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CORE STABILITY AND HIP RANGE OF MOTION CHANGES USING THREE DIFFERENT SHORT-TERM INTERVENTIONS AIMED AT MUSCLE FLEXIBILITY AND/OR MOTOR CONTROL AND STRENGTH

Mayrena Hernandez

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by

MAYRENA ISAMAR HERNANDEZ

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ABSTRACT

CORE STABILITY AND HIP RANGE OF MOTION CHANGES USING THREE DIFFERENT SHORT-TERM INTERVENTIONS AIMED AT MUSCLE FLEXIBILITY AND/OR MOTOR CONTROL AND STRENGTH

Mayrena Isamar Hernandez, B.S. Athletic Training

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Faculty Mentor: Cynthia Trowbridge

Previous research has emphasized the importance of incorporating core stability so the trunk and limbs can efficiently generate, transfer, and control forces of energy produced by from athletic activities. Because of the hip/spine interaction within the human body, a link between hip range of motion restrictions and core muscle weakness has been hypothesized. The primary purpose of this study is to assess the acute effects of three different short term therapeutic intervention programs on hip range of motion, core stability, and functional movement in patients with hip range of motion restrictions and altered neuromuscular control of their core muscles. Fourteen healthy UTA students volunteered for the study. They were randomized into one of three therapeutic intervention groups: Myofascial release; motor control and strengthening; or combination of release and exercises. Therapeutic interventions were 2 weeks with 6 total visits. Subjects were evaluated for the span of 6 weeks with pre-test during week 1, therapeutic interventions during weeks 2 and 3, post-test during week 4, and a residual post test during week 6. There were no significant therapeutic intervention group differences for the change scores from post to baseline ($p>0.05$) but at the end of the two-week intervention program, physical improvements were demonstrated across all intervention groups because change scores from post to baseline were positive, indicating an improvement in hip range of motion, core strength, and functional movement. Across all intervention groups change scores from residual to post demonstrated no physical improvements or regression towards baseline values after two weeks of not completing therapeutic exercises ($p>0.05$). Stretching and core interventions separately or combined do improve measures of hip range of motion, core strength, functional movement, and self-reported outcome measures after 6 visits. However, type of intervention did not influence the amount of change seen in measured variables. Six treatments were enough to see acute effects but were not enough for maintenance of gains.

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CHAPTER 1

INTRODUCTION

1.1 Problem Statement

The value of training the core muscles as a part of exercise regiments and therapeutic rehabilitation programs has increased significantly over the last ten years, as core training is pivotal in normal athletic activity.[1,2] Core training entails emphasizing strength, conditioning, flexibility, and neuromuscular control of the local and global muscles of the low back, abdomen, and hip that integrate together in the kinetic chain to stabilize the spine and control positions and motions of the trunk over the pelvis, thereby allowing for optimal production and transfer of forces.[1] Local muscles include the transverse abdominis, multifidus, internal oblique, transversospinalis, and pelvic floor musculature, and the global muscles include rectus abdominis, external obliques, latissimus dorsi, erector spinae, hamstrings, quadriceps, gluteus maximus, adductors, and abductors.[3-5] Strong core musculature provides proximal stability for distal mobility,[1] so the lower extremity can perform activities like kicking, jumping, and running.[1] Stabilizing the spine and pelvis proximally allows the large muscles of the lower extremity to anchor to a strong base of support. These muscles can then generate and transfer forces efficiently throughout the body for acceleration, deceleration, and direction changes that are component parts of most athletic activities.[1] It is often a misconception that just sit-ups or crunches form the basis of a core exercise program; however, some sit-ups or crunches actually place unnecessary high compressive loads on the intervertebral discs and tend to tighten the hip flexors.[5] Exercise prescriptions for the core that includes only sit-ups and crunches can cause muscle imbalances and joint dysfunctions including a common syndrome referred to as lower cross syndrome.[5]

Lower cross syndrome (LCS) presents with irritable or tight hip flexors and back extensors along with weak abdominals and gluteal muscles, which creates inefficient proximal stability, thereby reducing the function of the entire kinetic chain. The typical presentation of someone with LCS is an arched back and forwardly rotated pelvis along with hyperextended knees.[5] LCS is a frequent cause of low back pain and joint dysfunction within the lumbar spine and lower extremity because changes occur in the motor programming of muscles with the hip-spine interface. It has been suggested that proper stretching and strengthening of local and global core muscles may alleviate symptoms of LCS[4] and other dysfunctions.

Despite the evidence that core strengthening improves function and prevents joint dysfunction,[6] there is also evidence that there is no direct relation between core stability and function.[7] Several research studies[8-11] have attempted to identify the core stability effects of improving motor control along with the application of different stretches and/or strengthening exercises for the local and global muscles. However, the type and duration of the exercise prescriptions still needs to be investigated as the neuromuscular system often responds sooner than the actual muscle or tendon tissue so shorter duration programs, with an emphasis on motor control training, need to be assessed.

1.1.1 Purpose

The primary purpose of this study was to assess the acute and residual effects of three different short term (2-weeks) therapeutic intervention programs (stretch only, strength only, combination) on hip range of motion, core stability, and functional movement in patients with hip range of motion restrictions and altered neuromuscular control of their core muscles.

1.1.1.1 Research Questions

1. What were the effects of three different short term (2-weeks) interventions on hip extension, hip internal rotation, and hip external rotation range of motion; abdominal, low back, and pelvic muscles strength and motor control; and functional movements involving a hip-spine interaction?
2. What were the residual effects of three different short term interventions (2-weeks after intervention ended) on hip extension, hip internal rotation, and hip external rotation range of motion; abdominal, low back, and pelvic muscles strength and motor control; and functional movements involving a hip-spine interaction?

1.2 Significance

Research on these topics is an evolving process. As there is more of an emphasis on core stabilization within training and therapeutic rehabilitation programs, a link between core muscle weakness and hip range of motion deficits is becoming more apparent. Research[1] has emphasized the importance of incorporating core stability so the trunk and limbs can efficiently generate, transfer, and control forces of energy generated from athletic activities. Although previous literature did not provide evidence that core training was essential for functional performance, exercises designed to target both local and global muscles are successful at improving core stabilization and hip range of motion[9] thereby suggesting function may be improving although it has not been measureable.

The significance of this research is to add to previous research that emphasizes the importance of the hip-spine interaction and its relationship to muscular balance and to further identifies the importance of addressing muscle flexibility, motor control, and strength in an effort to improve daily living and recreational activities.[9,11,12] We are also attempting to identify a different time frame for making changes in core strength or motor control by using several concentrated exercise sessions.

1.3 Limitations

1. The sample of convenience was limited due to the people we could ask to volunteer. Subjects came from the UTA student population as well as nearby fitness centers.
2. Subjects had to attend supervised training sessions, which were 6 times out of the total of 9 visits they made for the study. The interventions could not be done on their own so this required them to make a trip to the campus lab which was at times a great time commitment for some subjects
3. Sample size decreased due to the inability to make it to training sessions or injury that occurred outside of study. This resulted in decreasing the effectiveness of the study.
4. The availability of facilities and primary investigator time limited the study. The facilities used where not always available, as well as the primary investigator only available for the training sessions three times a week for certain amount of hours. These hours did not fit the schedule of ever volunteer that was interested in the study.
5. The subject understood the explanation of abdominal bracing when they came in for their pre testing for the study. Abdominal bracing was required for hip extension measurement and core assessment.

6. The subject participated in outside training and competitions. Depending on their training and competitions, some days were either higher intensity or rest days and this could have altered the testing.

1.4 Delimitations

1. The age bracket was decided to be 18-40 years old. Initially we had to turn away volunteers just from their ages being greater than 40 years old.
2. To qualify for this study subjects had to have a hip range of motion of the following: total rotation: ≤66°, internal rotation: ≤31°, external rotation: ≤40°, extension: ≤-5°.
3. To qualify for the study subjects had to qualify with a Double Leg Lowering Test of "Fair" (Subject cannot lower legs past 45° while maintaining pressure in Stabilizer™ at or above 40 mmHg) and a Lower Abdominal Muscle Progression score of less than or equal to 3.
4. The number of treatments was limited to 3 times a week for 2 weeks because this study wanted to see the short-term effects of three different interventions.
5. The exercises/interventions for the 3 different groups were selected by the primary investigator. Although, these exercises are not the only exercises for each intervention that could have possibly been done, they were chosen specifically.

1.5 Assumptions

1. This study accounted for subjects performing exercises and tests to the best of their ability and did not rush them through exercises during their training sessions.
2. The primary investigator performed myofascial release properly and consistently across all subjects.

3. The language and demonstration used to teach the various exercises each subject had to perform was crucial for them to understand how to properly perform each exercise.
4. Practicing the abdominal bracing during exercises did not alter post-test assessments. Groups that involved core exercise training sessions were more exposed to abdominal bracing versus those that only performed an abdominal brace during the pre, post, and residual testing.

1.6 Operational Definitions

1. Core musculature was defined as including local musculature as the transverse abdominis, multifidus, internal oblique, transversospinalis, and pelvic floor musculature, and the global musculature including the rectus abdominis, external obliques, latissimus dorsi, erector spinae, hamstrings, quadriceps, gluteus maximus, adductors, and abductors.
2. Abdominal bracing was explained as a technique to recruit muscles for co-contractions that increase spinal stability. This is achieved with a neutral spine posture where normal respiration is maintained and the subject performs a bracing motion (e.g. bringing their sternum to their pelvis).

CHAPTER 2

LITERATURE REVIEW

2.1 Anatomy and Importance of Core

Core stability is an important integral for maximizing function that acts as an anatomical base for transfer of forces by motion of distal segments of the body.[1] This is known as proximal stability for distal mobility where the core is proximal and the moving extremities are distal. Numerous muscles make up the complexity of what the core is. [5] The core is typically divided into the systemic local muscle system (SLMS) and the systemic global muscle system (SGMS). The SLMS allows these movements to have a normal postural reflex mechanism, which transfer to spinal segmental control and small postural shift and adjustments that work synergistically in patterns. SLMS are known as the deeper intrinsic muscles, which include the transverse abdominis, lumbar multifidus, pelvis floor, diaphragm, rotatores interspinales, intertransversarrii, multifidus, intercostals, iliacus, psoas, deep neck flexor group, internal obliques, quadratus lumborum, glutei, lower scapular muscles, deep rotators of the hip and shoulder, and intrinsic foot muscles. The systemic global muscles system (SGMS) is more superficial and delivers more extrinsic movements. The SGMS include the erector spinae, superficial abdominals, lateral quadratus lumorum, latissimus dorsi, pectoralis major and minor, serratus anterior and posterior, strenoclediomastoid, scalenes, upper trapezius, levator scapulae, hamstrings, piriformis, hip flexors, short hip adductors, flexors of the upper limb, and extensors of the lower limb. Most prime movers (SGMS) for the distal segments such as the latissimus dorsi, pectoralis major, hamstrings, quadriceps, and iliopsoas attach to the core of the pelvis and the spine while most prime stabilizers (SLMS) such as the upper and lower trapezius, hip rotators, and glutei attach to the core. The SLMS are more closely linked to better stabilizing the joints of the hip and spine, and providing a strong anchor for the large lower extremity (global) muscles that are used to perform movements like running, jumping, and kicking. Core stability requires the control of the SLMS at simultaneous contraction of the pelvic floor muscles, diaphragm, and the abdominals (transverse abdominis, the internal and external obliques, and rectus abdominis) that increase intra-abdominal pressure to provide a rigid cylinder like support for the trunk and a more stable hip-spine interaction. Research has shown that the transverse abdominis is critical to stabilization of the lumbar spine and its contraction increases intra abdominal pressure before initiation of distal extremity movements. In this way the spine must be stabilized before extremity movement occurs to allow an optimal base of motion and muscle activation.[1]

2.2 Core Dysfunction

Defective pelvic control is due to difficulty activating the SLMS and instead attempts to control the pelvis by abnormal SGMS activation. With this continued altered activation of muscle systems, this will increase the likelihood for a muscle imbalance of inhibited and overactive muscles to occur. This can be described as upper and lower cross syndrome. Upper cross syndrome (UCS) is characterized with weak cervical flexors, rhomboids and lower trapezium muscles. It also presents with tight pectorals and upper trapezius and levator muscles. This result with a forward head posture elevated and protracted shoulders, increased cervical lordosis, and thoracic kyphosis. Lower cross syndrome (LCS) displays with an anterior pelvic tilt, increase lumbar lordosis, knee hyperextension, as well as lateral leg rotation and decreased hip range of motion. With LCS the abdominals and gluteals present as weak while the thoracolumbar extensors and hip flexors are tight. When these muscle patterns of neuromuscular control are altered, the body compensates with ways to perform activities that require transferring forces from the upper and lower extremities such as throwing, running, and kicking. The pelvis in this case can act in prime role as the center of weight shift in the body. When there are imbalances (UCS or LCS), the pelvis will either be postured more anteriorly, which will predominately use more axial flexor activity for movements or a more posterior position where extensor activity is more dominant. When movement patterns are compensated in the hip spine interaction, where the core is deficient, this can lead to low back pain or further injury down the kinetic chain like an ACL injury. Hewett and Myer indicated a mechanical link between altered pelvis postures with decreased neuromuscular control that could create a high knee load making it more susceptible to anterior cruciate ligament injury.[13] Deficits in neuromuscular control of the trunk and pelvis during cutting and landing can lead to uncontrolled pelvis posture that can increase knee abduction during lower extremity motions and torque during activity and put a high risk load on the ACL. Hip extensors, such as the gluteus maximus, play a major role in stabilizing the pelvis during movements like trunk rotation or when the body's center of gravity is shifted. Nadler et al supported that stabilization of the pelvis, with appropriate neuromuscular control of hip extensors, decreased non-specific chronic low back pain.[3] They investigated, over the course of two years, NCAA Division 1 College athletes with a complaint of non-blunt trauma low back pain and the relationship with hip extensor strength. Recent experimental evidence suggests that people with a history of low back pain have altered recruitment and deficient neuromuscular control.[14] Evidence also suggests that the core musculature relationship between the hip and low back can be a contributor to low back pain. To name a few; the psoas, quadratus lumborum, erector spinae, and gluteus maximus at contraction will affect the hip-spin interaction because of the common attachment sites.[15] This can be described as hip-spine syndrome (HSS), which depicts the hip joint as unaligned with an altered pelvis posture in relation to the spin, as well as inadequate muscle length and joint forces. With hip-spine syndrome, hip range of motion comes in as a factor. Studies have found that hip range of motion can affect the quality and ability to transfer forces optimally and allow an adequate neuromuscular control of the core. Core strengthening has come into prominence in sports training as a way to condition athletes, as well as a preventative measure to avoid injury to the spine and/or extremities.[9] Moreside and McGill indicated the link between core muscle weakness, hip range of motion deficits, and altered lumbar spine motion.[9] Altered lumbar spine motion is often linked to low back pain. They investigated the effects of four different 6-week exercise programs on hip range of motion in young men with limited hip mobility. Participants came once a week for formal therapy and completed at least 4 days/week of home exercises. The four programs include: stretching, stretching with motor control exercises, core endurance with motor control exercises, and a control group. The groups that included stretching demonstrated the most improved hip mobility; however, the group that only completed core endurance and motor control exercises also improved hip mobility. Therefore, in cases of limited hip range of motion, it might be important to include core stabilization exercises.

