my goal for the semester was to deepen my understanding of the MC and study the effect it had on my clinical practice. In addition, I planned to participate in an *a priori*-designed multi-site research study on the effect that NDS sliders had on patients with medial tibial stress syndrome (MTSS).

Upon returning to my clinical residency in the fall, I was immediately presented with an opportunity to begin my study of the effect of the MC on patients in my clinical practice. One of the first patients (RL-2016-61) I treated in the fall was a quarterback who presented with right (dominant) shoulder pain consistent with shoulder impingement and biceps tendinopathy. The patient's pain had begun 10 days prior to my initial evaluation, at which time he reported a current pain level on the NPRS of 3/10 and a "worst pain" level of 8/10 when throwing. During the evaluation process, the patient's most painful movement was determined to be forward flexion, so a MC mobilization with movement (MWM) was performed. Because an anterior MWM relieved the patient's pain with forward flexion, the patient was treated with the MC, and 3 sets of 10 repetitions with overpressure were performed. Following treatment, the patient reported 0/10 pain on the NPRS at rest and with forward flexion. The patient returned to the clinic the next day for a follow-up appointment and reported a current pain level of 1/10 and a "worst pain" level (when throwing) of 5/10 on the NPRS. Because the patient's chief complaint was pain during his throwing motion, I decided to add an MWM while the patient performed his throwing motion, which resolved the patient's symptoms. The patient performed 3 sets of 10 repetitions. Following treatment, he reported 0/10 pain on the NPRS at rest and with throwing. The patient was seen for a third time two days later and reported a current pain level of 0/10 and a pain level of 2/10 when throwing. The MWM treatment was repeated, and the patient was able to return to normal activities after the third treatment. He continued to report 0/10 pain on the NPRS at a two-week follow-up appointment.

During the fall semester, I had the opportunity to treat two additional patients (RL-2016-69, RL-2016-76) who presented with signs and symptoms consistent with shoulder impingement and long-head-of-the-biceps tendinopathy. Both patients were treated exclusively with the MC, which resulted in immediate reduction of pain and increased function. Both patients were also able to return to full participation after two treatment sessions, and they remained pain-free at one-week follow-up appointments. Patient-reported outcome measures on each of the three patients (Table 3.2) with shoulder pain whom I treated during the Fall II semester indicate that treatment using the MC was successful at improving each patient's function and at reducing their current pain levels. Each patient achieved an MCID of at least two points on the PSFS (Horn et al., 2012) and at least two points on the NPRS (Farrar et al., 2001) between the initial visit and the first follow-up as well as between the initial visit and discharge. The benefits of utilizing the MC for the treatment of impingement and biceps tendionopathy, in these cases, far exceed those reported in the literature. For example, in a recent randomized-control trial, patients who were diagnosed with shoulder impingement, and who were provided traditional therapeutic exercises aimed at increasing strength and ROM of the affected shoulder, did not have a clinically significant decrease in resting pain levels as reported on the visual analog scale after three weeks of treatment (Marzetti et al., 2014).

Table 3.2

Fall II Patients 2016-RL-61, 2016-RL-69, 2016-RL-76 Patient Reporte*d Outcomes Data – Treatment of Shoulder Pain U****sing the Mulligan Concept***

Pt. #	NPRS_initial	NPRS_post	NPRS_d/c	DPAS_Initial	DPAS_d/c	#Txs
2016-RL-61	3	0	0	24	10	3
2016-RL-69	3	0	0	30	0	2
2016-RL-76	3	0	0	24	0	2

***Note*. Pt. # – Patient identification number; NPRS_initial – initial Numeric Pain Rating Scale; NPRS_post – Numeric Pain Rating Scale post-treatment; NPRS_d/c – Numeric Pain Rating Scale at discharge; DPAS_initial – Initial Disablement in the Physically Active scale; DPAS_d/c – Disablement in the Physically Active scale at discharge; #Txs – number of treatments until discharge**

In addition to the three patients with shoulder pain during the fall semester, I collected patient outcomes on nine more patients that I treated using the MC. Areas treated include the shoulder (N = 3), hip (N = 3), foot (N = 3), ankle (N = 2), and shin (N = 1).

Patient-reported outcome measures collected and analyzed include current pain on the NPRS before and after each treatment session and at discharge, DPA scale, global rate of change (GRoC), and number of treatments until discharge. My research questions regarding my patient outcomes when using the MC included the following: a) What effect does one treatment utilizing the MC have on patient-reported pain level?; b) What effect does treatment utilizing the MC have on patient-reported pain level, DPA scale scores, and GRoC scores at discharge?; and c) What is the average number of treatment sessions until discharge when utilizing the MC?

To answer the questions regarding the effect of treatments that utilized the MC on patient-reported pain levels, a repeated measures ANOVA was conducted on the NPRS current pain scores collected at all three time points (pre-treatment, post-treatment, discharge). The results indicate a significant time effect (Wilks Lambda = 0.036, $F(2, 9) = 119.25$, $p < 0.001$, $\eta^2 = 0.964$). A follow-up comparison indicated a significant difference between pre-treatment and post-treatment reported pain levels (mean difference = 2.73, $p < 0.001$, 95% CIs: 1.93, 3.53) and between pre-treatment and discharge pain levels (mean difference = 2.82, $p < 0.001$, 95% CIs: 1.83, 3.81). The results of this analysis suggest that my treatment utilizing the MC was effective in immediately relieving my patients' pain levels. The results also demonstrate a positive effect on pain level at discharge. The mean difference scores between pre-treatment and post-treatment pain levels (2.73) and between pre-treatment and discharge (2.82) both exceed the reported MCID of 2 points on the NPRS (Farrar et al., 2001), suggesting that the treatment was successful at producing clinically meaningful change in my patients. The large effect size (0.964) also indicates that the treatment had a clinically meaningful effect on reducing patients' reported pain levels.

In addition to analyzing the effect the MC had on a patient's reported pain level, I analyzed the effect that treatment utilizing the MC had on the DPA scale at discharge. For this analysis, a paired t-test was run between the initial DPA scale score and the DPA scale score at discharge. A total of 11 patients had DPA scale scores at discharge. There was a significant mean change in DPA scale scores between the initial visit and discharge (mean difference = 13.455 ± 14.264, p = .011, 95% CI: 3.872, 23.037). The Cohen's *d* value of 1.3 suggests a high effect size (Hurley, Denegar, & Hertel, 2011) for the treatment, and the mean change of 13.455 is above the reported MCID of 6 points for chronic conditions and 9 points for acute conditions (Vela & Denegar, 2010). Therefore, the MC had a significant and clinically meaningful effect on patients' self-reported disablement as measured using the DPA scale.

The final analysis performed on the effect of the MC included the use of descriptive statistics. These statistics were used to analyze the patient-perceived benefits from treatment with the MC and to determine the average number of treatments until discharge. For the 11 patients who were discharged from treatment, the mean number of treatments was 2.45 ± 0.82. The mean GRoC score at discharge was 5.55 ± 2.622, which lies between the GRoC values of "quite a bit better" and "a great deal better." Only one patient reported a negative GROC score. Of the patients who reported a positive GROC score (N = 10), 50% reported the top score of 7, which is identified by "a very great deal better," 30% reported a score of 6 ("a great deal better") and 20% reported a score of 5 ("quite a bit better"). Overall, these data indicate that my ability to match patients with appropriate treatments that utilize the MC led me to successfully treat a variety of conditions in the clinical setting. The low number of treatments (2.45 ± 0.82) and days to discharge (5.5 ± 2.2) indicates that the MC can be used to help patients quickly return to normal activity levels.

Focusing on the MC and using it as part of my evaluation and treatment process has greatly enhanced my clinical practice. Prior to my enrollment in the DAT program, I would have relied on therapeutic modalities and exercise, and I would have expected improvement to occur over the course of several weeks versus immediately—which was the case in my new patient care. The change in my expectations is a reflection of the change in my patient care philosophy. Previous to this change, I had evaluated and treated patients through a pathoanatomical lens and had always focused on treating what I believed was the anatomical dysfunction that was causing a patient's pain. Therefore, my evaluations and treatments were localized to the site of pain, and my goal was to promote the natural healing process. I now view my patient care through an RI perspective, in that I no longer believe that all pain and dysfunction is the result of a local pathology. By changing my perspective, I no longer limit my evaluation and treatment options to those that assess and treat local anatomical structures. Consequently, I expect to see immediate results through treatment with paradigms such as the MC.

Along with my focus on utilizing the MC in my clinical practice during the fall semester, I also made a commitment to participate in multi-site research through an *a priori* study in which I collaborated with other members of my DAT cohort to research the effects that NDS sliders had on patients with MTSS. During the summer semester, members of our research team developed the methods of our study and decided to treat patients who presented with signs and symptoms of MTSS exclusively with NDS for a maximum of five visits. Our goal was to determine what effect NDS had on a patient's reported pain level and function.

Our group treated a total of eight patients who completed the study. Of the eight patients who were treated with NDS, no patient met the discharge criteria of reporting 0/10 pain on the NPRS and 10/10 function on the PSFS. In addition, the final results indicate that NDS sliders were not effective at treating patients with symptoms of MTSS, since none of the mean change scores on the patient outcome measures that were collected met an MCID. Although the results were not significant, our research team learned a lot about the process of conducting quality multi-site research. We learned that our methods were not consistent enough across members of our research team. We also learned that collecting clinician-oriented data throughout the study would have helped us to identify possible changes in ROM that occurred following treatment with NDS sliders. In addition, the presence of changes in ROM data would have helped to inform us of any effects that NDS sliders were having that may not have resulted in immediate relief of pain. Our group also determined that our decision to include all patients, regardless of testing positive or negative on a NDS screen, likely resulted in poorer outcomes, since those patients who test "negative" would not be classified into an NDS treatment. The decision to include these patients was a result of our desire to explore the effects of NDS sliders on all patients who present with signs and symptoms consistent with MTSS. In the future, I plan to participate in additional multi-site research studies and will take the lessons I have learned this fall and apply them to these future studies.

As I reflect back on the Fall II semester, I believe that it was my most successful semester and that it represents the greatest amount of growth during my time in the DAT program. My focus on deepening my understanding of the MC allowed me to advance my skills and confidence in this area, and my patient care improved, as a result. I also learned a great deal about scholarly practice and how important it is to eliminate the "shotgun" approach to patient care if a clinician is to better understand the effect a treatment has on a patient. In addition, I gained a greater appreciation for multi-site research and the challenges researchers must overcome in order to conduct high-quality multi-site research studies.

Final Reflection and Impact on Residency

Prior to enrolling in the DAT program, I was at a point of stagnancy in my career, and I felt complacent about my clinical practice. I still enjoyed treating patients, but I found myself performing the same treatments and exercises on most patients, with only modest results. The sense that something was missing in my clinical practice led me to decide to pursue a DAT degree. I wanted to advance my clinical practice while also advancing my academic degree, and I believed that the clinical residency component of the DAT program at the University of Idaho would provide me with that opportunity. As a result, my clinical residency site at Northwestern College has also been impacted by the changes I have made in my clinical practice.

During the first summer in the DAT program, I quickly realized that I had found what was missing in my clinical practice. I was exposed to several new treatment paradigms, and I was provided with the foundational knowledge to become an evidence-based practice (EBP) clinician and begin my journey towards becoming a practice-based evidence (PBE) clinician (Krzyzanowicz, May, & Nasypany, 2014).

The process of collecting patient outcomes and changing my approach to clinical practice was a much more involved learning process than I had originally expected.

Following the first summer in the DAT program, I felt that incorporating the new treatment paradigms that I had learned about into my clinical practice would be easy, and I would have immediate success when I returned to my clinic in the fall. I quickly learned, however, that simply wanting to change was not enough. I had to be committed to making the changes and to believing that my new approach to patient care would be successful. As I progressed through the DAT program, I remained committed to changing my practice; however, I did not always believe that the changes I was making were beneficial. I lacked confidence in the new treatment paradigms that I was using, and, as a result, the success I experienced in my clinical residency—especially during the first year of the DAT program—did not meet my expectations. I became too focused, early on, on the lack of success I was having with changing my clinical practice. This led to a lack of confidence in myself and in the new treatments that I was incorporating into my clinical residency.

I recognized this flaw during the Spring I semester, after a class discussion on patient care and the meaning of the patient outcomes that we were collecting in our clinical residencies. I realized that I was too invested in the results of the patient outcome measures. Instead, I needed to realize that the data I was collecting was not "my outcomes," but was simply *data* that I could use to help inform and improve my clinical practice. Following this eye-opening class discussion, I realized that I needed to invest more time into deepening my knowledge and understanding of the treatment paradigms I was utilizing. This, in turn, would increase my confidence in those paradigms, which would then lead to improved results. I decided to focus on deepening my knowledge and understanding of the MC. During the Fall II semester, I became confident in my use of the MC, which made a positive impact on my patient care.

In addition to changing my approach to patient care through the use of new treatment paradigms and the collection of patient outcomes, the clinical residency impacted my view on scholarship in athletic training. It also taught me the importance of becoming a PBE clinician who is a scholarly practitioner that generates and disseminates results from his or her clinical practice. Prior to entering the DAT program, I never imagined that I would contribute to the athletic training literature; however, by the end of my first year in the DAT program, I was able to successfully publish a case report manuscript and have since contributed to additional manuscripts that have been submitted for publication or accepted for publication. Through the DAT program and my clinical residency, I have gained a greater appreciation for clinical research and have become committed to continuing my journey toward becoming a scholarly practitioner. As an educator, I have begun to incorporate the knowledge and skills I have acquired regarding EBP and PBE into Northwestern College's athletic training program, and I hope my future students will be prepared to successfully incorporate these skills into their clinical practices.

My clinical residency experiences over the past two years has fostered changes in my approach to clinical practice, which, in turn, has made a significant impact on my residency site, Northwestern College. The most significant change I have seen within my residency site is a heightened focus on listening to the needs of our patients. By incorporating patient-centered outcomes into our clinical site, we have opened our eyes to the true needs of our patients and have stopped focusing on what we believe our patients desire. Our treatments have become more holistic, in that they are not just targeted at the site of a patient's pain or symptoms, but are focused on treating the whole patient, physically, psychologically, and spiritually. Finally, I have enjoyed the opportunity to expose my colleagues to several of the new treatment paradigms I have been introduced to during my time in the DAT program. My colleagues have embraced these changes and have provided positive support for the changes I have created at Northwestern College.

Overall, I believe that the DAT program and my clinical residency have changed who I am as a clinician and the clinic I work in. I have found a new desire to practice as a clinician and to develop further scholarship in athletic training, and I am excited to continue to grow as a scholarly practitioner. As evidenced by the patient outcomes presented in this chapter, my patient care has evolved over the past two years. I am confident that as I continue to believe in the treatments I am utilizing, my results will continue to improve, and the patients I serve at Northwester College will benefit from the changes I have made and am continuing to make in my patient care.

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CHAPTER 4

CRITICALLY APPRAISED TOPIC MANUSCRIPTS

4.1: Changes in Hamstring Range of Motion Following Proprioceptive Neuromuscular Facilitation Stretching Compared With Static Stretching: A Critically Appraised Topic

Authors:

Rick Loutsch, Christy Hancock, Bobby Bonser, Bethany Hansberger, Eric Stanford, and Alli Zeigel

Clinical Scenario

Stretching is commonly used in the medical, health, and fitness fields, as well as in school and military settings to increase flexibility and range of motion (ROM) at various joints.[1-3] Static stretching has been used for many years and requires the individual to lengthen the muscle to end range and hold this position for varying amounts of time.[4-6] Numerous studies have been performed to understand appropriate stretch duration; however, treatment application varies between five to 60 seconds.[4,7-9] Proprioceptive neuromuscular facilitation (PNF) stretching is another type of stretching used frequently to increase ROM.[5,10] A combination of contraction and relaxation of either agonist or antagonist muscles is used during PNF stretching.[5,6,10,11] Although both static and PNF stretching techniques have been touted as effective, there remains a need to identify whether one method is more effective than the other when focusing on the hamstrings musculature.

Several researchers have performed comparison studies to determine the most effective stretching technique and protocol for increasing ROM measures. A previous systematic review of PNF was performed to complete general comparisons for PNF and static stretch techniques for range of motion gains. The previous systematic review was published in 2006, and included studies that were not exclusive to hamstring ROM.[12] Therefore, there was a need to critically appraise the literature regarding the effects of PNF and static stretching on hamstring ROM. Critically appraising the efficacy of static versus PNF stretching in individuals with tight hamstrings may offer important insight into use of these techniques in clinical practice when treating individuals presenting with tight hamstrings.

Focused Clinical Question

In individuals with hamstring tightness, what is the effect of using PNF stretching compared to static stretching on traditional measures of hamstring ROM?

Search Strategy

A computerized search was completed in April 2015 (Figure 4.1).

Terms Used to Guide Search Strategy

- **P**atient/ Client group: Healthy adults with or without hamstring tightness
- **I**ntervention/Assessment: PNF OR proprioceptive neuromuscular facilitation
- **C**omparison: static stretching
- **O**utcome: flexibility OR range of motion

Sources of Evidence Searched

- CINAHL Plus
- Health Source
- SPORTDiscus
- PubMed Central

- Additional references obtained via reference list review and hand search

Inclusion Criteria

- Limited to studies that compared PNF stretching to static stretching
- Limited to studies that included individuals classified with tight hamstrings but absent of any additional pathology. Tight hamstrings are defined as 20° from vertical on the knee extension angle (KEA)[5] or active knee extension (AKE)[6,10] measurement with the hip at 90° of flexion.
- Limited to articles written in the English language
- Limited to articles written in the last 10 years (2005-2015)
- Limited to Level 4 evidence or higher

Exclusion Criteria

- Studies that used minors as participants
- Studies that used an injured population as participants
- Studies that did not compare PNF stretching to static stretching
- Studies that did not include pre- and post-treatment mean ROM outcomes

Evidence Quality Assessment

Validity of the selected studies was assessed using the Physiotherapy Evidence Database (PEDro) scale (Table 4.2). The three included articles were identified on the PEDro website with accepted and approved scores; these scores were utilized in this critically appraised topic (CAT).[13]

Results of Search

Three relevant studies were located using the search terms identified in the *Search Strategy* section. As described in Table 4.1, the studies selected for inclusion in this CAT were identified as the best evidence. The authors of these Level 2 studies considered the effects of static stretching in comparison to PNF stretching on traditional measures of ROM in individuals classified with hamstring tightness.

Summary of Search, Best Evidence Appraised, and Key Findings

- The literature search identified 202 studies; two randomized controlled trials (RCT) and one comparative crossover study met the inclusion and exclusion criteria (Table 4.1).
- In all of the studies that met inclusion and exclusion criteria, PNF stretching was compared to static stretching, with hamstring range of motion measurements as a primary outcome measure. In one study, an additional comparison was made to active self-stretch.[5]
- In the three studies that met inclusion/exclusion criteria, hamstring tightness was determined by the AKE [6,10] or KEA.[5] Tight hamstrings are defined as 20° from vertical on the KEA[5] or AKE[6,10] measurement with the hip at 90° of flexion.
- In all three studies, ROM measurements were taken with the participants in supine with the contralateral limb secured to the table with Velcro straps. The involved limb was placed in a 90° of hip and knee flexion. The participants actively extend the knee[5, 10] or an examiner passively extended the knee to record the measurement.[6] The AKE[6,10] or KEA[5] measurements were recorded using a digital inclinometer[5,6] or a manual protractor.[10]
- The PEDro scores were obtained from the Physiotherapy Evidence Database. Although the studies selected for inclusion in this CAT were identified as the best

evidence, the average PEDro score for included articles was 4.33/10 which indicates low-quality evidence.

- Of the articles included, the authors of two studies[6,10] indicated that both PNF and static stretching resulted in significant gains on the AKE[6,10] with no significant difference between techniques; however, the authors of one study[5] reported that static stretching was more effective. The best evidence for stretching techniques to increase ROM in individuals with tight hamstrings remains inconclusive.

Results of the Evidence Quality Assessment

As indicated previously, the PEDro scores provided guidance in determining the validity of each article. Evaluating the articles based on the PEDro criteria indicated lower validity with scores of three[5] and five.[6,10] Areas such as eligibility criteria,[5,10] concealing allocation of subjects,[5,6] blinding (subjects/therapists),[5,6,10] follow-up,[5,6,10] and an intent to treat analysis[5,6,10] were non-existent in the majority of the articles leading to the lower PEDro scores (Table 4.2).

Clinical Bottom Line

For individuals with hamstring tightness, there is low quality evidence to suggest either PNF or static stretching are more effective at increasing ROM. The effectiveness of PNF stretching compared to static stretching is inconclusive. Researchers in one[5] of the three included studies found that static stretching was more effective than PNF stretching, while the other two groups of researchers determined that both methods were equally effective at increasing ROM measures in healthy individuals with tight hamstrings.

Strength of Recommendation

Grade D evidence exists that PNF stretching performs as well as static stretching at increasing measures of hamstring ROM in individuals with limited hamstring flexibility. The

Oxford Center for Evidence-Based Medicine recommends a grade of D for troubling inconsistent or inconclusive studies as found within this CAT.[14]

Implications for Practice, Education, and Future Research

In the appraisal of the three included studies in this CAT, Davis et al.[5] found static stretching to be more effective at increasing KEA measurements than PNF-R (i.e., agonist contraction) and active self-stretch. The researchers attributed the superior ROM gains of the static stretch intervention to the facilitation of the GTO during the static stretch, whereas the active contraction of the agonist muscle during the PNF-R stretch may facilitate the hamstring muscles, limiting the muscles' ability to relax and elongate.[5,12] In contrast, Lim et al.[10] found both static stretch and PNF hold-relax technique to be effective at increasing AKE measurements acutely; however, no significant difference was found between the stretching techniques. These outcomes were comparable to Puentedura et al.[6] who compared similar stretch interventions.

The lack of significant findings between interventions could be attributed to the variance in methodology for both the static stretch and PNF stretching interventions. First, for the static stretch intervention, Lim et al.[10] and Puentedura et al.[6] performed a single treatment session consisting of one[10] or two[6] sets of 30 second stretches. Davis et al.[5] utilized two sets of 30 seconds performed three times per week for a duration of four weeks. Davis et al.[5] asserted that significant hamstring length cannot be achieved utilizing a protocol that includes a duration of less than two weeks and a 30 second stretch intervention. Other researchers have supported this theory by suggesting that a single, same-day series of an acute static stretch intervention will produce only transient ROM gains.[15-18]

Due to the lack of consistent methodology and results within the static stretching literature, comparison between the studies is difficult and clinical relevance of the results is questionable. Davis et al.[5] applied a passive straight leg raise (PSLR) to the point of a strong, but tolerable stretch sensation for the subject. Similarly, Lim et al.[10] also applied a PSLR; however, the stretch was applied to the point of light tolerable pain for the subject. Puentedura's et al.[6] methods were significantly different as they included a warm-up and may lack clinical relevance due to the inclusion of a pulley system that applied an arbitrarily chosen amount of torque to provide the passive stretch.

The lack of significant findings between interventions may also be attributed to the variance in methodology for the PNF stretching technique. Davis et al.[5] utilized an agonist contraction method for PNF stretching that involved a single 10 second active concentric contraction of the quadriceps muscle followed by a 30 second static stretch hold. In contrast, Lim et al.[10] incorporated a PNF hold-relax technique where subjects isometrically contracted their hamstrings against resistance for six seconds followed by a five second relaxation period, for a total of three sets.[10] Additionally, Puentedura et al.[6] also utilized the PNF hold-relax technique with a 10 second isometric contraction followed by a 10 second passive stretch for four total sets.

Based on the appraisal of the available evidence and identifying inconsistent stretch intervention methodology, determining a superior stretch intervention when comparing static to PNF stretching cannot be accurately accomplished based on the current literature. A comparison of the studies is difficult due to methodological differences. Additional high quality studies with standardized PNF and static stretching protocols are needed to determine the most effective stretching intervention. Further, if researchers are hoping to impact clinical practice and determine most effective stretching interventions that will translate to individual care, the application of the techniques that can be used within a clinic should be considered when determining methodology.