Research has demonstrated the importance of core stability with an efficient trunk to transfer and control forces carried out by extremity actions in human movement involving the kinetic chain. Sometimes core strength is not necessarily the best method of stabilization of the core. Core stabilizers such as the transverse abdominis, multifidus, rectus abdominis, and oblique abdominals were found to be activated consistently before any extremity movements allowing the trunk to have more stability and for movement to be more controlled.[14] Muscle activation and sequencing of the muscles were found to be more important for functional movements that require balance, flexibility, and stability along the kinetic chain in a sports related environment such as in throwing a baseball or kicking a ball.[16]

Pertaining to flexibility, it has also been studied that muscular imbalance can be caused from tight or inhibited muscles. This meaning that musculature is not at the optimal length-tension ratios to stabilize and carry out movements and forces. Fredericson and Mooreside studied the relationship between muscular balance, core stability and injury in runners.[2] They relate back to Hodges and Richardson's study showing that it not simply that the muscles are recruited but when and how they are recruited.[14] Fredericson and Mooreside applied techniques of abdominal bracing through a progressed core intervention program to address muscular imbalance, core strength, motor control through functional movement and stability.[9]

2.3 Assessing Core Strength and Hip Range of Motion

Assessing core strength begins with abdominal bracing. Abdominal bracing occurs when a neutral spine is established (slight lumbar lordosis), a normal respiration is maintained, and a sternal crunch is activated to mobilize the rib cage inferiorly and posteriorly without altering the lumbo-sacral posture.[17] Two very common assessment tests for core strength are the Double Leg Lowering Test (DLLT) and the Lower Abdominal

Muscle Progression test (LAMP); however, in order to be assured that an abdominal brace is present throughout the entire core assessment of these two test for true core strength, a Stabilizer cuff was used.[8,18] The Stabilizer cuff was placed horizontally underneath the supine subject's lower back. After the subject established an abdominal brace, the Stabilizer cuff was inflated to 40 mmHg and the subject had to maintain an abdominal brace indicated by 30 mmHg-50 mmHg ranges throughout core assessment with the DLLT and LAMP tests.

The Double Leg Lowering Test begins with an initial position of 90 degrees of hip flexion with the subject's knees extended while the subject lay supine on an exam table. Before assessment began, the subject was to abdominal brace by maintaining 30-50 mmHg. Once this was established the subject slowly lowered both their legs at the same time toward the table in a 5 second period. Scores ranged from Fair: 5/10, 6/10 (15- 45 degrees) to Good: 7/10, 8/10, 9/10 (45-90degrees) to Normal: 10/10 (90 degrees).

The LAMP was the second test to assess core strength. The LAMP test is modeled after a Sahrmann's progression with a top score of 5/5. Before assessment began, the subject was to abdominal brace by maintaining 30-50 mmHg. The subjects started in a supine hook-lying position (knees bent, feet on the table). Test positions were assessed and tested until the subject could no longer maintain an abdominal brace in each progressed position. The first assessment of the LAMP was a heel slide to extend the leg. If this was successful with an abdominal brace maintained, the subject received a score of a 0.10/5. The second assessment was from a hook-lying position to lift one foot off the table and flex the hip to 90 degrees. If this was successful, the subject received a score of a 0.20/5. The third assessment was to start with one foot lifted and holding the knee to chest with their hands and lifting the other foot off the table and flex the hip. If this was successful with an abdominal brace maintained, the subject received a score of a 0.50/5. The 4th assessment was to start with one foot lifted off the table to a hip flexion position of 115 degrees and then to lift the other foot to the same position. If this was successful with an abdominal brace maintained, the subject received a score of a 0.75/5. The 5th assessment was to start with one foot lifted off the table to a hip flexion position of 90 degrees and then to lift the other foot to the same position. If this was successful with an abdominal brace maintained, the subject received a score of a 1/5. The 6th assessment was to start with one foot lifted off the table to a hip flexion position of 90 degrees and then to lift the other foot to do a heel slide on the table. If this was successful with an abdominal brace maintained, the subject received a score of a 2/5. The 7th assessment was to start with one foot lifted off the table to a hip flexion position of 90 degrees and then to lift the other foot to does a heel slide in the air without touching the table. If this was successful, the subject received a score of a 3/5. The 8th assessment was to start with both feet lifted off the table to a hip flexion position of 90 degrees and then for both feet to perform heel slide on the table. If this was successful with an abdominal brace maintained, the subject received a score of a 4/5. The 9th and last assessment was to start with both feet lifted off the table to a hip flexion position of 90 degrees and then for both legs to straighten out in the air and slowly lower all the way down to the table. If this was successful with an abdominal brace maintained, the subject received a score of a 5/5.

The hip is a ball and socket joint with the ability to move in flexion and extension in the sagittal plane, abduction and adduction in the frontal plane, external rotation and internal rotation in the transverse plane, and in circumduction.[9] Hip range of motion can be measured with a traditional goniometer or a digital protractor. The placement of the goniometer or the protractor depends on which range of motion is being measured. For flexion and extension the fulcrum is placed on the lateral aspect of the hip referencing the greater trochanter. The stationary arm is positioned at the lateral midline of the pelvis, while the moving arm is on the lateral midline of the femur referencing the femoral lateral epicondyle. As for the protractor, it is positioned on the anterior side of the mid-thigh. For abduction and adduction, the fulcrum is positioned over the anterior superior iliac spine. The stationary arm is the imaginary horizontal line extending from one anterior superior iliac spine to the other anterior superior iliac spine. The moving arm is aligned on the anterior midline of the femur referencing to the patella midline. As for the protractor, it is positioned on the lateral side of the mid-thigh while the subject is side lying. For external and internal rotation, the fulcrum is over the anterior aspect of the patella. The stationary arm is perpendicular to the floor or parallel to the supporting surface. The moving arm is on the anterior midline of the lower leg referencing to the tibial crest and the midway point between the malleoli. The protractor is positioned on the calcaneus, while the subject is prone with their knee bent to 90 degrees. (Starkey)

Ranges of motion in the 90th percentile presented as the following: total rotation; 75 degrees; Internal rotation, 37 degrees; external rotation 46 degrees; hip extension -8 degrees.

2.4 Assessing Functional Movement

The Functional Movement Screen (FMS) is a testing tool to assess fundamental movement characteristics. The FMS consists of 7 fundamental movement tests aimed to categorize functional movement patterns. In this study only 3 of the 7 fundamental movement tests were used. These tests were the Over Head Squat (OHS), the Active Straight Leg Raise (ASLR), and the Trunk Stability Push up (TSPU).[19]

A 3-point scoring system assessed the Over Head Squat (OHS). The subject received a score of a 3 if their overhead squat with a dowel was performed with their upper torso parallel to their tibia, their femur was below horizontal, knees were aligned over their feet, and the dowel did not extend past their feet. A score of 2 was received if their overhead squat with a dowel was performed with their upper torso parallel to their tibia, their femur was below horizontal, knees were aligned over their feet, and the dowel did not extend past their feet, but they could only do this with a their heels supported on a 2x6 board. A score of a 1 was received if their overhead squat with a dowel was performed if their upper torso was not parallel to their tibia, their femur was not below horizontal, knees were not aligned over their feet, and lumbar flexion was noted.

The ASLR test positioned the subject supine with both legs on top of a 2x6 board underneath their knees and their arms out to their side with their thumbs up. The subject was to keep the non-tested leg down while the tested leg rose as high as they could and for both feet to be dorsiflexed the entire time. A 3-point scoring system was used for the Active Straight Leg Raise (ASLR). A score of a 3 was received if the subject's ankle resided between mid-thigh and ASIS when they lifted the tested leg, the opposite hip remained neutral and did not externally rotate and the toes remained pointing up, and knees remained in contact with the board. A score of a 2 was received if the subject's ankle resided between the mid-thigh and mid patella. A score of a 1 was received if the subject's ankle resided below the mid patella.

In Trunk Stability Push Up (TSPU), the subject was prone and a 3-point scoring system was used. A score of a 3 was received if the subject performed one rep with their thumbs aligned with their forehead (males) or thumbs aligned with their chin (females), their body is lifted as one united, and feet remained dorsiflexed. A score of a 2 was received if the subjects were to perform one rep with their thumbs aligned with their chin (males) or thumbs were aligned with their clavicle (females), their body was lifted as one unit, and feet remained dorsiflexed. A score of a 1 was received if they were unable to perform one rep with their thumbs aligned to their chin (males) or thumbs aligned with their clavicle (females).

2.5 Assessing Self-Reported Patient Outcomes

The SF-36 is a short form measure of generic health status within the general population that is designed to be self-administered over the age of 14.[20] The test consists of 36 items with eight different health profiles, which are: Physical Functioning (PF), Social Functioning (SF), Role Limitation Physical (RP), Bodily Pain (BP), General Medical Health (GH), Mental Health (MH), Role Limitations (RE), and Vitality (VT). Each scale is defined differently. The descriptions of the eight health profiles are as follows: (PF) limitations in physical activity because of health problems, (SF) limitations in social activities because of physical or emotional problems, (RP) limitations in usual role activities because of physical health problem, (BP) presence of pain and limitation due to pain, (GH) self-evaluation of personal health, (MH) psychological distress and well-being, (RE) limitation in usual role activities because of emotional problems, and (VT) energy and fatigue. Additionally two composite summary scores are measured for Physical Health (PCS) and Mental Health (MCS). These eight health profiles are also measured by norms. The scores are transformed to make a minimum and a maximum score of between 0 and 100. All score above or below 50 can be noted as above or below the general population norm. The deviation for each sub scale is set to 10 above and below 50. Lower scores closer to 0 mean that they have more disability compared to scores that are higher and closer to 100 indicating minimum disability. (Hayes)

Global Rating of Change (GROC) scales provide a method of obtaining patient rated change for outcome measures to quantify a patient's improvement or deterioration over time. The GROC asks that a person assess him or her on their current health status, recall that status as a previous time point, and then calculate the difference between the two time points. This difference is scored on a numerical or visual analogue scale from -7 to +7 with 0 indicating no change from the two time points.[21]

The Roland Morris Questionnaire is a health status measure completed by the patient to assess physical disability due to low back pain. It is used as an outcome measure and for monitoring progress through practice. Questions end with the phrase "because of my back pain" are targeted for low back pain. The Roland Morris Questionnaire score is calculated by adding up the number of items checked. Items are not weighted. The scores therefore range from 0 (no disability) to 24 (maximum disability).[22]

2.6 The Effect of Therapeutic Interventions of Hip Range of Motion

Limitations of the hip joint range of motion are known to affect lumbar spine kinematics. One must consider the hip joint a potential contributor to low back pain because of the given biomechanical relationship of shared musculature the hip and low back have.[15] Moreside et al analyzed the effect of 4 different exercise interventions on passive hip range of motion. The 4 interventions consisted of: 1) passive stretches to improve hip joint rotation and extension, 2) passive stretches to improve hip joint rotation and extension and motor control exercises to improve lower limb movements, 3) improvement of trunk muscle endurance with hip-spine exercises, and 4) control with no intervention.[9] Data collection consisted of hip range of motion assessments of subjects. Hip extension measurements were collected using a modified Thomas Test, which has the subject supine on the edge of a table with a neutral spine monitored by a blood pressure cuff and passively lowered by the researcher to position in maximum hip extension. The non-tested limb was held passively in a position of hip/knee flexion by the researcher. Hip rotation measurements were obtained in a prone lying position while maintaining 90 degrees of knee flexion. After 6 weeks of interventions there were no significant differences between right and left hip extension across all groups. However, there total rotation did demonstrate significance. In the groups that involved stretching (groups 1 and 2), hip range of motion increased significantly for extension, internal rotation, external rotation, right rotation, and left rotation. Specifically, the combination of stretching and motor control exercises improved in each direction. Groups 1 and 2 resulted in the largest increase of hip range of motion with an average extension increasing from the 8th (+7 degrees) percentile to the 75th (-5 degrees) percentile, right total rotation from the 15th (approximately 49 degrees) to the 85th percentile (70 degrees), and left total rotation from the 30th (approximately 55 degrees) to the 85th percentile (70 degrees). Group 3, that only received motor control exercises, only significantly increased their hip internal rotation, left total rotation, and right total rotation. Group 3 improved from 55th percentile (approximately 61 degrees) to 70th percentile (63 degrees) for right total rotation. Group 4, the control group, demonstrated no significant change in range of motion after the 6 weeks of interventions.