Based on the findings of the researchers, it appears that clinicians may utilize either static stretching or PNF stretching to achieve acute modest gains in range of motion; however, more high-quality research must be performed utilizing consistent methodology to determine the clinical efficacy of each stretching intervention. Additionally, both PNF and static stretching techniques should be compared to other techniques aimed at increasing ROM to determine the most effective intervention for clinical practice. Future studies should be focused on identifying the most effective stretching protocol for increasing ROM, both short and long term, using a high quality blinded randomized control trial. The current CAT should be reviewed in two years to identify whether additional evidence exists that may alter the clinical bottom line of this clinical question.

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Figure 4.1. Search strategy

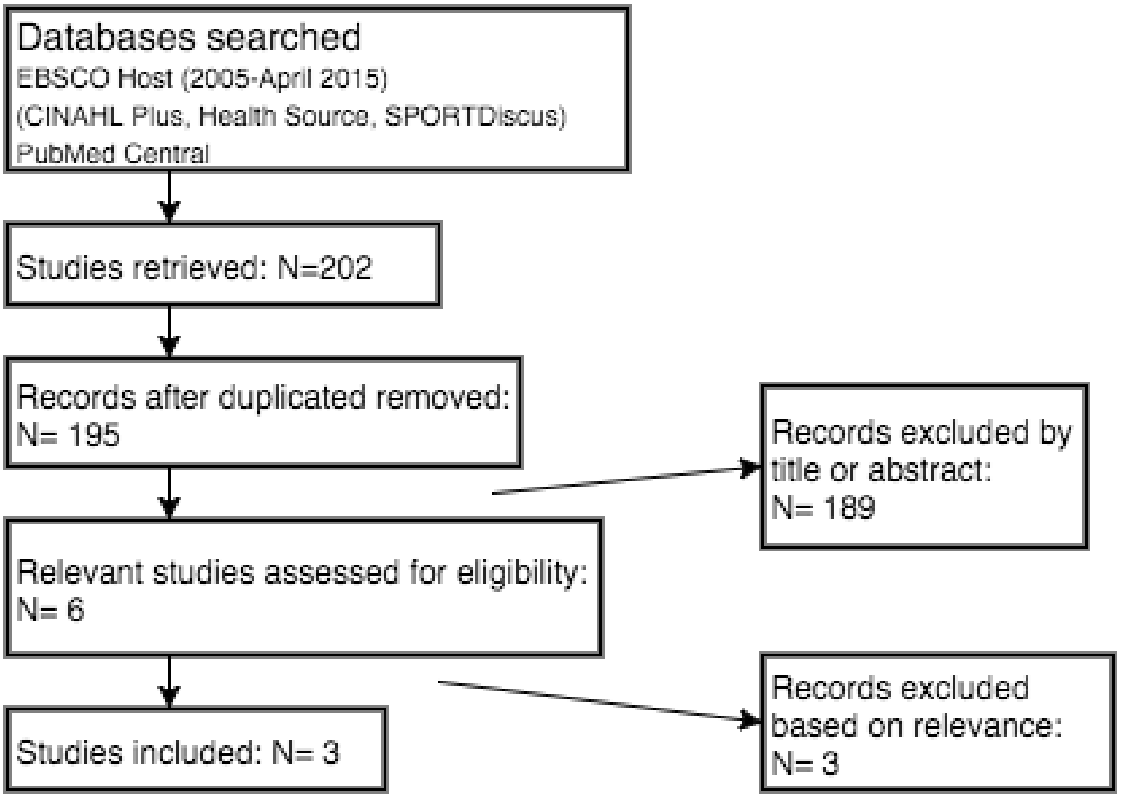

Table 4.1 Characteristics of Included Studies

Authors	**Davis et al**	**Lim et al**	**Puentedura et al**
Title	The Effectiveness of 3 Stretching Techniques on Hamstring Flexibility using Consistent Stretching Parameters	Effects on Hamstring Muscle Extensibility, Muscle Activity, and Balance of Different Stretching Techniques	Immediate effects of quantified hamstring stretching: Hold-relax proprioceptive neuromuscular facilitation versus static stretching
Study Design	Randomized controlled trial	Randomized controlled trial	Comparative study
Participants	19 subjects (11 males, 8 female) ages 23.1±1.5, range 21-35 years.	48 Adult males, age range 20-30; static stretch (n=16) 22.25±2.29 years, PNF (n=16) 23.50±2.16 years, and control (n=16) 22.38±2.31 years.	30 subjects (17 male / 13 female) mean age 25.7±3.0, range 22-17 years.
Inclusion and Exclusion Criteria	*Inclusion:* Tight hamstring as defined by a 20° Knee Extension Angle (KEA) with the hip in 90° of hip flexion; between 18 and 40 years of age. *Exclusion:* Previous history of lower-extremity pathology, which may adversely affect hamstring flexibility length.	*Inclusion:* Male adults in their 20s and 30s; Extensibility of hamstring muscle reduced by 20° as measured by the Active Knee Extension (AKE) Test. *Exclusion:* History of injury which could have affected hamstring muscle extensibility: herniated intervertebral disk, cruciate ligament damage, femoral muscle or hamstring muscle damage, sciatic neuralgia, etc. as well as dose who were or a history of surgery nervous or musculoskeletal systems, within the last 5 years, currently engaged in exercises such as stretching, yoga, Pilates, etc. for improving flexibility.	*Inclusion:* Not listed *Exclusion:* (possible) pregnancy, hamstring injury within the past year, exceeding 80° in the initial Active Knee Extension (AKE) test, and/or participation in sports that required regular hamstring stretching.
Interventions Investigated	Group 1 (active self-stretch): Supine, hip actively flexed to 90°, knee actively extended for 30 seconds, repeated bilaterally; 3x/week, 4 weeks. Group 2 (manual static stretch): Supine, Passive Knee Extension (PKE)'point of strong but	Static Stretch Group: Supine, Passive Straight Leg Raise (PSLR) - 1 set of 30 seconds. PNF Stretch Group: Hold-Relax Technique – Supine with PSLR, then 6 second contraction of hamstring, leg then lowered to table for 5 seconds repeated for	Static Stretch (SS) Group: 2 sets of 30 second stretches, 10 second rest interval between sets. PNF Stretch Group: Hold-Relax Technique – Supine

	tolerable stretch,' 30 second hold; repeated bi-laterally; 3x/week, 4 weeks. Group 3 (Proprioception Neuromuscular Facilitation (PNF)-Reciprocal Inhibition): Supine, PKE to 'point of strong but tolerable stretch', 10 second knee extension contraction; reposition to new 'point of strong but tolerable stretch' and 30 second hold; repeated bi-laterally; 3 x per week, 4 weeks Group 4 (control): No intervention.	total of 3 sets. Control Group: No intervention specified.	with leg raised to end range, 4 sets of 10 second isometric contraction with 10 second passive stretch intervals. Stretching interventions were applied using a custom pulley-weight system (weight proportional to 5% of subject's body mass and discomfort rating mean of 8.29 PNF, 8.06 SS).
Outcome Measures	Range of Motion (ROM) using Knee Extension Angle	ROM using Active Knee Extension (AKE); maximum voluntary isometric contraction using surface electromyography; static balance using force measuring plate	ROM using AKE
Main Findings	At week 2, no significant increase of ROM in all four groups compared to control group. Static stretch showed significant increase over baseline. At week 4, all three treatment groups show an increase of ROM over baselines, but only static stretch had significant increase over control group from baseline (Static Stretch: Mean Difference 23.7°, Control Group: Mean Difference 3.2°). Achieved a *MCID. Significant interaction between intervention and length of program ($p < .0016$).	Significant increase of ROM in both stretching groups ($p < 0.05$) compared to control No significant difference between stretching interventions. (Static Stretch: Mean Difference 9.62°, PNF Stretch: Mean Difference 11.87°). Achieved a *MCID. No significant differences in muscle activation or balance between groups.	Significant increase of ROM compared to control condition (PNF/Control $p < .0005$; SS/Control $p = .011$). No significant difference between stretching interventions. (PNF: Mean Difference 8.9°±7.7, Static: Mean Difference 9.1°±8.9, Control: Mean Difference 1.5°±9.3). Achieved a *MCID.
Level of Evidence	1b	1b	2b
Validity Score	PEDro 3/10	PEDro 5/10	PEDro 5/10

Conclusion	Static stretching was more effective than PNF stretching in individuals presenting with hamstring tightness.	Both static and PNF stretching are effective at increasing ROM in individuals presenting with hamstring tightness.	Both static and PNF stretching are effective at increasing ROM in individuals presenting with hamstring tightness.

The Minimal Clinically Important Difference (MCID) is a difference of 5 degrees (Chaudhary, Beaupre, & Johnston, 2008).

Table 4.2 Results of PEDro scale

	Davis et al	**Lim et al**	**Puentedura et al**
1. Eligibility criteria specified (yes/no; not included in overall score)	No	No	Yes
2. Subjects randomly allocated to groups (yes/no)	Yes	Yes	Yes
3. Allocation was concealed (yes/no)	No	Yes	No
4. Groups similar at baseline (yes/no)	No	Yes	Yes
5. Subjects were blinded to group (yes/no)	No	No	No
6. Therapists who administered therapy were blinded (yes/no)	No	No	No
7. Assessors were blinded (yes/no)	Yes	No	Yes
8. Minimum 85% follow-up (yes/no)	No	No	No
9. Intent to treat analysis for at least 1 key variable (yes/no)	No	No	No
10. Results of statistical analysis between groups reported (yes/no)	Yes	Yes	Yes
11. Point measurements and variability reported (yes/no)	No	Yes	Yes
Overall Score (out of 10)	3/10	5/10	5/10

4.2: Changes in Hamstring Range of Motion Following Neurodynamic Sciatic Sliders: A Critically Appraised Topic

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Authors:

Rick Loutsch, Bobby Bonser, Christy Hancock, Bethany Hansberger,

Eric Stanford, and Alli Zeigel

Clinical Scenario

Hamstring tightness (HT), a common condition across all age groups[1], has classically been thought to be caused by a reduction in tissue length leading to muscular strain and dysfunctional or restricted movement. Traditionally, HT has been addressed via static, dynamic, and proprioceptive neuromuscular facilitation (PNF) stretching techniques aimed at increasing range of motion (ROM) by treating what is assumed to be a tissue length issue in the hamstring muscle group.[2] Recently, researchers have questioned the efficacy of stretching as a treatment method for increasing ROM compared to other techniques.[3]
Neurodynamic Sliding (NDS) integrates both the musculoskeletal and nervous systems through a “flossing” of the nerves to achieve pain reduction or increased ROM in the extremities.[4] The use of NDS has recently been proposed as an alternative to stretching for patients with HT by addressing the neural factors of tightness without stretching the hamstring muscle tissue.[5,6,7] Several recent studies have examined the effectiveness of stretching compared to NDS.[5,6,7] Therefore, examining the evidence for NDS interventions versus traditional stretching techniques may offer more insight into practical clinical techniques for addressing patients with HT.

Focused Clinical Question

In an active population, what is the effect of using NDS compared to static or PNF stretching on traditional measures of hamstring ROM?

Summary of Search, Best Evidence Appraised, and Key Findings

- The literature search identified 6 studies. Of the 6 studies, one study was excluded as a duplicate study, two studies were excluded based on their title or abstract, and no studies were excluded based on lack of relevance to the critically appraised topic (CAT) (Figure 4.2).
- Two randomized controlled trials (RCT) and one comparative study met the inclusion and exclusion criteria (Table 4.3).
- All studies compared NDS targeting the sciatic nerve to stretching, with hamstring ROM measurements as a primary outcome measure. Both PNF[5] and static[6,7] stretching were included as comparisons.
- In the included studies, all researchers agreed that NDS targeting the sciatic nerve resulted in significant gains in ROM; however, only one group of researchers[6] reported NDS to be more effective than stretching. The double-blinded RCT had a large sample size and was the highest quality study included in the CAT,[6] according to the Physiotherapy Evidence Database (PEDro) scale.
- The authors of this CAT independently completed the PEDro scale and a consensus was obtained and determined for each article. The average score for included articles was 5/10.

Clinical Bottom Line

Evidence exists to support the use of NDS to increase measures of hamstring ROM in participants who present with limited hamstring flexibility; however, the effectiveness of NDS compared to traditional stretching is inconclusive. The authors of one of the three studies[6] demonstrated NDS was more effective than static stretching at increasing hamstring ROM measurements, while the authors of a second study[7] reported no difference between NDS and static stretching. The authors of the third study[5] evaluated in the CAT reported PNF stretching was superior to NDS at increasing hamstring ROM.