Another study only analyzed the effects of stretching on hip extension. With this study, Bushell et al evaluated the effectiveness of stretching only in a lunge position and a combination of stretching in a lunge position and foam rolling on their quadriceps over the course of 3 weeks with each session exactly 1 week from their previous session.[23] Throughout the three session of testing, only in foam rolling in session 2 was there a significant increase in hip extension, but these effects did were not maintained for session 3.

Cipriani et al studied the effects of time specific stretching on hip flexion. In this study each group was given one of the two hamstring stretching protocols for each leg: 10 second duration or 30 second duration, but both has a total stretching over the course of the day as 2 minutes. For a span of 6 weeks, the stretches were performed twice a day, with a total of 2 minutes for each leg. There were no significant differences between protocols of either 10-second duration of stretching or 30-second durations of stretching.[24]

2.7 The Effect of Therapeutic Interventions of Core Strength

Lack of core strength, and its ability to stabilize the trunk for the transfer of forces, can lead to injuries down the kinetic chain.[1] Haladay et al studied the effects of two different 8-week core-strengthening programs on two-core assessment test. The first core-strengthening program was called the Specific Stabilization Exercise (SSE) Group. In this group, exercises were 2-3 times per week and consisted of promoting contractions of the deep stabilizing muscles of the core (multifidus, transverse abdominis, and internal obliques). With the SSE group, exercises consisted of abdominal hallowing where at the same time subjects were to hold contractions of the deep stabilizing muscles while the second group, The General Stabilization Exercise Group (GSE), focused on strengthening of larger global muscles (erector spinae and obliques) for 2-3 times per week. From the 8-week period there was no significant difference detected with the DLLT for either the SSE or the GSE groups, but for the LAMP test there was a significant difference for the GSE group but not the SSE group. The authors concluded that the LAMP test was able to detect a change in muscle performance after an 8-week stabilization program because it is suggested that it is more sensitive to change, as well as having a higher reliability coefficient than the DLLT. These results revealed the usefulness of the LAMP during assessment of core strength.[8]

2.8 The Effect of Therapeutic Interventions of Functional Movement

Core strengthening for stability of the trunk are strongly linked to improving athletic performance in functional movements. Functional movement is the ability to produce and maintain balance between mobility and stability along the kinetic chain, while preforming fundamental patterns.[16] Tse et al study involved a two-factor experiment to observe if a core exercise intervention of 8 weeks improved core musculature strengthening, as well as to see if these changes had any effects on various functional tasks aimed at athletic performance such as: vertical jump, standing broad jump, 10 m shuttle run, 40 m sprint, and a 2-kg medicine ball overhead throw. There was no significant improvement in any of the functional tasks tested, nor significantly improved core musculature after the 8-week core intervention program on their college level rower subjects. It is hypothesized that the intervention program of 8 weeks, consisting of 16 workouts, was too short to elicit a significant effect, as well as the subject themselves were already well-conditioned athletes to begin with. Although there were improvements, they were not significant. It is prudent to say that significant results can take place with more non-competitive, healthy individuals.[10]

Similarly, Tomoko et al studied core stability, functional movement, and performance on 28 healthy individuals. These subjects were tested in 3 categories: Core stability (flexion, extension, right and left lateral bending), Functional Movement Screen (FMS) (overhead squat (OHS), trunk stability push up (TSPU), right and left hurdle step (HSr/HSl), in line lunge (inLLr, inLLl) shoulder mobility (SMr/SMl), active straight leg raise (ASLRr/ASLRl) and rotary stability (RSr/RSl)), performance test (backward medicine ball throw (BOMB), and T-run (TR, and single leg squat (SLS)). There were significant correlations between SLS and flexion and, as well, TR correlating with LATr/LATl. BOMB was significantly correlated with HSr , SMr, TSPU, and RSr, but there were no significant correlations between core stability and FMS in contrary to what was hypothesized. The authors suggest that the relationship between core stability and FMS supports that training as specific. The core assessment was measured with isometric contraction and muscle endurance, whereas the performance test involved dynamic movement.[16]

In another study, sedentary women were considered by seeing the effects of a dynamic exercise program aimed for functional movements that would improve their core strength. For 12 weeks, 3 times per week for 45 minutes, the sedentary women participated in a Swiss ball core training program made of functional/dynamic movements on trunk extensors of the lower back, abdominals, lower limb extensors and flexors, muscular strength and endurance, and flexibility. The effects of this training program revealed that core strength training exercises improved strength, endurance, flexibility, and balance in sedentary women.[25]

CHAPTER 3

METHODS

3.1 Experimental Design

This study consisted of a 3x3 between-within repeated measures design evaluating the independent variables of therapeutic intervention (Myofascial release/stretch (MR/S), Motor control/strengthening (MC/S), or Myofascial release/stretch + motor control/strengthening (Combo)), and time (pre, post, residual post). Dependent variables were hip range of motion (extension, internal rotation, and external rotation), abdominal/low back/pelvis and motor control/strength, and three functional movements involving a hip-spine interaction. Therapeutic interventions were 2 weeks with 6 total visits. We evaluated subjects for the span of 5 weeks with pre-test during week 1, therapeutic interventions during weeks 2 and 3, post-test during week 4, and a residual post-test during week 5. Details are provided in Table 3.1.

Table 3.1: Schedule of Visits for Assessment and Interventions

Week of Visit	Number of Visit	Name of Visit
Week 1	Visit 1	Inclusion and baseline
Week 2	Visits 2-4	Exercise session 1-3
Week 3	Visits 5-7	Exercise session 4-6
Week 4	Visit 8	Immediate post test
Week 6	Visit 9	Residual post test

3.2 Subjects

The study received approval from our Institutional Review Board (IRB #2016-0240) and a written informed consent was obtained from all participants before assessments or interventions began. Thirty-two healthy volunteers (12 males and 20 females) were initially recruited for the study through the University of Texas at Arlington and local fitness clubs. There were two levels of inclusion/exclusion criteria that needed to be met by subjects. Details are provided in Figure 3.1. Initially, ten subjects (7 females: 47±6 yrs; 3 males: 45±7 yrs) were excluded due to not meeting age range for the study. Included subjects then read and signed the informed consent and filled out the health history and activity questionnaire. No subjects were excluded for pregnancy or history of injury. Twenty-two subjects qualified for inclusion, and to begin their pre-testing for physical tests and subjective function assessment. After pre-testing for range of motion, five subjects were excluded based on hip extension assessment (4 females and 1 male), allowing 17 subjects to continue. Subjects that met all criteria then were randomized to one of the three intervention groups by selecting a random number, which assigned them to one of the three interventions group. Seventeen subjects were randomized, resulting in 5 subjects in the Myofascial release/stretch group (MR/S), 7 subjects in the Motor control/strengthening group (MC/S), and 5 subjects in the Myofascial release + motor control/strengthening group (Combo). During the course of study three subjects withdrew due to injury outside of data collection or inability to attend therapeutic intervention sessions. One male in the Combo group tore his anterior cruciate knee ligament while playing soccer and two females in the MC/S group failed to attend multiple intervention sessions. Subject demographics are in Table 3.2.

Figure 3.1: Flow Chart Illustration – Application of Inclusion/Exclusion Criteria and Subject Attrition

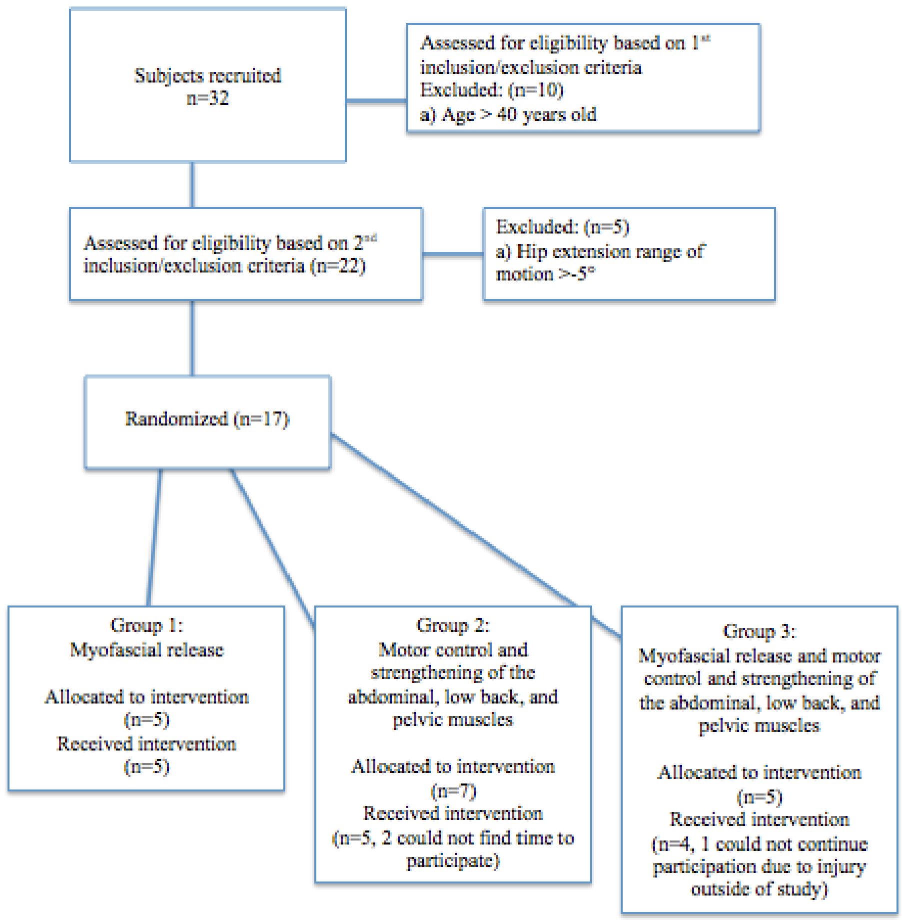


Table 3.2: Subject Demographics

	Myofascial release /stretch	Motor control/ strengthening	Myofascial release/ stretch + motor control/strengthening	TOTAL
No. of participants	5	5	4	14
Age (yrs)	27 ± 8	24 ± 8	27 ± 9	26 ± 7
Height (cm)	168 ± 12	175 ± 9	170 ± 15	171 ± 11
Mass (kgs)	77 ±24	78 ± 13	71 ± 24	76 ± 19
Body Mass Index	28 ± 9	25 ± 2	24 ± 4	26 ± 6

3.3 Instrumentation

3.3.1 Range of Motion Assessment

Range of motion was assessed at the hip for hip extension, internal rotation, and external rotation. For hip range of motion assessment, a digital goniometer and a therapy plinth were used to measure the three ranges. Hip extension was measured in a supine position using the modified Thomas test. Hip internal and external rotation was measured prone, with knees flexed to 90 degrees.

3.3.1.1 Hip Extension

Hip extension was measured in a modified Thomas test position, where the subject sat on the edge of the table and then lay supine with their legs hanging off the table (Figure 3.2). A Stabilizer™ inflatable cuff was used to ensure that the subject did not perform hip extension with hip-spine compensation. The Stabilizer™ cuff was placed under the subject's small of their back and inflated to 40 mmHg.[18] Any deviation of more than 10 mmHg indicated loss of abdominal bracing and a hip-spine compensation, resulting in an arched back. The subject was then instructed to bring the non-measured leg to their chest while the other leg was to be stretched out by remaining in an extended position. Each subject repeated this motion 5 times to alleviate any joint stiffness. The digital protractor was then zeroed out on a leveled surface and then placed parallel to the thigh in align with the patella. Neutral hip extension was achieved as a reference point by having the subject bring both knees towards the chest and perform an abdominal brace where inner and outer abdominal muscles were tightened to maintain a stable spine. The subject was successful if "circular" tension could be developed around the abdomen without pelvic motion while the navel was pulled inward towards the spine. The subject was successful if "circular"

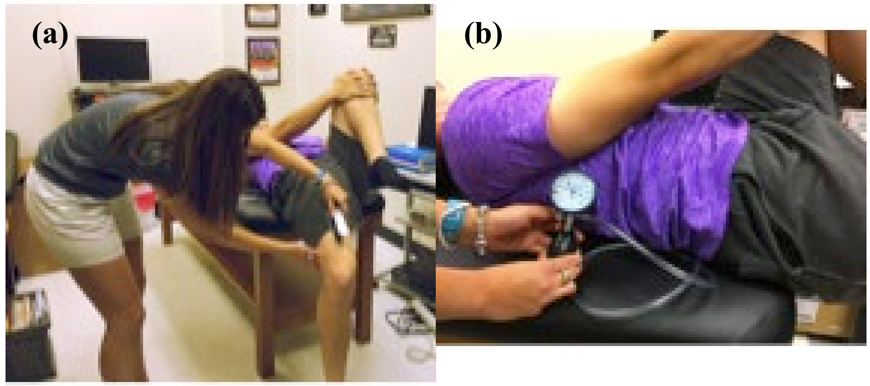


Figure 3.2: (a) Digital Protractor Measuring Hip Extension
(b) Stabilizer™ Ensuring Abdominal Bracing

tension could be developed around the abdomen without pelvic motion while the navel was pulled inward towards the spine. The primary investigator assessed abdominal bracing and neutral hip extension of the measured leg as the subject lowered one supported leg to a position parallel to floor, while maintaining the abdominal brace and opposite knee towards chest. The Stabilizer™ was inflated to 40 mmHg and the subject extended their leg further, while being encouraged to maintain their abdominal brace. Once the abdominal brace was lost, the subject was told to "tighten up" to regain the abdominal brace and further lower their leg into extension. If they were unable to maintain pressure within 10 mmHg on Stabilizer™, then the abdominal brace was lost and the position of the extended leg would be the measurement for their hip extension range of motion. The measurements for hip extension were the point they could extend the most without losing abdominal brace. Measurement for hip extension was repeated with the other leg.

3.3.1.2 Hip Internal and External Rotation

Hip internal rotation and external rotation were measured with the subject in a prone position (Figure 3.3). The subject was instructed to bend their knee to 90 degrees and rotate their hip externally by moving their lower leg toward the midline of the body and then to rotate their hip internally by moving their lower leg away from the midline. Subjects were instructed to not raise hips at the end of range of motion with doing true hip internal and external rotation. The subject was then told to alleviate joint stiffness by

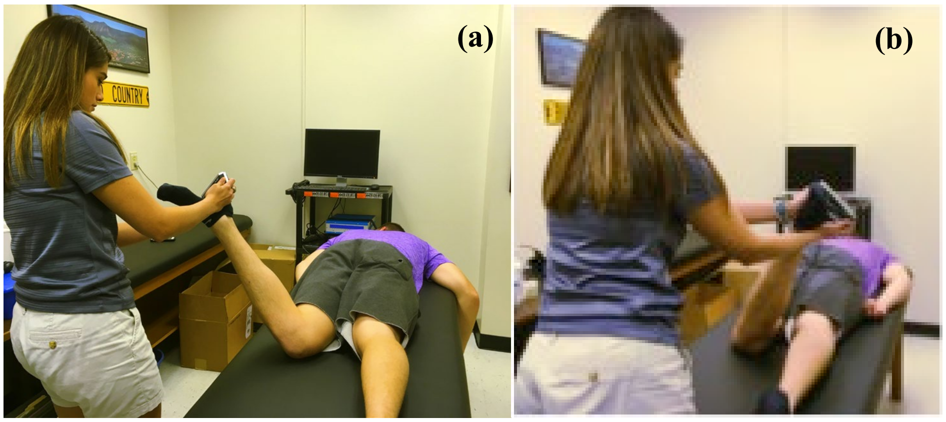


Figure 3.3: (a) Digital Protractor Measuring Hip Internal Rotation
(b) Digital Protractor Measuring Hip External Rotation

moving their hip in and out of internal and external rotation with their knee bent up 5 times. The digital protractor was then zeroed out on a leveled surface and then placed on the subject's calcaneus. The subject was then instructed to bring their foot out to measure internal rotation and then to bring their foot in to measure external rotation without lifting their hips off of the table to gain extra range. This was then repeated with the other leg.

3.3.2 Core Strength/Motor Control Assessment

Core strength/motor control was assessed with the Double Leg Lowering Test (DLLT) and the Lower Abdominal Muscle Progression (LAMP) test using the Stabilizer™ cuff. While in a hook-lying position, subjects were taught to perform an abdominal brace where inner and outer abdominal muscles were tightened to maintain a stable spine. The subject was successful if "circular" tension could be developed around the abdomen without pelvic motion while the navel was pulled inward towards the spine. A Stabilizer™

inflatable cuff was used to ensure that the subject did not perform the tests with hip-spine compensation. The Stabilizer™ cuff was placed under the subject's small of their back and inflated to 40 mmHg. Any deviation of more than 10 mmHg indicated loss of abdominal bracing and a hip-spine compensation resulting in an arched back.

3.3.2.1 The Double Leg Lowering Test

The DLLT (Figure 3.4) assesses the ability of the subject to maintain an abdominal brace as they lower their legs from a vertical starting position (90 degrees hip flexion). The supine subject was instructed to develop and maintain an abdominal brace and then lower both legs together towards the table. The DLLT was then graded by measuring the hip angle at the point where the subject was not able to maintain the abdominal brace and the pressure on the Stabilizer™ cuff changed. If the subject could not lower their legs past a 45 degrees hip angle, he/she received a score of 5/10, 6/10, or 7/10. If the DLLT score was less than or equal to 7/10, he/she was included in the study.

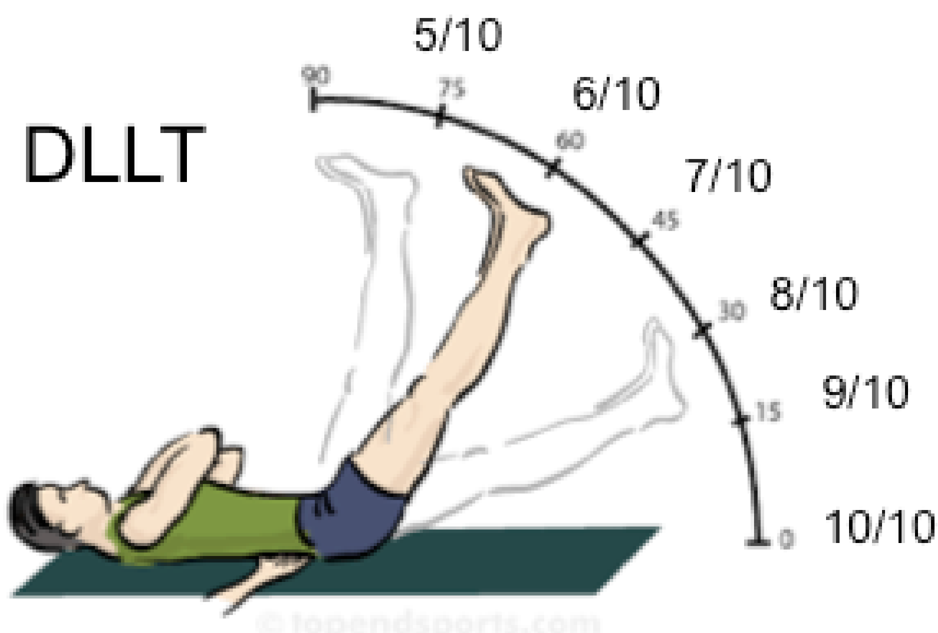


Figure 3.4: The Double Leg Limb Lowering Test (DLLT)

3.3.2.2 The Lower Abdominal Muscle Progression

The LAMP assesses the ability to maintain abdominal bracing throughout a series of progressive movements (Figure 3.5). Throughout all movements, the subject was instructed to maintain an abdominal brace that was measured by the Stabilizer™ cuff. The subject started all test positions with their knees bent to 90 degrees and their feet flat on the table surface. If the subject was successful at the test position, then he/she was allowed to reset and brace their abdomen prior to beginning the next series of movements. Details of scoring are provided in Table 3.3. The subject received a 0.10 if he/she could accomplish a unilateral heel slide, a 0.2 if he/she was able to lift one foot and flex the hip by bringing the knee to the chest, a 0.5 if he/she was able to lift one foot, hold this knee to their chest with their hand and lift the other foot slightly off the table, a 3.0 if the subject was able to lift one foot flexing their hip to 90 degrees and flex the other hip while holding their foot off the supporting table, and 5 if the subject was able to extend their knees then with both knees extended lower both together to the table without losing their abdominal brace. The subject was still included in the study if they scored less than or equal to 3.

Table 3.3: Test Positions for Lower Abdominal Muscle Progression Grading System

Test position	Grade
Slide heel to extend lower extremity	0.10/5
Lift 1 foot, flexing hip	0.20/5
Lift 1 foot, hold knee to chest with hand, lift other foot	0.50/5
Lift 1 foot flexing hip to 115°, lift other foot	0.75/5
Lift 1 foot flexing hip to 90°, lift other foot	1.00/5
Lift 1 foot flexing hip to 90°, flex the other hip and slide the foot on the supporting surface, extend hip/knee	2.00/5
Lift 1 foot flexing hip to 90°, flex the other hip and, while holding foot off the supporting surface, extend hip/knee	3.00/5
Lift both feet to flex hips, slide both feet along the supporting surface so that both hips and knees extend	4.00/5

Lift both feet to flex hips, keep hips flexed while extending knees, then, with both knees extended, lower both lower extremities to supporting surface	5.00/5

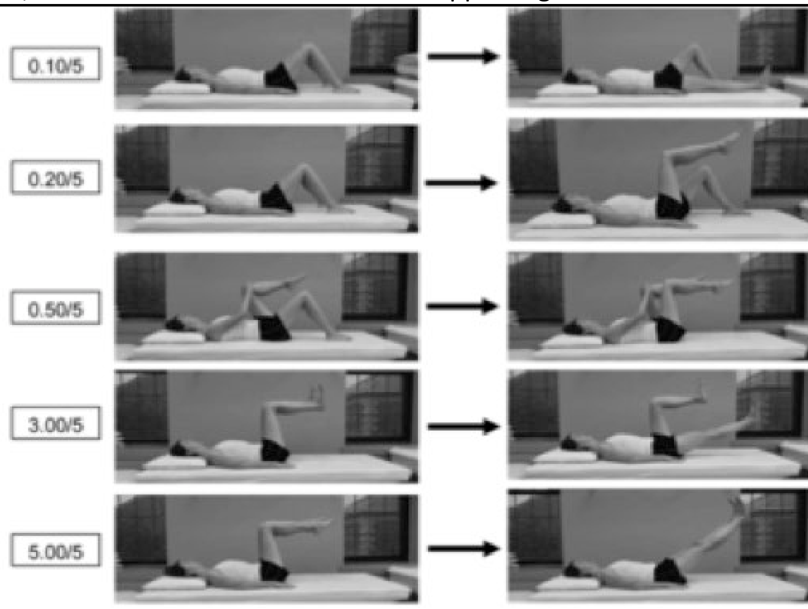


Figure 3.5: The Lower Abdominal Muscle Progression (LAMP) Test

3.3.3 Functional Assessment

The Functional Movement Screen (FMS) System is a series of fundamental movement tests designed to assess functional movement. Three of the seven tests were used for this study: the Deep Squat (DS), the Active Straight Leg Raise (ASLR), and the Trunk Stability Push Up (TSPU). A dowel was used for the Deep Squat, as well as measuring for the Active Straight Leg Raise. Three functional movement screens were done after the core strength assessment. The subject was taken into the hallway, for a more open area, where they were first assessed for their DS test followed by their ASLR and TSPU. For the DS (Table 3.4), the subject was instructed to stand shoulder-width apart and to go into a squat to 90 degrees of knee flexion without turning their feet out or bringing their heels up. If the subject was not able to reach 90 degrees of knee flexion, or they needed to bring their heels up or move their feet outward, or there was too much of a forward trunk lean, the subject then repeated their deep squat, but with a board underneath their heels.

Table 3.4: Scoring System for Deep Squat

3	2 (Performed with heels on board)	1 (Performed with heels on board)
• Upper torso is parallel with tibia or toward vertical • Femur below horizontal • Knees are aligned over feet • Dowel does not extend past feet	• Upper torso is parallel with tibia or toward vertical • Femur below horizontal • Knees are aligned over feet • Dowel does not extend past feet	• Tibia and upper torso are not parallel (remain upright) • Femur is not below horizontal • Knees are not aligned over feet • Lumbar flexion is noted

For the ASLR (Table 3.5), the subject lay on floor and actively raised their leg into a hip flexion while maintaining floor contact with the other leg. The relative distance the leg was raised was used to score this test.

Table 3.5: Scoring System for Active Straight Leg Raise

3	2	1
• Ankle/Dowel resides between mid-thigh and ASIS • Opposite hip remains neutral (does not externally rotate), toes remain pointing up • Knees remain in contact with board	• Ankle/Dowel resides between mid-thigh and mid patella	• Ankle/Dowel resides below mid-patella

For the TSPU (Table 3.6), the subject was instructed to perform a push-up with their hands positioned at the chin (males) or clavicles (females). The push–up needed to be error free without lag at any joints. See Tables 3.4-3.6 for more detail on scoring.

Table 3.6: Scoring System for Trunk Stability Push Up

3	2	1
• Males perform one rep with thumbs aligned with forehead • Females perform one rep with thumbs aligned with chin • Body lifted as one unit (no lag in spine) • Feet remained dorsiflexed	• Males perform one rep with thumbs aligned with chin • Females perform one rep with thumbs aligned with clavicle • Body is lifted as one unit • Feet remained dorsiflexed	• Males are unable to perform one rep with thumbs aligned with chin • Females are unable to perform one rep with thumbs aligned with clavicle

3.3.4 Patient Related Outcome Scales

Subjects also filled out patient related outcome scales during their initial pre testing session, post-testing, and residual testing. These are in Appendix A. The Roland Morris questionnaire is composed of 24 questions to assess back pain as experienced in the last 24 hours. "Yes" items are totaled, where a 24 would describe maximum disability. The second questionnaire that was used was the SF-36, which is a 36-item questionnaire that is divided into 8 subscales and 2 composite domains. These subscales are Physical Functioning (PF), Role Limitations Physical (RP), Bodily pain (BP), General Medical Health (GH), Vitality (VT), Social Functioning (SF), Role Limitations Emotional (RE), and Mental Health (MH). Two combined scores, called the Physical Component Score (PCS) and Mental Component Score (MCS), allow for data reduction into two distinct constructs. SF-36 answers were entered on software via scoring website and raw scores on a 0-100 scale. Normalized scores with a median of 50 were produced. Norm scores allow for comparison and changes >±10 are considered clinically meaningful.[20] The third questionnaire was the Global Rating of Change (GROC), which assesses the general worsening or improvement in functioning related to treatments received. It is commonly used in physical therapy settings to determine the effectiveness of treatment.[21]

3.4 Procedures

The subjects reported to the University of Texas at Arlington's Physical Education Building room 200 for informed consent, health history, range of motion, and core assessment. If the subject qualified, he/she was randomized into one of three intervention groups: (1) Myofascial release/stretch (MR/S), (2) Motor control and strengthening of the abdominal, low back and pelvic muscles (MC/S), and (3) a combination of groups 1 and 2 (Combo). Subjects then filled out a Roland Morris and a SF-36 Questionnaire and completed the functional movement screen with the DS, TSPU, and ASLR. After pre-testing, subjects began their assigned intervention. Subjects met at the same time for 5 more visits where they completed their interventions according to group assignment. After completion of 6 interventions, subjects repeated the hip ROM, DLLT, LAMP, FMS tests, and patient outcome questionnaires. These were also repeated one week after the post testing to test for residual effects.