Strength of Recommendation

Grade B evidence exists that NDS performs as well as traditional stretching techniques at increasing measures of hamstring ROM on participants with limited hamstring flexibility. The Strength of Recommendation Taxonomy[8] recommends a grade of B for inconsistent Level 1 evidence or Level 2 evidence.

Search Strategy

A computerized search was completed in April 2015 (Figure 4.2).

Terms Used to Guide Search Strategy

- **P**atient/ Client group: hamstring tightness; hamstring
- **I**ntervention/Assessment: neurodynamic or slider or sciatic*
- **C**omparison: static stretching; PNF stretching
- **O**utcome: flexibility or range of motion

Sources of Evidence Searched

- CINAHL Plus

- Health Source
- MEDLINE
- SPORTDiscus
- Additional references obtained via reference list review and hand search

Inclusion Criteria

- Limited to studies that compare NDS targeting the sciatic nerve to stretching
    - *Excluded studies based on criteria*
        - Trampas A, Kitsios A, Sykaras E, Symeonidis S, Lazarou L. Clinical massage and modified proprioceptive neuromuscular facilitation stretching in males with latent myofascial trigger points. *Physical Therapy in Sport*. 2010;11(3):91-98.
        - Szlezak AM, Georgilopoulous P, Bullock-Saxton JE, Steele MC. The immediate effect of unilateral lumbar Z-joint mobilization on posterior chain neurodynamics: A randomized controlled study. *Manual Therapy*. 2011;16(6):609-613.
- Limited to articles written in the English language
- Limited to articles written in the last 10 years (2006-2015)
- Limited to humans

Exclusion Criteria

- Studies that used minors as participants
- Studies that used an injured population as participants
- Studies that used sciatic tensioners instead of sciatic sliders
- Studies that combined sciatic sliders with stretching as treatment
- Studies that did not include pre- and post-treatment mean range of motion outcomes

Results of Search

Three relevant studies were located using the above search terms (Table 4.3). Validity of the selected studies was identified using the PEDro scale (Tables 4.4 & 4.5). Each author independently reviewed the studies and completed the checklist. All authors met to determine agreement for each item on the checklist.

Best Evidence

As described in Table 4.3, the studies selected for inclusion in this CAT were identified as the best evidence. The authors of these level 2 or higher studies considered the use of NDS targeting the sciatic nerve on traditional measures of ROM in comparison to traditional stretching.

Implications for Practice, Education and Future Research

The studies included in this CAT were conducted to identify the effect of NDS targeting the sciatic nerve compared to stretching on hamstring ROM measures in a healthy population. In regards to the indications for use of NDS for the treatment of HT, heightened neural mechanosensitivity may cause pathomechanical dysfunction, such as muscular tightness.[4] The "tightness" reported by the patient may be based on a perception of tightness, rather than a tissue length issue.[9] Addressing the neural component within the muscle tissue may result in increased measures of ROM.[4] Therefore, NDS s have been offered as a method to increase ROM compared to traditional stretching within rehabilitation programs.

The researchers of the three studies examined in this CAT identified NDS to be effective as a stand-alone treatment; however, the efficacy of using sciatic sliders compared to stretching in the treatment of hamstring tightness is inconclusive. In the highest quality study[6] available, researchers randomized 120 individuals with bilateral complaints of HT and decreased ROM on the passive straight leg raise test (PSLR). Following statistical analysis, the researchers reported that the use of NDS was more effective at increasing ROM than stretching, and that both NDS and stretching were more effective at increasing ROM than a placebo group.[6] The findings were in contrast to those of researchers who conducted less rigorous studies[5,7] and found there was either no difference[7] or that stretching was more effective than NDS in the treatment of participants with apparent HT.[5] The researchers[5,6,7] who compared NDS directly to stretching, however, have not utilized consistent methodologies, which makes it difficult to assess outcomes across the limited evidence available. For example, when evaluating the three studies included in this CAT, three of the primary inconsistencies are variations in the method of assessment, application of the stretching intervention, and the application of NDS sliders.

The assessment methodology differed between the three studies. The active knee extension (AKE) was the method of assessment in one study[5] while the PSLR was utilized in the other studies[6,7] included in this CAT. The methodological discrepancies in assessment of hip flexion angle and knee extension angle are important, because they are two methods that are commonly thought to represent HT. The tension of the hamstring musculature may be a limiting factor for both the AKE and PSLR, and may differ between passive and active motions, possibly translating to differences in effectiveness of the treatment intervention between the studies.

In addition to assessment type, the number of treatment sessions and type of intervention differed between the studies. Some researchers found that a single application of NDS was more effective at increasing ROM than static stretching[6] while others determined both NDS and static stretching significantly increased ROM equally following three sessions over a one week period.[7] Another group of researchers also used three treatment sessions, but had participants perform hold-relax PNF as the comparison treatment rather than static stretching.[5] The researchers determined that both PNF and NDS interventions were effective at increasing ROM; however, the PNF stretching demonstrated greater efficacy.

The last inconsistency in the studies is observed in the difference between the applications of the NDS treatment. In the application of NDS, two researchers[5,7] used a seated position while the third[6] used a supine position. Similarly conflicting, overpressure was only used in one study,[5] possibly contributing towards the differences identified between NDS and PNF treatments. Lastly, each of the three researchers also chose to mobilize different joints within their sciatic slider treatments. Mobilizing different joints may affect the amount of nerve excursion, possibly affecting the treatment outcome.[10]

Clinicians should use caution when interpreting these results in an injured population as all three of the studies used subjects categorized with HT but who were otherwise apparently healthy. Based on the studies examined in this CAT, additional high quality studies are needed to determine the effects of NDS sciatic sliders on ROM measures in various populations. Injured populations (such as those with altered nervous system function) should be examined to determine their response to NDS treatments. Future researchers should identify the most effective NDS protocol for increasing ROM. Further, the researchers should identify the immediate, short and long-term effects of the intervention. The current CAT should be reviewed in two years to identify whether additional evidence exists that may alter the clinical bottom line of this clinical question.

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Figure 4.2. Search strategy

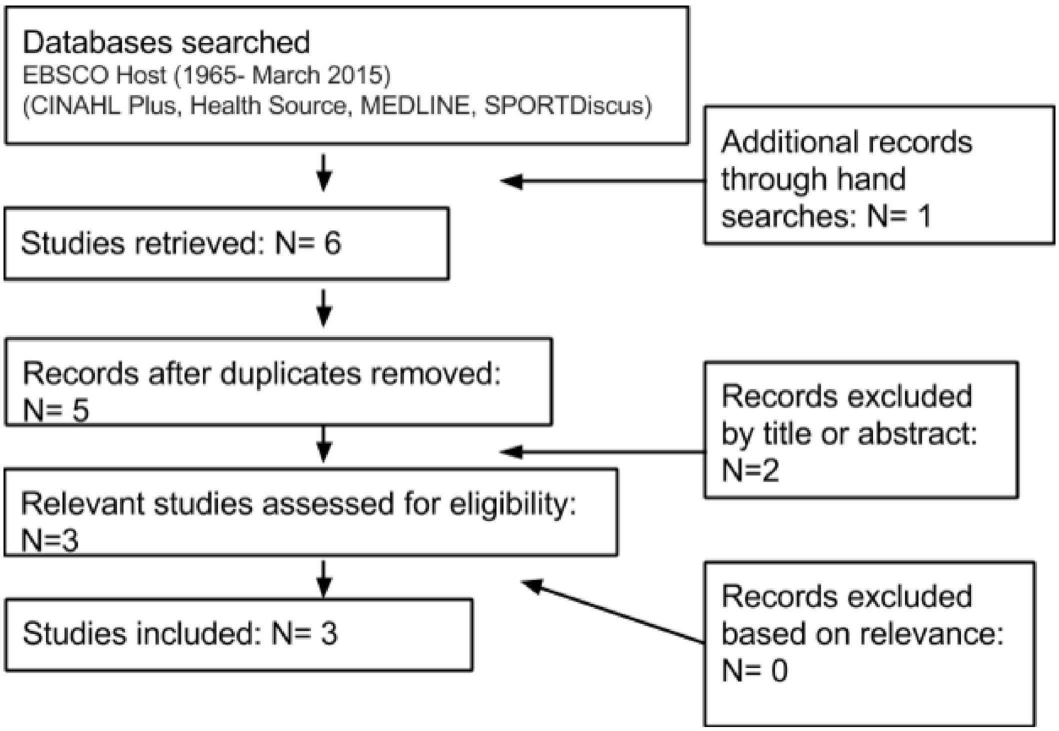

Table 4.3 Summary of Study Designs of Articles Retrieved

Level of evidence	Study design	Number located	Reference
1b	Randomized, double-blinded controlled trial	1	Castellote-Caballero et al
2b	Randomized, controlled trial	1	Pagare et al
	Comparative Study	1	Vidhi et al

Table 4.4 Characteristics of Included Studies

	Castellote-Caballero et al	**Pagare et al**	**Vidhi et al**
Study Design	Randomized, double-blinded controlled trial	Randomized, controlled trial	Comparative study
Participants	120 patients (60 female, 60 male; mean age 33.4 ± 7.4, range 20–45 years) with decreased PSLR ROM, otherwise apparently healthy.	30 male football players (NDS group 20.87 ± 2.89; stretch group 22.47 ± 2.48 years) with decreased PSLR ROM, otherwise apparently healthy.	60 patients (mixed males and females – number not specified) with decreased AKE ROM, otherwise apparently healthy.
Interventions Investigated	NDS Group: Supine with neck/thoracic flexion. Hip/knee flexion alternated with hip/knee extension. Perform for 180 seconds. Stretching Group: Supine, PSLR hamstring stretch. Perform 5x30 seconds. Placebo Group: Supine with passive intrinsic foot joint mobilization.	NDS Group: Seated slump position (no overpressure) with active cervical and knee flexion/ankle plantarflexion alternated with cervical and knee extension/ankle dorsiflexion. Perform 5x60 seconds with 15sec rest for three days over one week period. Stretching Group: Modified hurdler's position with flexion at hip. Hold for 30sec three days over one week period.	NDS Group: Seated slump position (overpressure by clinician) with passive knee extension/ankle dorsiflexion alternated with knee flexion. Perform 3x30 reps on 3 consecutive days. Stretching Group Hold-relax PNF (Supine with 10sec stretch, 6sec static hold/contract, 30sec stretch). Perform 3 reps on 3 consecutive days.
Outcome Measures	ROM using PSLR test	ROM using PSLR	ROM using AKE
Main Findings	Significant improvement in ROM in NDS and stretching groups compared to placebo ($p<0.001$). NDS group significantly greater improvements than stretching group ($p=0.006$).	Significant improvement in ROM in both groups ($p<0.001$). No difference between groups ($p=0.057$).	Significant improvement in ROM in both groups (p-value not reported). Stretching group significantly greater improvements than NDS group ($p=0.0435$).
Level of Evidence	1b	2b	2b
Validity Score	PEDro 7/10	PEDro 4/10	PEDro 4/10

Conclusion	Both static stretching and neurodynamics were effective, with neurodynamic treatment being the most effective method to increase ROM.	Range of motion improvements were not different between groups.	Both PNF stretching and neurodynamics were effective, with PNF stretching being the most effective method to increase ROM.

Abbreviations: PSLR = Passive Straight Leg Raise; AKE = Active Knee Extension; ROM = Range of Motion; PNF = Proprioceptive Neuromuscular Facilitation; NDS = Neurodynamic Sliders

Table 4.5 Results of PEDro scale

	Castellote-Caballero et al[6]	**Pagare et al[7]**	**Vidhi et al[5]**
1. Eligibility criteria specified (yes/no)	Yes	Yes	Yes
2. Subjects randomly allocated to groups (yes/no)	Yes	Yes	Yes
3. Allocation was concealed (yes/no)	Yes	Yes	No
4. Groups similar at baseline (yes/no)	Yes	Yes	Yes
5. Subjects were blinded to group (yes/no)	Yes	No	No
6. Therapists who administered therapy were blinded (yes/no)	No	No	No
7. Assessors were blinded (yes/no)	Yes	No	No
8. Minimum 85% follow-up (yes/no)	No	No	No
9. Intent to treat analysis for at least 1 key variable (yes/no)	No	No	No
10. Results of statistical analysis between groups reported (yes/no)	Yes	Yes	Yes
11. Point measurements and variability reported (yes/no)	Yes	No	Yes
Overall Score (out of 10)	7/10	4/10	4/10

Item 1 not included in overall score

CHAPTER 5

APPLIED CLINICAL RESEARCH

Hamstring Range of Motion Following Total Motion Release® Forward Flexion Trunk Twist Versus Sham Treatment

Authors:

Rick Loutsch, Bobby Bonser, Christy Hancock, Bethany Hansberger,

Eric Stanford, Alli Zeigel

Key points:

- Traditional evaluation and treatment techniques of apparent hamstring tightness (AHT) fail to consider alternative causative factors, such as neural drive or fascial restriction, when addressing movement dysfunction.
- The Total Motion Release® (TMR®) forward flexion trunk twist (FFTT) may effectively address the underlying neural or fascial causes of AHT by utilizing multi-planar movement at the trunk and lumbopelvic complex.
- Participants categorized with AHT significantly improved on measures of ROM immediately after a single treatment of the TMR® FFTT compared to a sham group.