3.5 Intervention Programs

The therapeutic Intervention period was a 2-week intervention with 3 days of exercises each week. Exercises were determined by the group assignment. MR/S group performed stretching and tissue extensibility exercises, MC/S group performed motor control training exercises and core exercises using a Swiss ball, and Combo group performed both training regimens. Exercise regimens were approximately 30-45 minutes/day and were completed on-site at UT-Arlington. Every group went through six separate exercise intervention days (from visit 2-visit 7). After Visit 7 subjects were to resume their normal routine and not work on these exercises.

3.5.1 Myofascial Release/Stretching Intervention

If the subject was assigned to group 1 they received a myofascial release and stretching intervention. This included 15 minutes of myofascial release to core muscles and 15 minutes of lower body stretches. Ironing was the myofascial release technique used by primary investigator and was performed by applying one hand to pin down a proximal area of the body while the other hand moved away from the pinned one to create a smooth technique of pressure across the surface of the targeted muscle. See Table 3.7 for intervention specifics. Pictures are included in Appendix B.

Table 3.7: Myofascial Release/Stretch (MR/S)

Stretches (3 sets x 30 seconds)*	Myofascial Release*
Clinician Assisted Hip Extension Hip Internal Rotation Hip External Rotation Prone Press Up Child's Pose Pigeon Hamstring Lunge Side- Bend	15 minutes of myofascial ironing to latissimus dorsi, quadratus lumborum, hamstrings, gastrocnemius/ soleus

*These exercises/release techniques will be performed at visits 2-7

3.5.2 Motor Control/Strengthening of the Abdominal, Low Back, and Pelvic Muscles

If the subject was assigned to MC/S their interventions consisted of 30 minutes core exercises to strengthen the abdominals, low back, and pelvic muscles. Their exercises were assigned by their level of advancement in core strength from baseline testing in the pre testing core assessments. These exercises consisted of abdominal bracing, motor control, and functional core strength exercises. These included exercises were performed on the treatment table or on a Swiss ball. See Table 3.8 for details.

Table 3.8: Motor Control and Strengthening of the Abdominal, Low Back, and Pelvic Muscles (MC/S)

Intervention Session Day	Exercises	Resistance
1	Control of core translation (supine) 3x10	
	Sahrmann Exercises 3x10 – based on level	
	Weighted Belt Feedback 3x10	
	Dead bug exercises 3x10	
2	Control of core translation (supine) 2x10	
	Sahrmann Exercises 3x10	
	Weighted Belt Feedback 3x10	
	Dead bug exercises 3x10	
	Swiss-ball straight-arm crunch 3x10	
	Swiss-ball alternate arm and leg extension 3x10	
3	Sahrmann Exercises 3x10	
	Weighted Belt Feedback 3x10	
	Dead bug exercises 2x10	
	Swiss-ball straight-arm crunch 3x10	
	Swiss-ball alternate arm and leg extension 3x10	
	Swiss-ball wall squat 3x10	
	Swiss-ball back extension 3x10	
4	Sahrmann Exercises 4x10	Theraband
	Weighted Belt Feedback 3x10	
	Swiss-ball straight-arm crunch 4x10	
	Swiss-ball alternate arm and leg extension 3x10	
	Swiss-ball wall squat 4x10	
	Swiss-ball back extension 3x10	
5	Sahrmann Exercises 3x10	DB/ Ankle Cuff
	Weighted Belt Feedback 3x10	Weighted bar
	Swiss-ball alternate arm and leg extension 3x10	DB/Ankle Cuff
	Swiss-ball wall squat 5x10	
	Swiss-ball Shoulder Bridge 3x10	
6	Sahrmann Exercises 3x10	DB/ Ankle Cuff
	Weighted Belt Feedback 3x10	
	Swiss-ball alternate arm and leg extension 3x10	DB/ Ankle Cuff
	Swiss-ball Shoulder Bridge 3x10	
	Swiss-ball leg raise 3x10	

3.5.3 Myofascial Release/Motor Control and Strengthening of the Abdominal, Low Back, and Pelvic Muscles

If the subject was assigned to Combo group they were required to do a combination of group 1 and 2 that was 45 minutes long. The stretching/release was reduced from 30 minutes to 15 minutes (5 minutes of manual, 10 minutes of stretches) and the core exercises were 30 minutes long and the same as group 2. See Table 3.9 for details.

Table 3.9: Myofascial Release and Motor Control and Strengthening of the Abdominal, Low Back, and Pelvic Muscles (Combo)

Stretches (3 sets x 30 seconds)*	Myofascial Release*
Clinician Assisted Hip Extension Hip Internal Rotation Hip External Rotation Pigeon Hamstring Lunge Side- Bend	5 minutes of myofascial ironing to latissimus dorsi, quadratus lumborum, hamstrings, gastrocnemius/ soleus

*These exercises/release techniques will be performed at visits 2-7

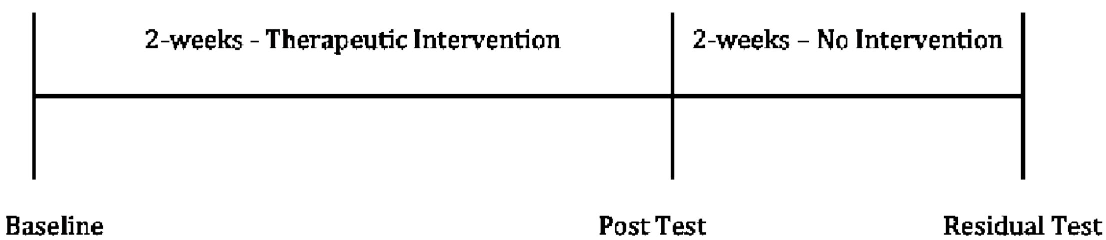
Intervention Session Day	Exercises	Resistance
1	Control of core translation (supine) 3x10	
	Sahrmann Exercises 3x10 – based on level	
	Weighted Belt Feedback 3x10	
	Dead bug exercises 3x10	
2	Control of core translation (supine) 2x10	
	Sahrmann Exercises 3x10	
	Weighted Belt Feedback 3x10	
	Dead bug exercises 3x10	
	Swiss-ball straight-arm crunch 3x10	
	Swiss-ball alternate arm and leg extension 3x10	
3	Sahrmann Exercises 3x10	
	Weighted Belt Feedback 3x10	
	Dead bug exercises 2x10	
	Swiss-ball straight-arm crunch 3x10	
	Swiss-ball alternate arm and leg extension 3x10	
	Swiss-ball wall squat 3x10	
	Swiss-ball back extension 3x10	
4	Sahrmann Exercises 4x10	Theraband
	Weighted Belt Feedback 3x10	
	Swiss-ball straight-arm crunch 4x10	
	Swiss-ball alternate arm and leg extension 3x10	
	Swiss-ball wall squat 4x10	
	Swiss-ball back extension 3x10	
5	Sahrmann Exercises 3x10	DB/ Ankle Cuff
	Weighted Belt Feedback 3x10	Weighted bar
	Swiss-ball alternate arm and leg extension 3x10	DB/Ankle Cuff
	Swiss-ball wall squat 5x10	
	Swiss-ball Shoulder Bridge 3x10	
6	Sahrmann Exercises 3x10	DB/ Ankle Cuff

	Weighted Belt Feedback 3x10	
	Swiss-ball alternate arm and leg extension 3x10	DB/ Ankle Cuff
	Swiss-ball Shoulder Bridge 3x10	
	Swiss-ball leg raise 3x10	

3.6 Statistical Analysis

The study design was 3 x 3 (group x time) between-within model with repeated measures for time. Independent variables included group and time. For group, we had a Myofascial Release/Stretch, Motor Control and Strengthening, and Combination of two groups. For time, we had baseline, post, and residual measure (Figure 3.6).

Figure 3.6: Timeline for Research Study



We measured several dependent variables including hip range of motion, core strength, functional movement, and self-reported function. However, due to variability in baseline measures for several dependent variables and a limited sample size we reduced data to analyze two separate change scores for each dependent variable. A post-baseline change score and a residual-post change score were calculated and analyzed separately using an ANCOVA with group as the between factor and baseline measures for each dependent variable as the covariate. NCSS version 10 statistical software (NCSS[10], Kaysville, UT) was used and alpha was set *apriori* = 0.05 and Tukey-Kramer post-hoc testing was performed to determine differences between groups.

CHAPTER 4

RESULTS

4.1 Hip Extension Range of Motion

Baseline, post intervention, and residual range of motion data for left and right hip extension range of motion are included in Appendix C (Table C.1 and Figure C.1).

There was no group significant difference for post-baseline change score for left hip extension ($F_{(2,10)}$=0.01, p=0.98) and right hip extension ($F_{(2,10)}$=1.11, p=0.36) (Figure XX). Post-baseline changes for left extension indicated improved and were 21±8.8°(95%CI:-3.4°-45.8°) (Myofascial), 28±3.3°(95%CI:18.5°-37°) (Core), and 25±8.6°(95%CI:-2.5°-52.5°) (Combo) and right extension were 35±7.8°(95% CI:13.6-57.2°) (Myofascial), 23±5.1° (95%CI:8.6°-36.8°) (Core), and 13±8.8° (95%CI:-14.7°-41.5°) (Combo).

There was no group significant difference for residual-post change score for left hip extension ($F_{(2,10)}$=2.02, p=0.18) and right hip extension ($F_{(2,10)}$=0.70, p=0.51) (Figure XX). Residual-post for left extension were changes were -6.8±3.1° (95%CI:-15.4°-1.8°) (Myofascial), -1.4±3.9° (95%CI:-12.3°-9.7°) (Core), and -17.9°±10 (95%CI:-50°-13.96°) (Combo) Residual-post changes were -13±7.4° (95%CI:-33.7°-7.4°) (Myofascial), -3±1.2° (95%CI:-6.2°-0.5°) (Core), and -10±11.6° (95% CI:-46.7°-26.9°) (Combo).

Therefore, none of the interventions were more successful than the other for improving hip extension range. However, all groups demonstrated improvements from baseline to post assessment because of positive change scores. At post-test, both the MC/S and Combo groups resulted in greater improvement to left hip extension (non-dominant leg), but MR/S groups resulted in greater improvement to right hip extension (dominant leg). At residual assessment there was either no improvement or a loss of range of motion relative to the post assessment. Range of motion improvements diminished over the 2 weeks without therapeutic interventions, indicating that the magnitude of the acute effects of the intervention did not last. Box plots of changes are in Appendix D (Figure D.1 and D.2).

4.2 Hip Total Rotation Range of Motion

Baseline, post intervention, and residual range of motion data for left and right hip total rotation (degrees from internal to external rotation) range of motion are included in Appendix C (Table C.2 and Figure C.2).

There was no group significant difference for post-baseline change score for left total hip range of motion ($F_{(2,10)}$=2.36, p=0.14) and for right total hip range of motion ($F_{(2,10)}$=0.39, p=0.68) (Figure XX). Post-baseline changes for left total hip were 21±9.2° (95%CI:-4.3°-46.7°) (Myofascial), 12.5±2.9° (95%CI:4.6°-20.5°) (Core), and 16.1±4.6° (95%CI:1.4°-30.8°) (Combo) and for right total hip were 8±3.1° (95%CI:-0.9°-16.3°) (Myofascial), 12±6.1° (95%CI:-4.7°-29.4°) (Core), and -13.7±4.8° (95%CI:-1.7°-28.9°) (Combo).

There was no group significant difference for residual-post change score for left total hip range of motion ($F_{(2,10)}$=0.69, p=0.52) and for right total hip range of motion ($F_{(2,10)}$=0.01, p=0.99) (Figure XX). Residual-post changes for left total hip were -7.1±4.1° (95%CI:-18.4°-4.2°) (Myofascial), -1±2.3° (95%CI:-7.8°-5°) (Core), and -7±5.4° (95% CI:-24°-10°) (Combo) and for right total hip were 3±3.2° (95%CI:-5.6°-

12.2°) (Myofascial), 4±2.9° (95%CI:-4.4°-12°) (Core), and 3±6.9° (95%CI:-18.7°-25.5°) (Combo).

Therefore, none of the interventions were more successful than the other for improving total hip rotation. However, all groups demonstrated improvements from baseline to post assessment because of positive change scores. At post-test, MR/S group improved total left hip rotation (non-dominant leg) whereas the MC/S and Combo group improved total right hip rotation (dominant leg). At residual assessment there was either no improvement or a loss of range of motion relative to the post assessment. Range of motion improvements diminished over the 2 weeks without therapeutic interventions, indicating that the magnitude of the acute effects of the intervention did not last. Box plots of changes are in Appendix D (Figure D.3 and D.4).

4.3 Core Assessment

Baseline, post intervention, and residual scores for Double Leg Lowering Test (DLLT) and the Lower Abdominal Muscle Progression (LAMP) test are included in Appendix C (Table C.3 and Figure C.3).

There was group significant difference for post-baseline change score for the DLLT ($F_{(2,10)}$=3.21, p=0.08) (Figure XX). Post-baseline changes for the DLLT were 0.2±0.4 (95%CI:-0.8-1.2) (Myofascial), 1.4±0.24 (95%CI:0.7-2.1) (Core), and 2±0.8 (95%CI:-0.6-4.1) (Combo). There was no group significant difference for residual-post change score for the DLLT ($F_{(2,10)}$=0.44, p=0.65) (Figure XX). Residual-post changes for the DLLT were -0.4±0.4 (95%CI: -1.5-0.7) (Myofascial), -0.4±0.5 (95%CI:-1.8-1.0) (Core), and -1±0.5 (95%CI:-2.3-0.8) (Combo).

There was no group significant difference for post-baseline change score for the LAMP ($F_{(2,10)}$=0.06, p=0.94) (Figure XX). Post-baseline changes for the LAMP were 1.1±0.5 (95%CI: 2.5-2.1) (Myofascial), 2.1±0.3 (95%CI: -1.2-2.9) (Core), and 2.2±1.0 (95%CI:-1.0-5.4) (Combo). There was no group significant difference for residual-post change score for the LAMP ($F_{(2,10)}$=0.08, p=0.92) (Figure XX). Residual-post changes for the LAMP were 0.4±0.6 (95%CI:-1.3-2.1) (Myofascial), 0.4±0.4 (95%CI:-0.7-1.5) (Core), and 0.8±0.8 (95% CI:-1.6-3.1) (Combo).