Abstract

Context: Hamstring tightness is a common condition typically treated by stretching interventions. Limited evidence exists to support the use of the Total Motion Release® (TMR®) forward flexion trunk twist (FFTT) as a holistic approach to resolving hamstring tightness.

Objective: To assess the immediate and short-term effects of the TMR® FFTT on measures of hamstring extensibility.

Design: Multisite randomized controlled clinical trial.

Setting: University athletic training clinics.

Patients or Other Participants: Sixty (34 male, 26 female) healthy, physically active individuals presenting with signs of AHT.

Intervention(s): Participants were randomized into one of two groups: (a) treatment (TMR® FFTT) group or (b) sham group.

Main Outcome Measure(s): Hamstring ROM was assessed using the active knee extension (AKE), passive straight leg raise (PSLR), finger to floor distance (FFD), and v-sit and reach (VSR) tests. All measures were performed at baseline, immediately post-treatment, and at one day follow-up. Repeated measures ANOVAs were utilized to assess both within group and between groups differences. Holm's sequential Bonferroni corrections were performed to determine differences between groups. Statistical significance was considered at $p<.05$

Results: The TMR® FFTT group demonstrated significantly more improvement in ROM than the sham group immediately post-treatment for the AKE-Most Restricted (MR) (6.4° ±

4.8° vs. 2.7° ± 6.6°, $p = 0.018$, Cohen's d = 0.65, 95% CIs: 0.66°, 6.8°), PSLR-MR (5.8° ± 4.2° vs. 2.2° ± 4.5°, $p = 0.002$, Cohen's d = 0.85, 95% CIs: 1.7°, 6.4°), FFD (4.6cm ± 3.4cm vs. 2.0cm ± 4.1cm, $p = 0.01$, Cohen's d = 0.73, 95% CIs: 0.67cm, 4.7cm), and VSR (4.4cm ± 3.1cm vs. 1.7cm ± 2.9cm, $p = 0.001$, Cohen's d = 0.92, 95% CIs: 0.93cm, 4.0cm). No between-group differences were found at the one day follow-up.

Conclusions: The TMR® FFTT effectively increased ROM on measures of hamstring extensibility immediately following a single intervention compared to a sham treatment that consisted of a sub-optimal form of static stretching. In an effort to promote clinical relevance and increase external validity, the methodology of the study featured materials and methods readily available in athletic training clinics; however, limitations of the study may have hindered the magnitude of effect identified in the results. Future researchers should consider more stringent inclusion criteria and the response of various ROM measures following TMR® FFTT treatment.

Key Words: Regional interdependence, hamstring, tightness, stretching

Introduction

Hamstring tightness, commonly defined as a lack of hip flexion range of motion (ROM) with a concomitant feeling of restriction in the posterior thigh, has been documented across all age groups as a potential problem leading to dysfunctional or restricted movement.[1–9] The term hamstring tightness denotes that a lack of hip flexion or knee extension ROM is due to a tissue length deficit; however, researchers have drawn attention to multiple causal factors such as neural tension,[10–13] fascial restriction,[14] lumbopelvic dysfunction,[15,16] and/or joint or tissue length restrictions[17–20] that may contribute to this lack of ROM or tissue extensibility. Thus, the term apparent hamstring tightness (AHT) may be a better descriptor of the hamstring tightness phenomenon because the underlying cause may not be related to tissue length, and immediate gains in hamstring extensibility may be experienced following an intervention that does not address a tissue length deficit.

Tissue length deficits have been proposed to result from deformation in the elastic or plastic regions of connective tissue, leading to restricted joint motion.[19,21,22] Traditionally, AHT has been assessed using tests thought to measure the length of the hamstring muscle tissue, such as the active knee extension (AKE),[10,23–26] passive straight leg raise (PSLR),[27–31] finger to floor distance (FFD),[32] and sit and reach (SR)[33] tests. Likewise, treatment techniques commonly used for AHT were focused directly on muscle tissue (e.g., length changes) and include static, proprioceptive neuromuscular facilitation (PNF), and dynamic stretching.[34,35] Researchers have postulated that a stretching intervention may change tissue length due to the properties of viscoelastic deformation, plastic deformation, sarcomere adaptation, and neuromuscular relaxation.[21,22] The variance in repetitions, frequency, and duration of stretch protocols has led to inconsistent efficacy throughout the literature,[36–38] resulting in a lack of consensus regarding the most effective stretching protocol.

In light of the questionable efficacy and appropriateness of stretching to treat AHT, clinicians have been encouraged to rethink the classical approach to addressing AHT and consider factors other than tissue length deficits that may contribute to the perceived tightness.[39] Researchers examining alternative treatments involving more comprehensive movement patterns and lumbopelvic exercises have demonstrated promising results for increased knee ROM[40] and prevention of recurrent hamstring strain.[16] One novel technique that has yet to be studied extensively is Total Motion Release® (TMR®), a treatment philosophy based on regional interdependence in which the clinician assesses and treats imbalances throughout the body.

The regional interdependence theory is the idea that dysfunction or pain perceived in one area of the body may be influenced by a dysfunction or restriction in the neural, musculoskeletal, or fascial systems, amongst others.[41,42] A specific TMR® intervention, the TMR® forward flexion trunk twist (FFTT), has been proposed to treat AHT.[43,44] While the TMR® FFTT lacks a direct focus on lengthening hamstring musculature, improvements in both active hip flexion and knee extension ROM have been demonstrated after performing the technique.[44] Despite the paucity of research conducted on the TMR® FFTT, the technique may be a beneficial intervention for patients categorized with AHT. Therefore, the purpose of this study was to assess the immediate and short-term effects of the TMR® FFTT compared to a sham group on measures of hamstring ROM among healthy, physically active individuals presenting with signs and symptoms of AHT.

Methods

Participants

Participants were recruited from five different research sites across the country [athletic training clinics and student bodies at universities (2 NCAA Division I, 1 NCAA Division II, 1 NCAA Division III, and 1 NAIA)]. Physically active was defined as performing physical activity for at least 150 minutes a week or an average of 30 minutes a day five days per week.[35] Participants were active in a variety of settings (36 intercollegiate, 22 recreational, and 2 club sports) with the most common sports after recreational activity (22) being soccer (9), baseball (6), and track/field (6). A total of 70 physically active individuals (35 men: 20.8 ± 1.7 years; 35 women: 20.4 ± 1.4 years) volunteered to participate in this multisite research study and were screened for the following inclusion criteria: AKE angle of at least 20°, a TMR® FFTT asymmetry of at least 5 points, and a score of at least 1 on the Perceived Tightness Scale (PTS). The AKE was performed bilaterally and the leg with the most restricted motion was identified as the "most restricted" (MR) leg for ROM measurements throughout the study.

The following exclusion criteria were applied: (1) lower extremity injury in the previous six weeks; (2) lumbar pathology including back injury in the previous six weeks, known lumbar spine pathology limiting ROM (e.g., discogenic), prior lumbar spine surgical procedures, known lumbosacral spine physical impairments limiting ROM and function; (3) lower extremity surgery within last six months; major ligamentous surgery within last one year; (4) vestibulocochlear disturbances/concussion (5) joint hypermobility syndrome (Beighton Score of four or higher); (6) connective tissue disorders (e.g., Marfans, Ehlos

Danlos); or (7) lower extremity neurovascular pathology, including numbness, tingling, and loss of sensation. A total of 10 participants were excluded from the study. One participant did not meet the physically active requirement; two participants had bilateral AKE angle measurements of less than 20°; five participants did not have a TMR® FFTT asymmetry; one participant reported low back pain; and one participant reported a lower extremity injury in the prior six weeks.

In total, 60 participants met the inclusion/exclusion criteria; 30 were randomly assigned to the TMR® FFTT group (20.7 ± 1.7 years; 42.3° ± 7.9° AKE-MR; 35.3 ± 20.1 TMR® asymmetry) and the other 30 were assigned to the sham group (20.6 ± 1.5 years; 45.1° ± 10.1° AKE-MR; 27.6 ± 17.8 TMR® asymmetry) (Table 5.1). Dropout criteria determined *a priori* included pain that developed during treatment; verbal request by participant to discontinue the study; and non-compliance (i.e., failure to return for one-day follow-up testing). Based on these criteria, two of the 60 participants dropped out of the study due to pain during the treatment (1) and noncompliance (1), leaving a total of 58 participants (TMR® FFTT = 28, sham = 30) who completed all stages of the study.

Prior to beginning the study, the research procedures were explained to each participant. All participants provided written consent to participate in this study and the study was approved by the Institutional Review Board of XXXXXX along with the Institutional Review Board at each of the five research sites.

Experimental Procedures

The principal investigators (n = 5) administered all ROM measurements and interventions at their respective sites. Prior to initiating the study, the clinicians completed the

TMR® training courses and conducted a pilot study to validate their methods and establish consistency of treatments and measurements. To ensure measurement reliability amongst all clinicians participating in this multisite research study, the intra-rater and inter-rater reliabilities of the AKE, PSLR, FFD, and v-sit and reach (VSR) were assessed prior to beginning this study. All measurements had high intra-rater and inter-rater reliability assessed with Intraclass Correlation Coefficients (ICC) (3,1), with absolute agreement (Table 5.2).[45] The high reliability was consistent with the intra- and inter-rater values reported in the literature for the AKE,[23,31,46,47] PSLR,[46,48] FFD,[32] and VSR.[49] The standard error of measurement (SEM) and minimal detectable change (MDC) values were also calculated for each dependent variable from the reliability testing data performed prior to this study (Table 5.2). Standard measurement error was derived using the interrater ICC and the following formula: $SEM=SD \times \sqrt{((1)-ICC)}$.[50] Minimum detectable change for this study was subsequently calculated using the formula $MDC=1.96 \times \sqrt{2} \times SEM$ (Tables 5.2 - 5.3).[50]

Group allocation of the participants was concealed from the clinician until after baseline measurements were taken, at which point group assignment was revealed by opening a sealed, opaque envelope containing the participant's group assignment. All baseline measurements were performed in a pre-determined, randomized order using a random number generator (random.org) without a rest period between measurements. After baseline measurements, participants completed the treatment intervention according to their group assignment. Following the intervention, immediate post-treatment and one day follow-up measurements were recorded in the same order as baseline measures.

Total Motion Release® (TMR®) Forward Flexion Trunk Twist (FFTT) Treatment

The TMR® FFTT treatment intervention began with a screening procedure by having the participant stand with feet together and arms crossed in front of the chest. The participant was instructed to flex forward at the waist into a neutral position or just prior to the point of discomfort (Figure 5.1a) and then twist to the right, return to the neutral position and then twist to the left. The participant was shown a TMR® grading scale (0-100) in which a score of zero equals “no problems at all” and a score of 100 equals “the worst” in regards to how the motion felt (i.e., pain, tightness, ROM, strength, tension, nervousness, and quality). The participant was asked to score the difference between twisting to the right versus twisting to the left by identifying a difficult side and indicating a percent difference between the difficult and easy sides. For the feet apart position, the participant was asked to stand with feet apart, flex forward at the waist over the right leg (Figure 5.2a), return to the starting position, and then flex forward at the waist over the left leg noting which leg “felt better” to flex forward over (i.e., the good leg). Following this, the participant forward flexed at the waist over the leg that “felt worse” and twisted towards midline, returned to the neutral position over the “bad leg,” and then twisted away from midline. The participant then identified which direction was more difficult and scored the motion in the same way as described above for the feet together position.

Following the screening procedure, each participant in the TMR® FFTT group performed two sets of 10 repetitions of the feet together FFTT to the side previously identified as the “easy side” during the screening procedure.[44,51] After twisting, the participants were instructed to slowly release anything felt to be preventing further movement (e.g., bending the knee, extending the trunk, looking over the shoulder) which would allow for further twisting motion with each repetition (Figure 5.1b). The participant was given 30 seconds to rest between sets. Following the TMR® FFTT treatment with feet together, the participant repeated the same procedure with feet apart, twisting in the "more difficult" direction over the good leg, as identified in the screening procedure (Figure 5.2b).[51] The participant performed two sets of 10 repetitions in the feet apart position with the same "twist and then release" instructions provided. Immediately following the TMR® FFTT treatment, all participants completed post-treatment measurements.

Sham Treatment

The sham treatment required each participant to maintain a position of forward trunk flexion, without the twisting motion present in the TMR® FFTT, simulating a position often utilized in static stretching. Each participant randomized into the sham treatment group was instructed to stand with the feet together and arms crossed in front of the chest. The participant was then instructed to forward flex at the waist to approximately 90° or just prior to the point of discomfort to ensure that maximal, end-range stretching was avoided (Figure 5.1a). Each participant held this position for 30 seconds and then returned to the starting position. A total of four repetitions with 30 second holds were performed and 30 seconds of rest was provided between each repetition. Immediately following the sham treatment, all participants completed post-treatment measurements.

Range of Motion Measurement Methods

An inclinometer application (Clinometer, https://www.plaincode.com/products/clinometer/) was installed on an iPhone or Android smartphone device by each researcher. The Clinometer application was utilized to collect the AKE and PSLR measures and was calibrated before each participant's arrival. While not utilized in the lower extremity literature, the Clinometer application has been found to be reliable for measuring shoulder ROM [ICC (2,1) = .8].[52] Prior to collecting ROM measurements, a mark was placed on the anterior tibia (three inches below the tibial tuberosity) and on the anterior thigh (six inches above the tibial tuberosity) of each leg for all participants to ensure accurate and consistent placement of the smartphone for use of the Clinometer app. A cloth tape measure was used for the FFD and VSR tests. For all tests requiring unilateral measurements (AKE, PSLR), the right leg was assessed first, followed by the left leg. A total of three measurements were taken for all tests and the average of the three was reported, with the exception of the VSR, in which the third measure stood as the final score.[53]

Active Knee Extension (AKE) Measurement

The AKE was measured by the clinician with the participant in a supine position with one leg in a 90-90 position as an assistant stabilized the contralateral leg in an extended position (Figure 5.3a). The clinician placed one hand on the posterior thigh four inches superior to the knee while the other hand placed the smartphone inclinometer on the participant's anterior thigh with the top of the phone in line with the marking on the participant's thigh to assess maintenance of 90-degree positioning. The participant was then instructed to actively extend the knee to the point of discomfort, while maintaining 90 degrees of hip flexion. When the participant reached the point of discomfort (i.e., an uncomfortable amount of tension),[54] the clinician relocated the smartphone inclinometer from the anterior thigh to the mark at the mid-anterior tibia, making sure to keep the other hand on the posterior thigh to maintain 90 degrees of hip flexion (Figure 5.3b).

Passive Straight Leg Raise (PSLR) Measurement

The PSLR was measured by the clinician as the participant lay supine with the legs extended. The clinician passively flexed the participant's hip while maintaining knee extension and monitoring for pelvic rotation until the point of discomfort was reached. An assistant stabilized the contralateral leg in an extended position during the procedure (Figure 5.4). The ROM measurement was recorded with the smartphone inclinometer placed at the mark on the thigh.

Finger to Floor Distance (FFD) Measurement

The FFD test was performed with the participant standing on a 20 cm box with the feet together and the toes positioned at the edge of the box. The participant flexed at the waist with hands on top of one another, reaching for the toes, and stopping at the point of discomfort (Figure 5.5). The clinician visually ensured the participant's knees did not flex while performing the movement. The clinician measured from the top edge of the box to the tip of the middle finger of the top hand in centimeters. A measurement of "0" indicated the fingertip was in line with the edge of the box. A positive number indicated that the fingers had not reached the edge of the box, while a negative number indicated the fingers were past the edge of the box. Measurements were rounded to the nearest half centimeter.

V-Sit and Reach (VSR) Measurement

A cloth tape measure was affixed to the floor using pieces of tape to assess the participant's ROM. A piece of tape denoting the baseline "zero" point was placed at the 40 cm mark of the cloth tape measure. On the baseline tape strip, two marks were placed 15 cm on either side of the tape measure to denote the spot where the participant's feet would be placed (Figure 5.6).

The participant was instructed to sit on the floor with the legs extended, the feet spaced 30 cm apart, and the plantar surface of the feet touching a box to keep the ankle joints in a neutral position.[53] An assistant stabilized one leg on the floor in an extended position, while the clinician stabilized the other leg. The participant placed one hand over top of the other and flexed at the waist towards the toes to the point of discomfort. The motion was performed three times and the measurement was taken on the third attempt. The clinician measured from the edge of the baseline "zero" tape line to the tip of the middle finger. A measurement of "0" indicated the fingertip was in line with the edge of the baseline "zero" tape line. A negative number indicated that the fingers had not reached the edge of the line, while a positive number indicated the fingers were past the edge of the line. Measurements were rounded to the nearest half centimeter.

Perceived Tightness Scale (PTS)

The participant's perception of tightness was identified using the Perceived Tightness Scale (PTS) which was adapted from the 0-10 numeric rating scale (NRS). The NRS is a numerical ranked scale that measures the intensity of the participant's pain;[55] however, in this study, the participants were asked to rate their amount of perceived hamstring tightness at baseline, immediately following the treatment, and at one day follow-up. On the PTS, a score of 0 indicated "no perceived tightness" and a score of 10 indicated "extreme tightness."

Data Analysis

Statistical analysis was performed using SPSS statistical software (version 23; SPSS Inc., Chicago, IL). Each dependent variable was assessed for outliers by treatment group using estimates of skewness and kurtosis, visual inspection through histograms, as well as with Levene's test and the Shapiro-Wilk test. One-way within subject repeated measures analysis of variance (RM-ANOVAs) were performed to assess the effect of the TMR® FFTT on each dependent variable over time. Bonferroni comparison testing was used for post-hoc analysis. Significance was considered to be $p \leq .05$. Between-groups effects were assessed using RM-ANOVAs for each dependent variable. Independent sample t-tests were used to assess between group differences at each time point (baseline-post treatment; baseline-one day follow-up). A Holm's sequential Bonferroni correction was performed to establish new alpha levels (i.e., .025, .05) for significant findings. Differences at baseline were assessed using independent t-tests; if a baseline difference was discovered, the variable was assessed using an independent t-test on the difference scores rather than with the RM-ANOVA. To determine the treatment effect size, the Cohen's d statistic was calculated, with small $\geq .2$, medium $\geq .5$, and large $\geq .8$.[56]

Effect size indicates the magnitude of difference between two groups, with moderate to large differences associated with increased clinical meaningfulness of the results.[56] Additionally, a conservative Holm's sequential Bonferroni adjustment results in a decreased risk of Type I error, but also results in low power.[57] Low statistical power is associated with an increased risk of making a Type II error.[58] Therefore, our conservative statistical choices reduce the risk of incorrectly concluding the two groups are statistically different when they actually are not, but the tests may not have the power needed to detect differences that exist.[57]

Results

Active Knee Extension (AKE) - Most Restricted (MR) Leg

There were no differences at baseline in AKE-MR measurements ($t_{(56)} = -0.93$, $p = .354$, 95% CIs: -7.0°, 2.5°) between TMR® FFTT (42.9° ± 7.7°) and sham treatment (45.1° ± 10.1°). The between-subjects time*group interaction was significant ($\lambda = 0.9$, $F_{(2,55)} = 3.21$, $p = .048$, partial eta squared = 0.1, power = 0.59) (Table 5.4). Utilizing the Holm's sequential Bonferroni adjustment for follow-up testing, there was a significant difference between TMR® FFTT (mean difference = 6.4° ± 4.8°) and sham treatment (mean difference = 2.7° ± 6.6°) immediately post-treatment ($t_{(56)} = 2.43$, $p = .018$, Cohen's d = 0.65, 95% CIs: 0.66°, 6.8°). There were no significant differences between groups at one day follow up ($t_{(56)} = 1.65$, $p = .105$, Cohen's d = 0.44, 95% CIs: -0.53°, 5.5°).

The within-subjects time main effect for the TMR® FFTT group was significant ($\lambda = 0.31$, $F_{(2,26)} = 29.11$, $p < .001$, partial eta squared = 0.69, power = 1.0) (Table 5.5). Bonferroni post-hoc testing revealed a significant increase in ROM from baseline to post-treatment (mean difference = 6.4°, SEM = 0.91°, $p < .001$) and from baseline to one day follow-up (mean difference = 5.0°, SEM = 1.1°, $p < .001$). Between time points within the TMR® FFTT group, participants maintained 79% of their post-treatment changes at the one day follow up for the AKE.

Passive Straight Leg Raise (PSLR) - Most Restricted (MR) Leg

There were no significant differences at baseline in PSLR-MR measurements ($t_{(58)} = -1.95$, $p = .056$, 95% CIs: -15.8°, 0.2°) between TMR® FFTT (51.6° ± 14.8°) and sham treatment (59.0° ± 14.1°). The between-subjects time*group interaction was significant ($\lambda =$

0.85, $F_{(2,55)} = 4.98$, $p = .01$, partial eta squared = 0.15, power = 0.79). Following the post-hoc assessment, a significant difference between TMR® FFTT (mean difference = 5.8° ± 4.2°) and sham treatment (mean difference = 2.2° ± 4.9°) was identified immediately post-treatment ($t_{(58)} = 3.2$, $p = .002$, Cohen's d = 0.85, 95% CIs: 1.6°, 6.0°). There were no significant differences between groups at one day follow up ($t_{(56)} = 1.6$, $p = .115$, Cohen's d = 0.43, 95% CIs: -0.86°, 7.7°).

The within-subjects time main effect for the TMR® FFTT group was significant (λ = 0.34, $F_{(2,26)} = 25.32$, $p < .001$, partial eta squared = 0.66, power = 1.0). Bonferroni post-hoc testing revealed a significant increase in ROM from baseline to post-treatment (mean difference = 5.8°, SEM = 0.8°, $p < .001$) and from baseline to one day follow-up (mean difference = 4.4°, SEM = 1.5°, $p = .023$). Between time points within the TMR® FFTT group, participants maintained 76% of their post-treatment changes at the one day follow up for the PSLR.

Finger to Floor Distance (FFD)

Outlier assessment revealed a skewness value of 1.11 (SE = 0.43) with a kurtosis value of 2.16 (SE = 0.83) for the sham group at baseline. Histogram, box plot, and visual inspection of the data revealed two possible outliers; data for the FFD was removed for these participants prior to further analysis. Following outlier removal, skewness for the baseline FFD was -0.199 (SE = 0.44) and kurtosis was -1.05 (SE = 0.86). There was a significant difference at baseline in FFD measurements ($t_{(56)} = 2.48$, $p = .016$, 95% CIs: 1.2cm, 11.2cm, power = 0.57) between TMR® FFTT (10.5 cm ± 10.5 cm) and sham treatment (4.3 cm ± 8.1 cm). Independent sample t-tests were used and revealed a significant difference between

TMR® FFTT (4.6 ± 3.4cm) and sham treatment (2.0 ± 4.1cm) immediately post-treatment ($t_{(54)}$ = 2.67, p = .01, Cohen's d = 0.73, 95% CIs: 0.67 cm, 4.7 cm). There were no significant differences between groups at one day follow up (t(54) = 1.4, p = .155, Cohen's d = 0.39, 95% CIs: -0.73 cm, 4.5 cm).