Therefore, none of the interventions were more successful than the other for improving DLLT and LAMP. However, all groups demonstrated improvements from baseline to post assessment because of positive change scores. The groups that performed core strengthening exhibited the best changes at post-test. At residual assessment there was either no improvement or a of core control relative to the post assessment. Core control scores diminished over the 2 week without therapeutic interventions, indicating that the magnitude of the acute effects of the intervention did not last. Box plots of changes are in Appendix D (Figure D.5 and D.6).

4.4 Functional Assessment

Baseline, post intervention, and residual scores for functional assessment data for the Overhead Squat (OHS), Active Straight Leg Raise (ASLR), and Trunk Stability Push Up (TSPU) are included in Appendix C (Table C.4 and Figure C.4).

There was no group significant difference for post-baseline change score for the OHS ($F_{(2,10)}$=0.22, p=0.80), ASLR ($F_{(2,10)}$=2.04, p=0.18), and TSPU ($F_{(2,10)}$=2.59, p=0.12) (Figure XX). Post-baseline changes for OHS were 0.6±0.2 (95%CI:-0.1-1.3) (Myofascial), 0.6±0.2 (95%CI:-0.1-1.3) (Core), and 0.8±0.3 (95%CI:-0.04-1.5) (Combo), ASLR were

1±0.3 (95%CI:0.1-1.9) (Myofascial), 0.6±0.2 (95%CI:-0.1-1.3) (Core), and 0.8±0.3 (95%CI:-0.04-1.5) (Combo), TSPU were 1±0.3 (95%CI:0.1-1.9) (Myofascial), 0.8±0.2 (95%CI:0.2-0.2) (Core), and 0.8±0.3 (95%CI:-0.04-1.5) (Combo).

There was no group significant difference for residual-post change score for the OHS ($F_{(2,10)}$=0.08, p=0.92), ASLR ($F_{(2,10)}$=2.04, p=0.18), and TSPU ($F_{(2,10)}$=2.59, p=0.12) (Figure XX). Residual-post changes for OHS were -0.2±0.2 (95%CI:-0.8-3.6) (Myofascial), -0.2±0.2 (95%CI:-0.8-3.6) (Core), and 0±0 (95% CI:0-0) (Combo), ASLR were 0±0 (95%CI:0-0) (Myofascial), -0.4±0.2 (95%CI:-1.1-0.3) (Core), and -0.3±0.3 (95%CI:-1.0-0.5) (Combo), TSPU were 0.2±0.6 (95%CI:-1.4-1.8) (Myofascial), -0.2±0.2 (95%CI:-0.8-0.4) (Core), and 0.8±0.3 (95% CI:-0.04-1.5) (Combo).

Therefore, none of the interventions were more successful than the other but all groups exhibited positive changes indicating improvements. However, there were trends towards better improvements for the MS/R group for the ASLR and TSPU test at post assessment. Functional movement scores diminished over the 2 weeks without therapeutic interventions indicating that the magnitude of the acute effects related to the intervention did not last. Box plots of changes are in Appendix D (Figure D.7 and D.8).

4.5 Patient Outcome Scales

Baseline, post intervention, and residual scores for the eight subscales of the SF-36 health questionnaire are found in Appendix C (Table C.5 and Figure C.5 a-h). Normalized scores (0-100, population norm = 50) are presented for Physical Functioning (PF), Role Limitations Physical (RP), Bodily pain (BP), General Medical Health (GH), Vitality (VT), Social Functioning (SF), Role Limitations Emotional (RE), Mental Health (MH) are the subscales. Two combined scores called the Physical Component Score (PCS) and Mental Component Score (MCS) allow for reduction of data into two subscales, these are presented in Appendix C (Tables C.6 & C.7 and Figure C.6 and C-7).

There were significant differences for post-baseline change score for the PF ($F_{(2,10)}$=4.43, p=0.04), GH ($F_{(2,10)}$=5.58, p=0.02), and PCS ($F_{(2,10)}$=4.83, p=0.03) scores. (Figure XX). Post-baseline changes for PF were 1.7±1.0 (95%CI:-1.2-4.5) (Myofascial), -0.4±0.4 (95%CI:-1.6-0.7) (Core), and 1.1±0.6 (95%CI:-0.9-2.9) (Combo), for GH were 6.1±3.5 (95%CI:-3.7-15.9) (Myofascial), -2.2±2.5 (95%CI:-9.1-4.8) (Core), and 0.2±1.0 (95%CI:-2.8-3.6) (Combo), and for PCS were 3.4±1.7 (95% CI:-1.6-8.1) (Myofascial), -1.1±1.2 (95% CI:-4.3-2.2) (Core), and -1.±0.89 (95% CI:-3.8-1.8) (Combo). The MS/R group experienced the most positive changes in physical functioning, general health, and the physical composite score. However, the combination group also saw more improvement in physical functioning. However, changes of >±10 for norm scores are interpreted as clinically meaningful.

There were no group significant differences for RP ($F_{(2,10)}$=0.77, p=0.48), BP ($F_{(2,10)}$=1.31, p=0.31), VT ($F_{(2,10)}$=2.54, p=0.12), SF ($F_{(2,10)}$=1.01, p=0.39), RE ($F_{(2,10)}$=0.85, p=0.45), MH ($F_{(2,10)}$=0.10, p=0.90), and MCS ($F_{(2,10)}$=1.17, p=0.34) for post-baseline change scores. Post-baseline changes for RP were 1.4±1.4 (95%CI:-2.5-5.3) (Myofascial), -1.4±1.4 (95%CI:-5.3-2.5) (Core), and 0±0 (95%CI:0-0) (Combo), BP were 03.8±2.7 (95%CI:-3.8-11.5) (Myofascial), -0.2±3.1 (95%CI:-8.6-8.6) (Core), and -0.1±3.9 (95%CI:-12.6-12.4) (Combo), VT were 2.4±2.3 (95%CI:-3.9-8.56) (Myofascial), 2.4±2.9 (95%CI:--5.7-10.4) (Core), and 5.9±2.8 (95%CI:-3.0-14.9) (Combo), SF were 1.1±1.1 (95%CI:-1.9-4.1) (Myofascial), 0±0 (95%CI:0-0) (Core), and 4.1±2.6 (95%CI:-4.2-12.3) (Combo), RE were 2.1±2.1 (95%CI:-3.7-7.9) (Myofascial), -4.2±4.2 (95%CI:-

15.9-7.5) (Core), and 5.3±5.3 (95%CI:-11.5-22.1) (Combo), MH were 1.3±2.7 (95%CI:-6.1-8.7) (Myofascial), 2.7±1.5 (95%CI:-1.5-6.9) (Core), and 3.4±2.7 (95%CI:-5.2-12.0) (Combo), MCS were 1.4±2.4 (95%CI:-5.4-8.1) (Myofascial), 0.4±1.9 (95%CI:-4.8-5.6) (Core), and 6.1±3.2 (95%CI:-3.9-16.2) (Combo).

There were no group significant differences for all subscales and composite scores for residual-post changes. Residual-post changes for PF -1.3±0.8 (95%CI: -3.9-1.1) (Myofascial), 0.4±0.4 (95%CI:-0.7-1.6) (Core), and 0±0 (95%CI:0-0) (Combo), BP were -5.6±1.6 (95%CI:-9.9- -1.3) (Myofascial), -2.1±2 (95%CI:-7.5-3.4) (Core), and -1±2.6 (95%CI:-9.3-7.3) (Combo), RP were 0±0 (95%CI:0-0) (Myofascial), -2.8±2.8 (95%CI:-10.7-5.0) (Core), and 0±0 (95%CI:0-0) (Combo), BP were -5.6±1.6 (95%CI:-9.9- -1.27) (Myofascial), -2.1±2 (95%CI:-7.5-3.4) (Core), and -1±2.6 (95%CI: -9.3-7.3) (Combo), GH were -1.6±1.8 (95%CI:-6.6-3.4) (Myofascial), -0.2±2.1 (95%CI: -6.1-5.7) (Core), and 0.6±3.4 (95%CI:-10.1-11.3) (Combo), VT were -4.2±3.3 (95%CI: -13.4-4.9) (Myofascial), -3.8±1.9 (95%CI:-9.1-1.7) (Core), and -0.03±1.6 (95%CI:-5.3-5.2) (Combo), SF were -3.3±3.2 (95%CI:-12.2-5.7) (Myofascial), -1.1±1.1 (95%CI:-4.1-1.9) (Core), and -1.4±1.4 (95%CI:-5.6-2.9) (Combo), RE were -4.2±4.2 (95%CI:-15.86-7.5) (Myofascial), 4.2±4.2 (95%CI:-7.5-15.9) (Core), and -5.3±5.3 (95%CI:-22.1-11.5) (Combo), MH were -3.1±4.1 (95%CI:-14.6-8.3) (Myofascial), 0.9±2.1 (95%CI:-4.9-6.8) (Core), and 0.±0.9 (95%CI:-3-2.98) (Combo), PCS were -1.4±1.4 (95%CI:-5.3-2.5) (Myofascial), -2.6±2.1 (95% CI:-8.3-3.1) (Core), and 0.8±2.3 (95%CI:-6.3-7.9) (Combo), MCS were -4.3±4.8 (95% CI:-17.8-9.1) (Myofascial), 1.4±2.7 (95%CI:-6.2-9.) (Core), and -2.5±2.8 (95%CI:-11.6-6.5) (Combo).

The non-significance of most of the subscales was likely because our subjects were not injured, so there was little room for improvement on these subscales which measure general physical and mental health improvements after treatments. But vitality (VT) did demonstrate trends toward significance between groups, which indicates improved energy and reduced with MR/S group. The 2 weeks without therapeutic interventions either did not change the scores or resulted in slight decreases so there were no acute or residual effects of the interventions on these patient rated measures. Box plots of changes are in Appendix D (Figure D.9 and D.10).

Global Rating of Change (GROC) scores related to personal performance and personal recovery after receiving interventions are presented in Appendix C (Table C.8 and Figure C.8). There were no group significant differences for scores for the GROC related to Personal Performance and Personal Recovery ($F_{(2,11)}$=3.83, p=0.54). The GROC scores for Personal Performance were 6±0.8 (95%CI:3.8-8.2) (Myofascial), 3±1.1 (95% CI:-0.04-6.0) (Core), and 5.8±0.5 (95% CI:4.2-7.3) (Combo). The GROC scores for Personal Recovery were 6±0.96 (95%CI:3.1-8.5) (Myofascial), 3±1.0 (95%CI:-0.03-5.6) (Core), and 6±0 (95%CI:0-0) (Combo). Therefore, subjects did indicate that they felt better in their personal performance and personal recovery after being involved in the study. Those in the two groups that involved myofascial release/stretch demonstrated higher ratings of change. Box plots of changes are in Appendix D (Figure D.11 and D.12).

CHAPTER 5

CONCLUSION

The primary purpose of this study was to assess the acute and residual effects of three different short term therapeutic intervention programs on hip range of motion, core stability, and functional movement in patients with hip range of motion restrictions and altered neuromuscular control of their core muscles.

5.1 Therapeutic Intervention Effects

At the end of the two-week intervention program, physical improvements were demonstrated across all intervention groups (MR/S, MC/S, and Combo) because change scores from post to baseline were positive indicating an improvement in hip range of motion, core strength, and functional movement (Appendix D). Therefore, we did demonstrate that 6 visits were enough to create acute change in various measures of physical function. Our data correspond to Moreside et al who studied the effects of a stretching group and a combine grouped of stretching and core strengthening on hip range of motion and found there was significant improvement in both those groups verses the 3rd group of only core exercises to not show any significant changes.[9] We also concur with Haladay that core assessment tests were responsive after core strengthening intervention programs.[8] And we also agree with Trampas et al in that core strength training alone and core strength training combined with myofasical trigger point release can improve functional tasks.[12] Our data also concur with Kibler's theory (2006) of proximal stability contributing to distal mobility because we got improvements in range of motion with core strengthening alone.[1]

However, there were no significant therapeutic intervention group differences for the change scores from post to baseline ($p>0.05$). Therefore, we have no evidence that an intervention involving only stretching, an intervention involving only core strengthening, or an intervention that combined stretching and strengthening can create independent significant improvements in physical function measurements including range of motion, core strength, and functional movement.

At the end of two-week intervention program there were significant difference between groups in self-reported outcomes including norms for physical functioning, general health and the physical component score (PCS) ($p<0.05$). The Combo and MR/S had improved scores relative to MC/S group, indicating that the myofascial release and stretch probably the most to these changes. Hands-on treatment via myofascial release is the likely cause of these group differences as patients often respond positively to direct therapist contact. However, some caution should be used in interpreting these significant results because these changes still do not meet the minimum standards for a "true" clinical change (SF-36).

Trends toward group differences in the change scores from post to baseline were seen in DLLT ($p<0.08$), ASLR ($p<0.18$), and TPSU ($p<0.12$). The two groups that included core strengthening improved DLLT scores the most. The groups with myofascial release improved the ASLR and TPSU functional scores the most. Therefore, there may be a role for a specific intervention for specific goals. In our study, strengthening improved a strength test and myofascial release improved motions that require flexibility.

Across all intervention groups (MR/S, MC/S, and Combo) change scores from residual to post demonstrated no physical improvements or regression towards baseline values after two weeks of not completing therapeutic exercises. There were no significant therapeutic intervention group differences for the residual to post change scores in hip range of motion, core strength, functional movement, and self-reported function ($p>0.05$). Therefore, we demonstrate that 6 visits were not enough to create residual effects after 2 weeks of not completing therapeutic exercise.