The within-subjects time main effect for the TMR® FFTT group was significant (λ = 0.34, $F_{(2,26)}$ = 25.64, p < .001, partial eta squared = 0.66, power = 1.0). Bonferroni post-hoc testing revealed a significant increase in ROM from baseline to post-treatment (mean difference = 4.6 cm, SEM = 0.64 cm, p < .001) and from baseline to one day follow-up (mean difference = 2.9 cm, SEM = 0.87 cm, p = .008). Between time points within the TMR® FFTT group, participants maintained 63% of their post-treatment changes at the one day follow up for the FFD.

V-Sit and Reach (VSR)

There were no differences at baseline in VSR measurements ($t_{(58)}$ = -0.9, p = .374, 95% CIs: -7.4 cm, 2.8 cm) between TMR® FFTT (-13.5 cm ± 11.0 cm) and sham treatment (-11.2 cm ± 8.3 cm). The between-subjects time*group interaction was significant (λ = 0.81, $F_{(2,55)}$ = 6.3, p = .003, partial eta squared = 0.19, power = 0.88). Post-hoc testing using independent t-tests and a Holm's sequential Bonferroni adjustment revealed a significant difference between TMR® FFTT (4.4 cm ± 3.1 cm) and sham treatment (1.7 cm ± 2.9 cm) immediately post-treatment ($t_{(58)}$ = 3.45, p = .001, Cohen's d = 0.92, 95% CIs: 1.1 cm, 4.3 cm). There were no significant differences between groups at one day follow up (t(56) = 2.0, p = .054, Cohen's d = 0.53, 95% CIs: -0.04 cm, 4.6 cm).

The within-subjects time main effect for the TMR® FFTT group was significant (λ = 0.3, $F_{(2,26)}$ = 31.018, $p < .001$, partial eta squared = 0.71, power = 1.0). Bonferroni post-hoc testing revealed a significant increase in ROM from baseline to post-treatment (mean difference = -4.4 cm, SEM = 0.6 cm, p < .001) and from baseline to one day follow-up (mean difference = -2.2 cm, SEM = 0.6 cm, p = .005). Between time points within the TMR® FFTT group, participants maintained 49% of their post-treatment changes at the one day follow up for the VSR.

Perceived Tightness Scale (PTS)

Outlier assessment revealed no significance at baseline for either the TMR® FFTT group (Shapiro-Wilk = 0.93, p = .068) or the sham group (Shapiro-Wilk = 0.97, p = .591). The non-parametric Mann Whitney U was not significant for baseline (U = 368.5, p = .417), immediate post-treatment (U = 332, p = .162) or one day follow-up (U = 337.5, p = .194).

Discussion

In this exploratory study, the TMR® FFTT produced significant improvements in ROM on the AKE, PSLR, FFD, and VSR to a greater extent than the sham treatment immediately following a single session. No significant differences were found to suggest the TMR® FFTT had an effect on ROM measures greater than the sham treatment at a one day follow-up. Although statistically significant gains in ROM were produced, further analysis of the data highlighted the clinical meaningfulness of the results. Moderate (0.65) to large (0.92) Cohen's *d* effect sizes were identified post-treatment, suggesting the TMR® FFTT treatment was clinically relevant with a moderate to large effect on ROM immediately following treatment.

The clinical relevance of this study is also enhanced due to the methodological decisions and a focus on external validity. For example, all participants were active individuals with complaints of AHT who presented to clinicians within collegiate athletic training clinics, with each ROM measurement completed utilizing methods and materials commonly located within clinics. Additionally, the Clinometer application used to record ROM is available for both Android and iPhone users. While participants were asked not to change their activity level during the study, their outside activities were not controlled between the immediate post-treatment measurements and the one day follow-up measurements by the clinicians at any of the five research sites. Therefore, the effects of a single treatment of TMR® FFTT after one day must be interpreted with caution due to the potential for confounding variables as well as the large standard deviations associated with the baseline-one day calculations.

Although the immediate results of the TMR® FFTT were statistically significant, the gains in ROM the participants experienced were moderate by clinical standards on all measures. One explanation for why the gains in ROM were not greater may be that participants were only required to present with restricted ROM on the AKE to be included. As a result, several participants were included who did not display restrictions in ROM on the PSLR (TMR® FFTT = 2, Sham = 3), FFD (TMR® FFTT = 7, Sham = 9), or VSR (TMR® FFTT = 4, Sham = 5). In addition, the lack of restriction in ROM on the PSLR, FFD, and VSR may have contributed to the low percentage (0%, 9.5%, and 2%, respectively) of individuals who achieved functional levels of ROM on each measure immediately following treatment. Although in this preliminary study, the TMR® FFTT demonstrated only moderate results immediately following treatment and no changes after one day, the technique has been explored in other research.

The inclusion of the TMR® FFTT as a regionally interdependent treatment for AHT is supported in the literature in the form of a case study in which the patient gained 20°-30° on the AKE after a single TMR® FFTT treatment.[44] A possible explanation for the greater gains in ROM on the AKE compared to our study is that the case described by Baker et al.[44] featured a patient with a history of lumbar spine pathology with chronic AHT symptoms (over 5 years), and a large TMR® FFTT asymmetry at initial exam. Additionally, the patient's baseline AKE measurements were 13-17° more restricted than the average baseline AKE in our study, which may contribute to the greater gain in ROM achieved on the AKE following a single treatment. Although the patient's changes in AKE ROM were different from our findings, her changes on the SR (4.9cm) were similar to our results for the VSR (4.2cm). The VSR results may be more similar to the SR as both assessments require attention not only to isolated tissue tension, but also to the lumbopelvic and thoracic movements that occur with active trunk flexion. Likewise, increases in hamstring extensibility have been demonstrated on other measures (e.g., AKE, PSLR) with the application of regionally interdependent treatments focused on joint mobility[59,60] and the nervous system.[61]

Similar to the TMR® FFTT, the Mulligan Concept and neurodynamics are treatment paradigms demonstrated to address AHT through a regionally interdependent approach. Neural tension[10,13] and lumbopelvic dysfunction may result in restricted extensibility by creating a perception of hamstring tightness. Treatment of the lumbopelvic complex through Mulligan Concept hip mobilizations with movement effectively increased ROM on the PSLR by 13°-17° in individuals classified with tight hamstrings.[59, 60] Additionally, neurodynamic sliders of the sciatic nerve have also been found to be significantly more effective (9.9° ± 2.5°, 95% CIs: 9.1°, 10.7°) than static stretching (5.5° ± 1.6°, 95% CIs: 5.0°, 6.0°, p=0.006) at improving hip flexion ROM on the PSLR.[61] Compared to the results of these studies, we observed a 5.8° increase in hip flexion ROM on the PSLR immediately following one treatment of the TMR® FFTT. Although the specific mechanism by which the TMR® FFTT affects AHT is unknown, the technique has been proposed to increase hamstring extensibility using the theories of neural coupling[62-64] and biotensegrity.[65] Aside from treatments with a holistic approach, stretching is perhaps the most common local treatment used for addressing AHT.

In several studies, static stretching of the hamstrings musculature has resulted in knee extension and hip flexion ROM gains.[24,36–38,66] DePino et al.[24] found a 5-6° improvement of knee extension ROM on the AKE after four consecutive 30-second static stretches. De Weijer et al.[66] conducted a similar study, identifying a 13° increase in extensibility on the AKE using three 30-second hamstring stretches performed following a warm-up. In addition to a warm-up, variation in methodologies between the two studies include that participants in the De Weijer group were passively stretched in an AKE test position with an adjustment made to increase the stretch if the participant became acclimated after 15 seconds, while participants in the DePino study performed active stretching in a standing position with no adjustments. The TMR® FFTT resulted in gains in ROM on the AKE that were similar to the DePino study (6.4°), but not as drastic as the De Weijer study. The methodological variation in the De Weijer study may help to explain the increased ROM compared to both the DePino study and this study, neither of which included a warm-up or passive stretch with an adjustment for stretch tolerance. Within both the DePino et al. and De Weijer et al. studies, the gains lessened as time progressed, with decreases in motion occurring three[24] to 15 minutes[66] after the cessation of the stretching intervention. The duration of static stretching effect is conflicting in the literature, with return to baseline scores ranging from shortly after treatment to more than one day following treatment. Following the cessation of the stretch intervention, only 4.5% of the extensibility gains were maintained at nine minutes,[24] compared to other reports of 59% maintained after 24 hours.[66]

Although the TMR® FFTT group had statistically significant and clinically meaningful results in comparison to the sham group, the sham group also demonstrated gains in ROM on the AKE immediately post-treatment (2.7°±6.6°) and at a one day follow-up (2.6°±5.5°). A possible explanation for the ROM gains in the sham group is that the forward flexed position may have placed a low-grade static stretch on the musculotendinous and neural structures of the posterior chain. According to the sensory theory,[22] the application of a short-duration stretching technique may perpetuate an increase in stretch tolerance, producing ROM gains over time. Despite the sham group demonstrating gains in ROM and maintaining those gains at one day follow-up, the relatively small ROM gains are within the SEM on the AKE (3.28°) and are likely not clinically meaningful.

In the current study, all participants were identified to have an asymmetry based on the TMR® FFTT evaluation, which may aid in identifying the underlying factors of AHT beyond tissue length deficits. Traditional evaluation of AHT accounts for the joint and tissue length restriction via assessments that include the AKE and PSLR, leading to treatment choices such as stretching. By incorporating a regionally interdependent approach to evaluation, such as the TMR® FFTT, clinicians may be able to more effectively classify patients and provide treatments that address alternative causal factors perpetuating AHT. Therefore, we propose that clinicians should utilize a holistic assessment that guides clinical decision making and treatment selection based on exam findings for patients with AHT.

Limitations and Future Research

Several methodological choices resulted in procedural limitations in this study, including: (a) the multi-site nature of the study, with multiple raters assessing ROM; (b) the decision to focus on a sham comparison versus a direct comparison to an established treatment; (c) no blinding of the clinician occurred in this study; (d) only the AKE was utilized as an inclusion method; (e) the outside activities of the participants were not controlled; (f) each ROM measure was assessed consecutively, with no rest in between. Other limitations include that the results of this study may not be generalized to a population outside of a healthy, young, active group of participants with restricted hamstring extensibility on an AKE assessment. As the focus of this study was on short-term efficacy of a single treatment, implications for long-term results of the TMR® FFTT, or the TMR® system, may not be derived from this study. Additionally, the clinicians providing treatment were relative novices using TMR®, practicing the paradigm for just less than two years.

Future investigators may wish to set more stringent inclusion criteria to determine a more accurate presentation of the treatment's effect on participants who present with restrictions on multiple measures of hamstring extensibility. Similarly, it may be beneficial to identify how AHT varies across the different assessment methods and how each method responds to TMR® FFTT treatment. Furthermore, future studies should be conducted to examine the most effective method of implementing the TMR® FFTT protocol (e.g., feet together or feet apart first).

Conclusion

The current study represents the preliminary exploration of the effects of the TMR® FFTT on patients with limited extensibility on the AKE. The TMR® FFTT is effective at increasing ROM on measures of hamstring extensibility immediately following a single intervention compared to a sham treatment that consisted of a sub-optimal form of static stretching. Despite the many limitations of this study, the outcomes support that the TMR® FFTT may be a promising alternative intervention to the traditional methods, however, further investigation is needed to support this hypothesis.

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Table 5.1. Demographic data for included participants at baseline (N=58).

	TMR® FFTT	Sham
Gender	13 F, 15 M	13 F, 17 M
Age	20.8 ± 1.7	20.6 ± 1.5
AKE (most restricted leg)	42.9º ± 7.7º	45.1º ± 10.1º
TMR® Asymmetry	36.1 ± 20.2	27.8 ± 17.8
PTS Score	5.2 ± 2.0	5.8 ± 1.8
Population	17 IC, 0 CS, 11 REC	17 IC, 2 CS, 11 REC
AKE=active knee extension; PTS=Perceived Tightness Scale; TMR®=Total Motion Release® Activity Level: IC=intercollegiate; CS=club sport; REC=recreational		

Table 5.2. Inter-rater reliability data for all range of motion measurements.

Measurement	Inter-Rater ICC	Inter-Rater 95% CI	SEM	MDC
AKE	0.94	0.90, 0.97	3.28°	9.08°
PSLR	0.88	0.77, 0.94	6.88°	19.07°
FFD	0.98	0.96, 0.99	1.54 cm	4.26 cm
VSR	0.98	0.97, 0.99	1.40 cm	3.89 cm
AKE=active knee extension; CI=confidence interval; FFD-finger to floor distance; ICC=intraclass correlation coefficient; MDC=minimal detectable change; PSLR=passive straight leg raise; SEM=standard error of measurement; VSR=v-sit and reach				

Table 5.3. Intra-rater reliability data for all range of motion measurements.

Rater	AKE	PSLR	VSR	FFD
AZ				
ICC	0.879	0.871	0.95	0.959
SEM	4.31°	5.78°	2.33cm	1.92cm
MDC	11.95°	16.03°	6.46cm	5.31cm
BB				
ICC	0.8	0.889	0.957	0.935
SEM	5.42°	6.49°	2.18cm	2.56
MDC	15.02°	17.98°	6.05cm	7.11cm
BH				
ICC	0.894	0.914	0.951	0.949
SEM	4.30°	5.06°	2.28cm	2.16cm
MDC	11.92°	14.04°	6.31cm	5.98cm
CH				
ICC	0.867	0.872	0.943	0.947
SEM	4.33°	4.99°	2.47cm	2.13
MDC	12.01°	13.82°	6.86cm	5.89cm
RL				
ICC	0.861	0.902	0.965	0.954
SEM	4.86°	5.12°	1.88cm	2.00cm
MDC	13.47°	14.19°	5.22cm	5.55cm

AKE=active knee extension; CI=confidence interval; FFD-finger to floor distance; ICC=intraclass correlation coefficient; MDC=minimal detectable change; PSLR=passive straight leg raise; SEM=standard error of measurement; VSR=v-sit and reach

Table 5.4. Between-subjects effects of TMR® FFTT vs. sham over time.

	Pre-Post (mean difference ± SD)				Pre-One Day (mean difference ± SD)			
	TMR® FFTT	Sham	p-value	95% CI of difference	TMR® FFTT	Sham	p-value	95% CI of difference
Most restricted AKE	6.4°±4.8°	2.7°±6.6°	0.018*	0.66, 6.8	5.0°±6.0°	2.6°±5.5°	0.105	-0.53, 5.5
Most restricted PSLR	5.8°±4.2°	2.2°±4.5°	0.002*	1.4, 6.0	4.4°±8.1°	1.0°±8.1°	0.115	-0.86, 7.7
FFD	4.6±3.4 cm	2.0±4.1 cm	0.010*	0.67, 4.7	2.9±4.6 cm	1.0±5.1 cm	0.155	-0.73, 4.5
VSR	4.4±3.1 cm	1.7±2.9 cm	0.001*	1.1, 4.3	2.2±3.3 cm	-0.12±5.2 cm	0.054	-0.04, 4.6

*Indicates significance using Holm's sequential Bonferroni post-hoc testing.
AKE=active knee extension; CI=confidence interval; FFD=finger-floor distance; PSLR=passive straight leg raise; TMR® FFTT= Total Motion Release® forward flexion trunk twist; VSR=v-sit and reach

Table 5.5. Within-subjects effects of TMR® FFTT over time (mean ± SD).

	Baseline	Immediate Post-Treatment	One-day Follow-up
Most Restricted AKE	42.9º ± 7.7º	36.5º ± 6.8º*	37.9º ± 10.2º*
Most Restricted PSLR	51.6º ± 14.8º	57.4º ± 15.2º*	56.0º ± 13.6º*
FFD	10.5cm ± 10.5cm	5.9cm ± 8.8cm*	7.6cm ± 11.4cm*
VSR	-13.5cm ± 11.0cm	-9.1cm ± 11.0cm*	-11.4cm ± 11.4cm*^

*Significant difference from baseline ($p \le 0.05$)
^Significant difference from immediate post-treatment ($p \le 0.05$)
AKE=active knee extension; FFD=finger-floor distance; PSLR=passive straight leg raise; VSR=v-sit and reach

Figure 5.1. Sham treatment (A only) and TMR® FFTT feet together position (A and B).

Figure 5.2. TMR® FFTT feet apart treatment.

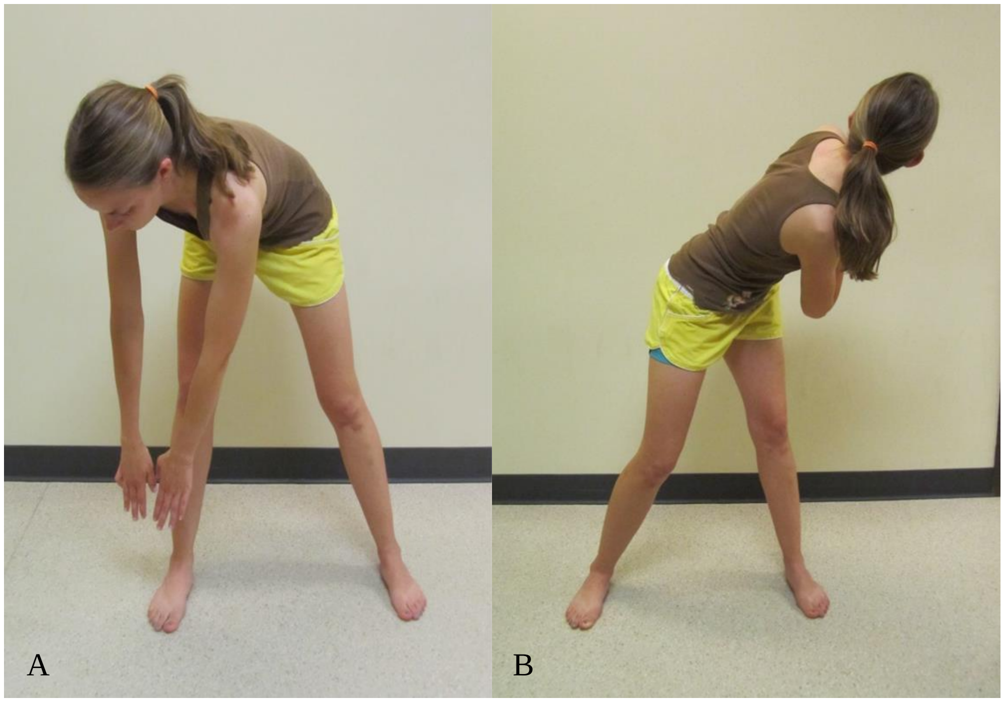


Figure 5.3. Active knee extension (AKE) assessment.

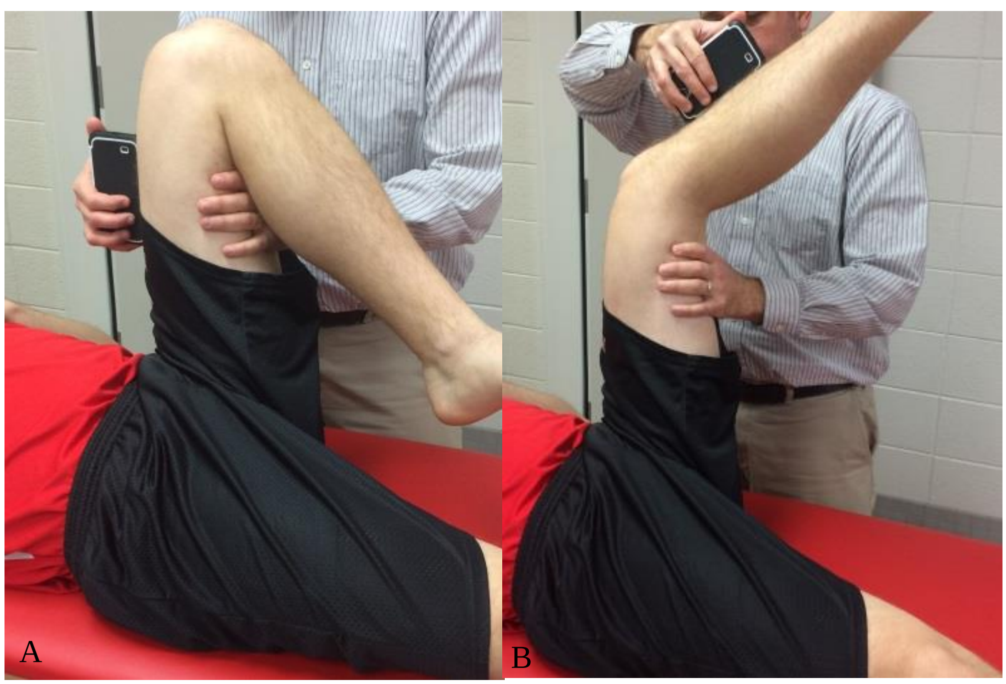


Figure 5.4. Passive straight leg raise (PSLR) assessment.

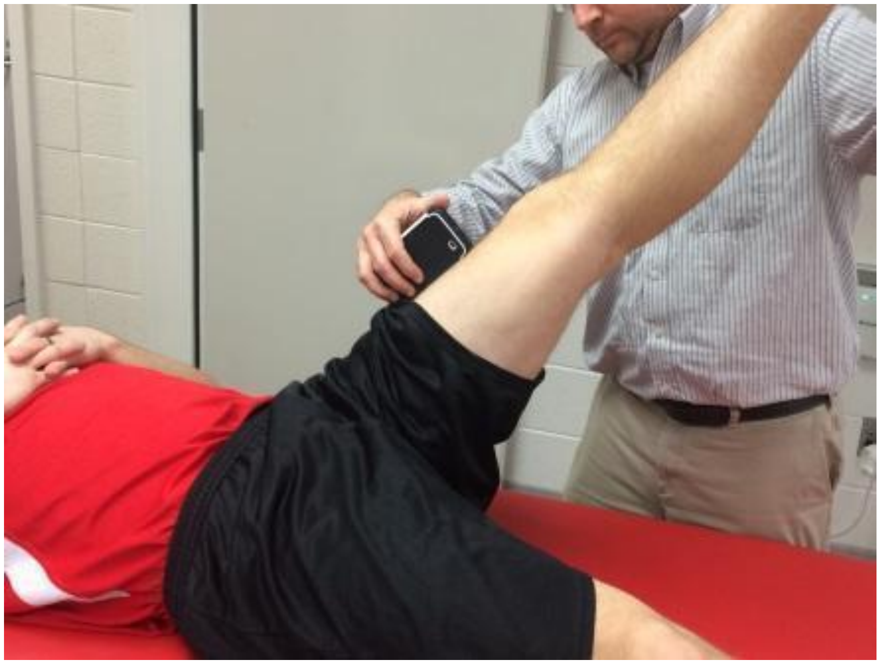
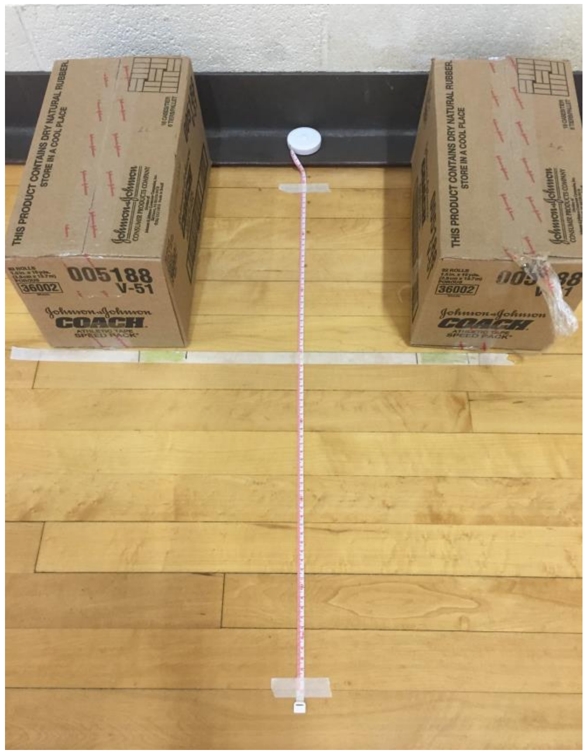


Figure 5.5. Finger to floor distance (FFD) assessment.

Figure 5.6. V-sit and reach (VSR) set-up.



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Author names (in order of authorship): Christy L Hancock, Bethany L Hansberger, Rick A Loutsch, Eric K Stanford Alli K Zeigel, Robert J Bonser, Russell Baker, Scott Cheatham, James May, Alan Nasypany

Manuscript Title: Changes in Hamstring Range of Motion following Proprioceptive Neuromuscular Facilitation Stretching Compared with Static Stretching: A Critically Appraised Topic

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