Although, the Global Rating of Change scale was only tested overall after the intervention on personal performance and personal recovery there was significance in the groups that involved myofascial release and stretching. Group 2, which was just, MR/S did not significantly change in comparison. It is hypothesized that the groups that received more hands-on treatment personally felt better because of the individual treatments.

There were several assumptions and limitations to this study that may have affected our results. Throughout the study it was assumed that the subjects in this study performed the intervention exercises to the best of their ability without rushing and keeping correct form. It was also assumed that the investigator provided the subject with consistent and proper myofascial release as part of the MR/S and Combo intervention. It was also assumed the investigator explained and demonstrated these intervention exercises efficiently. This was very crucial for the study and specifically for the abdominal bracing technique that was taught to all subjects in the study. It was assumed that subjects understood the concept and how to abdominally brace. The first of limitations was that the sample size was limited. Although the goal was to aim for 30 subjects, the subjects just never materialized in the amount of time given for the study. Thus producing a low power. Another limitation was the number of visits. Perhaps if treatment times in the number of visits were to be increased the trends presented would be significant. A third limitation would be the availability of the testing facility and the schedule of the principle investigator. Lastly, controlling subjects' outside training was not implemented in this study. Subjects at times would share that their outside individual training regimens in their recreational sport was ramping up, or that they had just competed in a marathon or triathlon.

Future studies should lengthen the duration of treatment sessions and restrict subject's physical activity so they are not making major changes in routines such as changing phases in training plane from base training to strength phase or participating in competitions that would limit their ability to perform well on strenuous core assessment of flexibility test. Finally, more subjects should be include as a power analysis with alpha set at 0.05 and Beta set at 0.80 determined that 10 subjects per intervention group would have been optimal.

5.2 Practical Applications

It is important to reiterate that the human body is a kinetic chain as stretching improved strength and strengthening improved range of motion and both increased function. But six treatments were simply not enough to carry over strength gains and range of motion improvements for maintenance. To improve physical function, both myofascial release/stretch and motor control/strengthening are important components of a therapy intervention.

Thus, it is important for therapists to consider the kinetic chain when designing therapy interventions for the hip and spine because of the connection between motor control/strength, flexibility, and function. These interventions should be based off the patients' needs and not simply protocols.

APPENDIX A

SELF-REPORTED PATIENT OUTCOME QUESTIONNAIRES

The Roland-Morris Low Back Pain and Disability Questionnaire

Patient name:____File #_________________
Date:____

Please read instructions: When your back hurts, you may find it difficult to do some of the things you normally do. Mark only the sentences that describe you today.

☐ I stay at home most of the time because of my back.
☐ I change position frequently to try to get my
☐ back comfortable. I walk more slowly than
usual because of my back.
☐ Because of my back, I am not doing any jobs that I usually
☐ do around the house. Because of my back, I use a handrail
to get upstairs.
☐ Because of my back, I lie down to rest more often.
☐ Because of my back, I have to hold on to something to get
☐ out of an easy chair. Because of my back, I try to get other
people to do things for me.
☐ I get dressed more slowly than usual because of my back.
☐ I only stand up for short periods of time
☐ because of my back. Because of my back, I
try not to bend or kneel down.
☐ I find it difficult to get out of a chair
☐ because of my back. My back is painful
almost all of the time.
☐ I find it difficult to turn over in bed
☐ because of my back. My appetite is not
very good because of my back.
☐ I have trouble putting on my sock (or stockings) because of
☐ the pain in my back. I can only walk short distances
because of my back pain.
☐ I sleep less well because of my back.
☐ Because of my back pain, I get dressed with the
☐ help of someone else. I sit down for most of the
day because of my back.
☐ I avoid heavy jobs around the house because of my back.
☐ Because of back pain, I am more irritable and bad tempered with
☐ people than usual. Because of my back, I go upstairs more slowly
than usual.
☐ I stay in bed most of the time because of my back.

Instructions:

1. The patient is instructed to put a mark next to each appropriate statement.
2. The total number of marked statements are added by the clinician. Unlike the authors of the Oswestry Disability Questionnaire, Roland and Morris did not provide descriptions of the varying degrees of disability (e.g., 40%-60% is severe disability).
3. Clinical improvement over time can be graded based on the analysis of serial questionnaire scores. If, for example, at the beginning of treatment, a patient's score was 12 and, at the conclusion of treatment, her score was 2 (10 points of improvement), we would calculate an 83% (10/12 x 100) improvement.

Figure A.1: Roland-Morris low back pain and disability questionnaire

Medical Outcomes Study Questionnaire Short Form 36 Health Survey

This survey asks for your views about your health. This information will help keep track of how you feel and how well you are able to do your usual activities. Thank you for completing this survey! For each of the following questions, please circle the number that best describes your answer.

1. In general, would you say your health is:	
Excellent	1
Very good	2
Good	3
Fair	4
Poor	5

2. Compared to one year ago,	
Much better now than one year ago	1
Somewhat better now than one year ago	2
About the same	3
Somewhat worse now than one year ago	4
Much worse now than one year ago	5

3. The following items are about activities you might do during a typical day. Does your health now limit you in these activities? If so, how much? (Circle One Number on Each Line)	Yes, limited a lot (1)	Yes, limited a little (2)	No, not limited at all (3)
a. Vigorous activities, such as running, lifting heavy objects, participating in strenuous	1	2	3
b. Moderate activities, such as moving a table, pushing a vacuum cleaner, bowling, or playing golf	1	2	3
c. Lifting or carrying groceries	1	2	3
d. Climbing several flights of stairs	1	2	3
e. Climbing one flight of stairs	1	2	3
f. Bending, kneeling, or stooping	1	2	3
g. Walking more than a mile	1	2	3
h. Walking several blocks	1	2	3
i. Walking one block	1	2	3
j. Bathing or dressing yourself	1	2	3

4. During the past 4 weeks, have you had any of the following problems with your work or other regular daily activities as a result of your physical health?	Yes (1)	No (2)
a. Cut down the amount of time you spent on work or other activities	1	2
b. Accomplished less than you would like	1	2
c. Were limited in the kind of work or other activities	1	2
d. Had difficulty performing the work or other activities (for example, it took extra effort)	1	2

5. During the past 4 weeks, have you had any of the following problems with your work or other regular daily activities as a result of any emotional problems (such as feeling depressed or anxious)? (Circle One Number on Each Line)	Yes	No
a. Cut down the amount of time you spent on work or other activities	1	2
b. Accomplished less than you would like	1	2
c. Didn't do work or other activities as carefully as usual	1	2

6. During the past 4 weeks, to what extent has your physical health or emotional problems interfered with your normal social activities with family, friends, neighbors, or groups?	
Not at all	1
Slightly	2
Moderately	3
Quite a bit	4
Extremely	5

7. How much bodily pain have you had during the past 4 weeks?	
None	1
Very mild	2
Mild	3
Moderate	4
Severe	5
Very severe	6

8. During the past 4 weeks, how much did pain interfere with your normal work (including both work outside the home and housework)?	
Not at all	1
A little bit	2
Moderately	3
Quite a bit	4
Extremely	5

These questions are about how you feel and how things have been with you during the past 4 weeks. For each question, please give the one answer that comes closest to the way you have been feeling. (Circle One Number on Each Line)

9. How much of the time during the past 4 weeks . . .	All of the time	Most of the time	A good bit of the time	Some of the time	A little of the time	None of the time
a. Did you feel full of pep?	1	2	3	4	5	6
b. Have you been a very nervous person?	1	2	3	4	5	6
c. Have you felt so down in the dumps that nothing could cheer you up?	1	2	3	4	5	6
d. Have you felt calm and peaceful?	1	2	3	4	5	6
e. Did you have a lot of energy?	1	2	3	4	5	6
f. Have you felt downhearted and blue?	1	2	3	4	5	6
g. Did you feel worn out?	1	2	3	4	5	6
h. Have you been a happy person?	1	2	3	4	5	6
i. Did you feel tired?	1	2	3	4	5	6

10. During the past 4 weeks, how much of the time has your physical health or emotional problems interfered with your social activities (like visiting with friends, relatives, etc.)? (Circle One Number)	
All of the time	1
Most of the time	2
Some of the time	3
A little of the time	4
None of the time	5

11. How TRUE or FALSE is each of the following statements for you. (Circle One Number on Each Line)	Definitely True	Mostly True	Don't Know	Mostly False	Definitely False
a. I seem to get sick a little easier than other people	1	2	3	4	5
b. I am as healthy as anybody I know	1	2	3	4	5
c. I expect my health to get worse	1	2	3	4	5
d. My health is excellent	1	2	3	4	5

Please rate your overall assessment of how your ***personal performance*** during your associated recreational activities/sports felt from the time before the 2-week treatment started to the time the treatments ended.

☐ A very great deal worse (-7)	☐ About the same (0)	☐ A very great deal better (+7)
☐ A great deal worse (-6)		☐ A great deal better (+6)
☐ Quite a bit worse (-5)		☐ Quite a bit better (+5)
☐ Moderately worse (-4)		☐ Moderately better (+4)
☐ Somewhat worse (-3)		☐ Somewhat better (+3)
☐ A little bit worse (-2)		☐ A little bit better (+2)
☐ A tiny bit worse (almost the same) (-1)		☐ A tiny bit better (almost the same) (+1)

Please rate your overall assessment of how your ***personal recovery*** from your recreational activities/sports felt from the time before the 2-week treatment started to the time the treatments ended.

☐ A very great deal worse (-7)	☐ About the same (0)	☐ A very great deal better (+7)
☐ A great deal worse (-6)		☐ A great deal better (+6)
☐ Quite a bit worse (-5)		☐ Quite a bit better (+5)
☐ Moderately worse (-4)		☐ Moderately better (+4)
☐ Somewhat worse (-3)		☐ Somewhat better (+3)
☐ A little bit worse (-2)		☐ A little bit better (+2)
☐ A tiny bit worse (almost the same) (-1)		☐ A tiny bit better (almost the same) (+1)

Figure A.3: Global Rating of Change Scales for Performance and Recovery

APPENDIX B

THERAPEUTIC INTERVENTION PICTURES

Figure B.1: Myofascial Ironing Technique on Latissimus Dorsi for MR/S and Combo

Figure B.2: Myofascial Ironing Technique on Latissimus Dorsi for MR/S and Combo

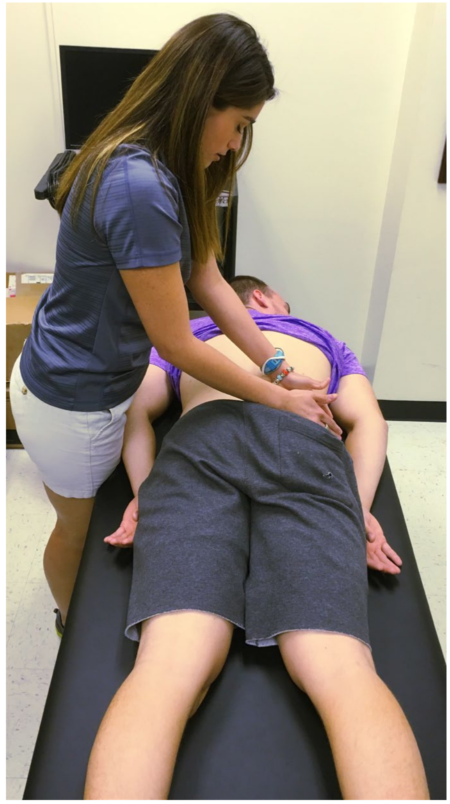


Figure B.3: Myofascial Ironing Technique on Quadratus Lumborum for MR/S & Combo

Figure B.4: Myofascial Ironing Technique on the Hamstrings for MR/S & Combo

Figure B.5: Myofascial Ironing Technique on the Hamstrings for MR/S and Combo

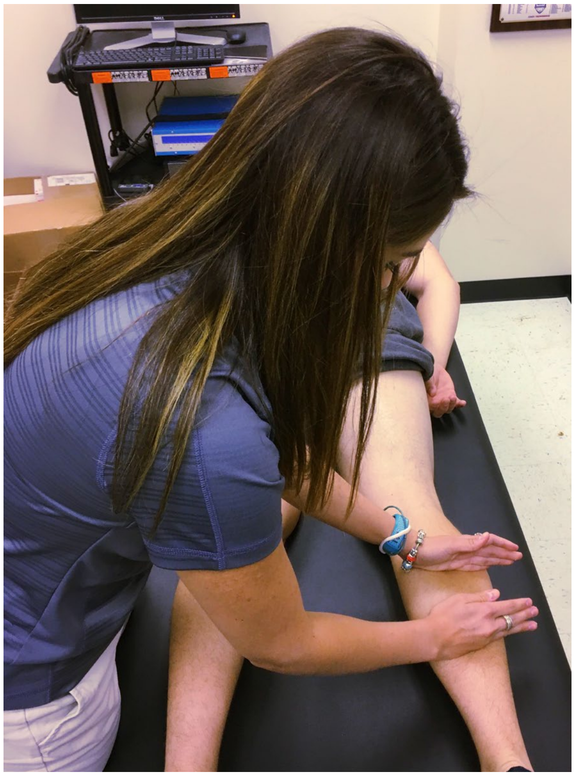


Figure B.6: Myofascial Ironing Technique on the Calf for MR/S and Combo

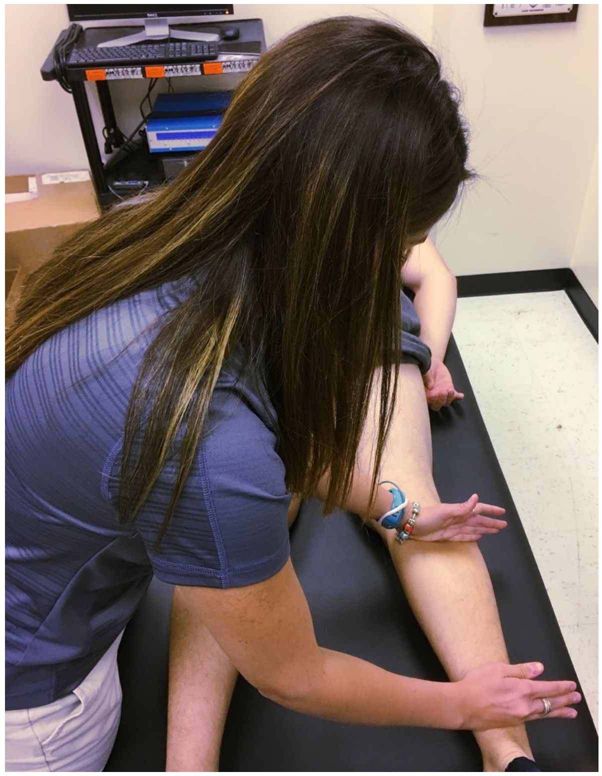


Figure B.7: Myofascial Ironing Technique on the Calf for MR/S and Combo

Figure B.8: Internal Rotation Stretch for MR/S and Combo

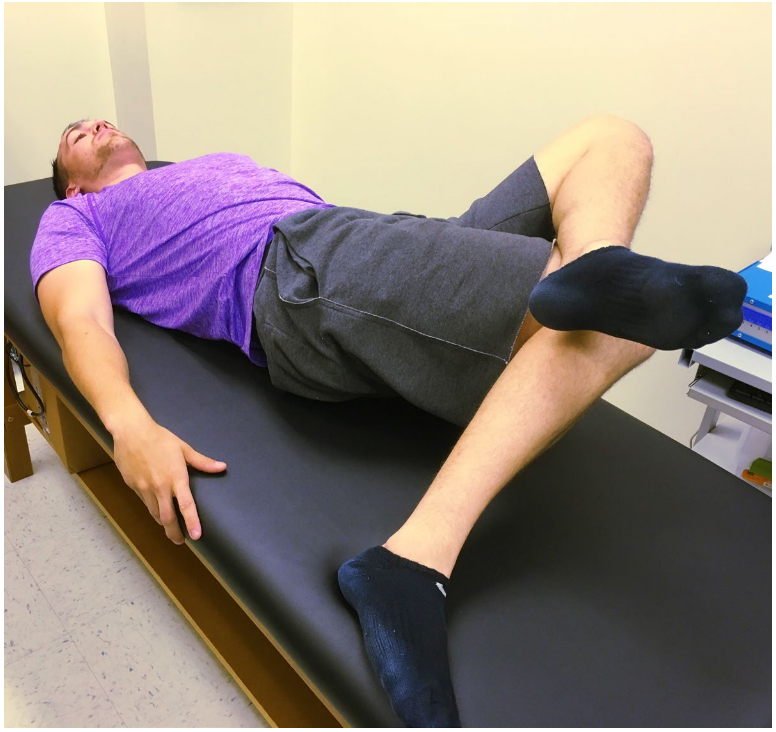


Figure B.9: External Rotation Stretch for MR/S and Combo

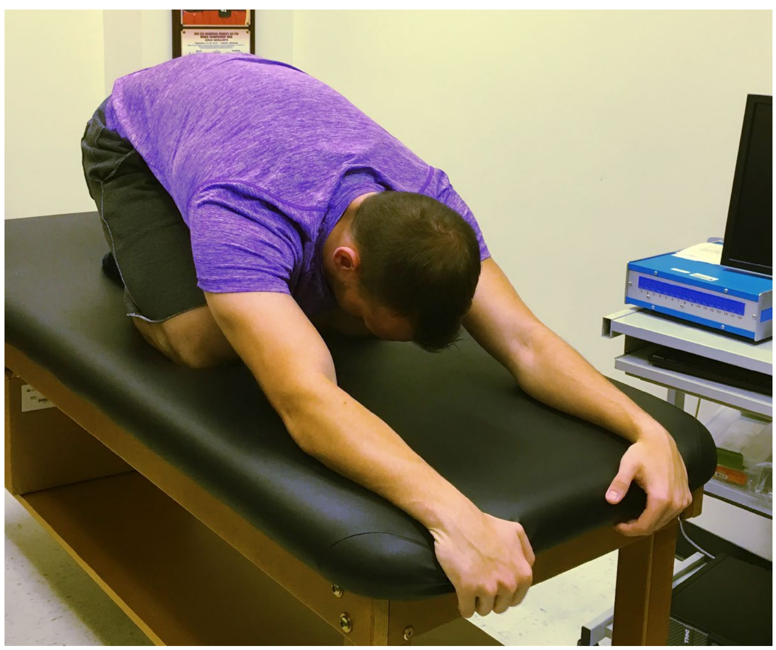


Figure B.10: Child's Pose Stretch for MR/S and Combo

Figure B.11: Pigeon Stretch for MR/S and Combo

Figure B.12: Prone Press up Stretch for MR/S and Combo

Figure B.13: Hamstring Stretch for MR/S and Combo

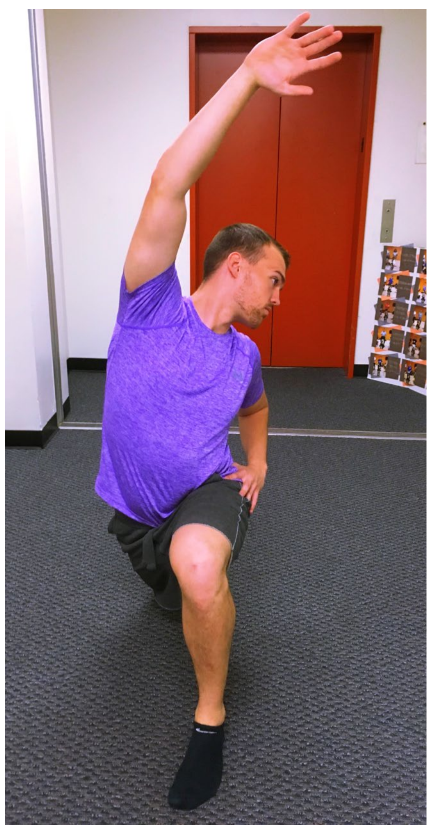


Figure B.14: Lunge stretch for MR/S and Combo

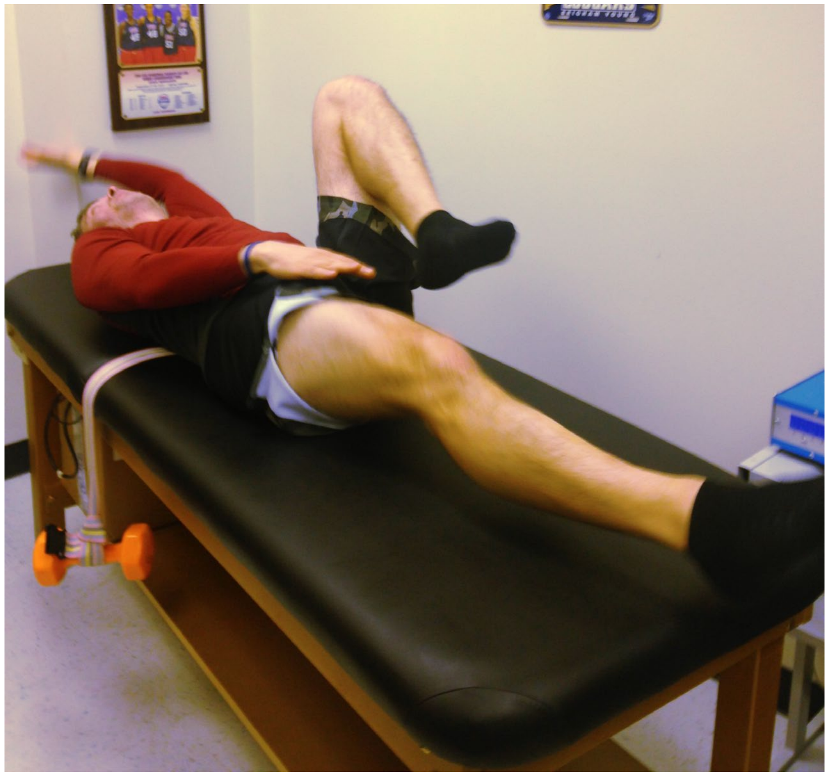


Figure B.15: Weighted Feed Back Exercise for MC/S and Combo

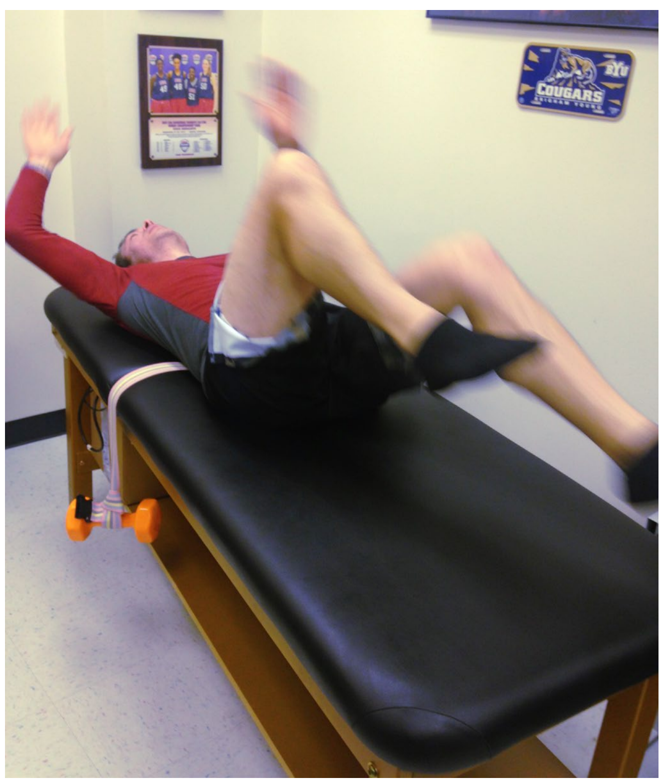


Figure B.16: Weighted Feed Back Exercise for MC/S and Combo.

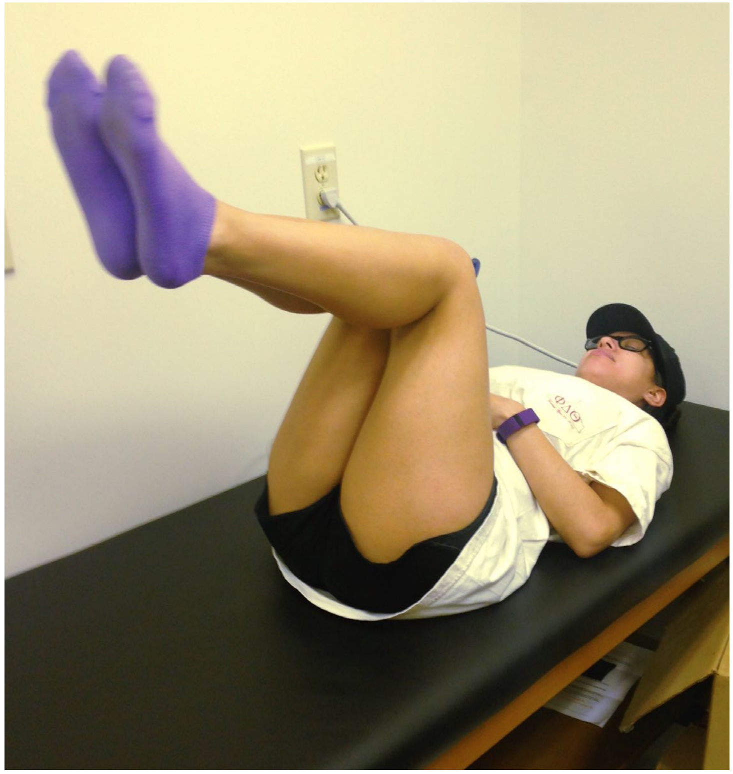


Figure B.17: Stabilizer Cuff Exercise for MC/S and Combo

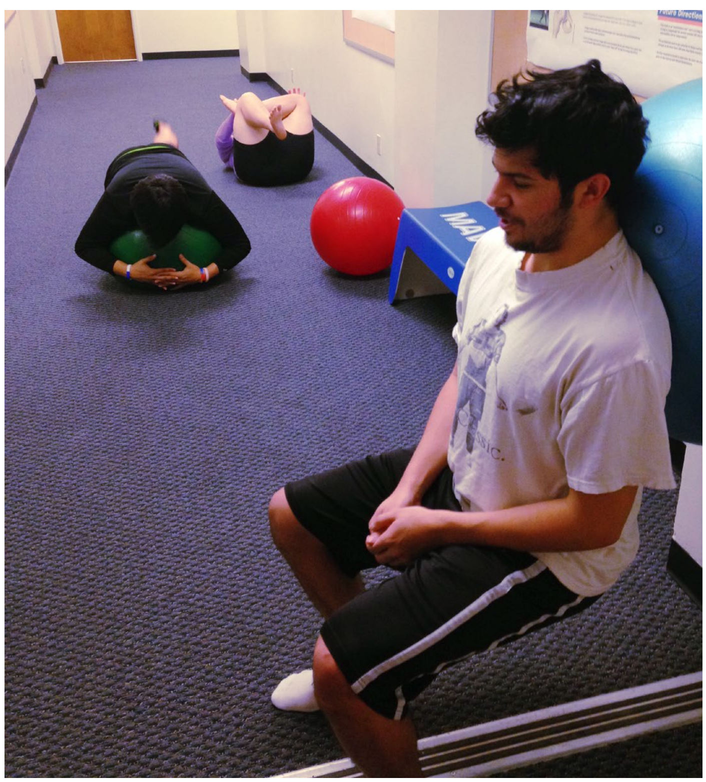


Figure B.18: Swiss Ball Exercises and Stretching for MR/S, MC/S, and Combo

APPENDIX C

DESCRIPTIVE STATISTICS AND GRAPHS FOR
GROUP x TIME FOR RAW SCORE

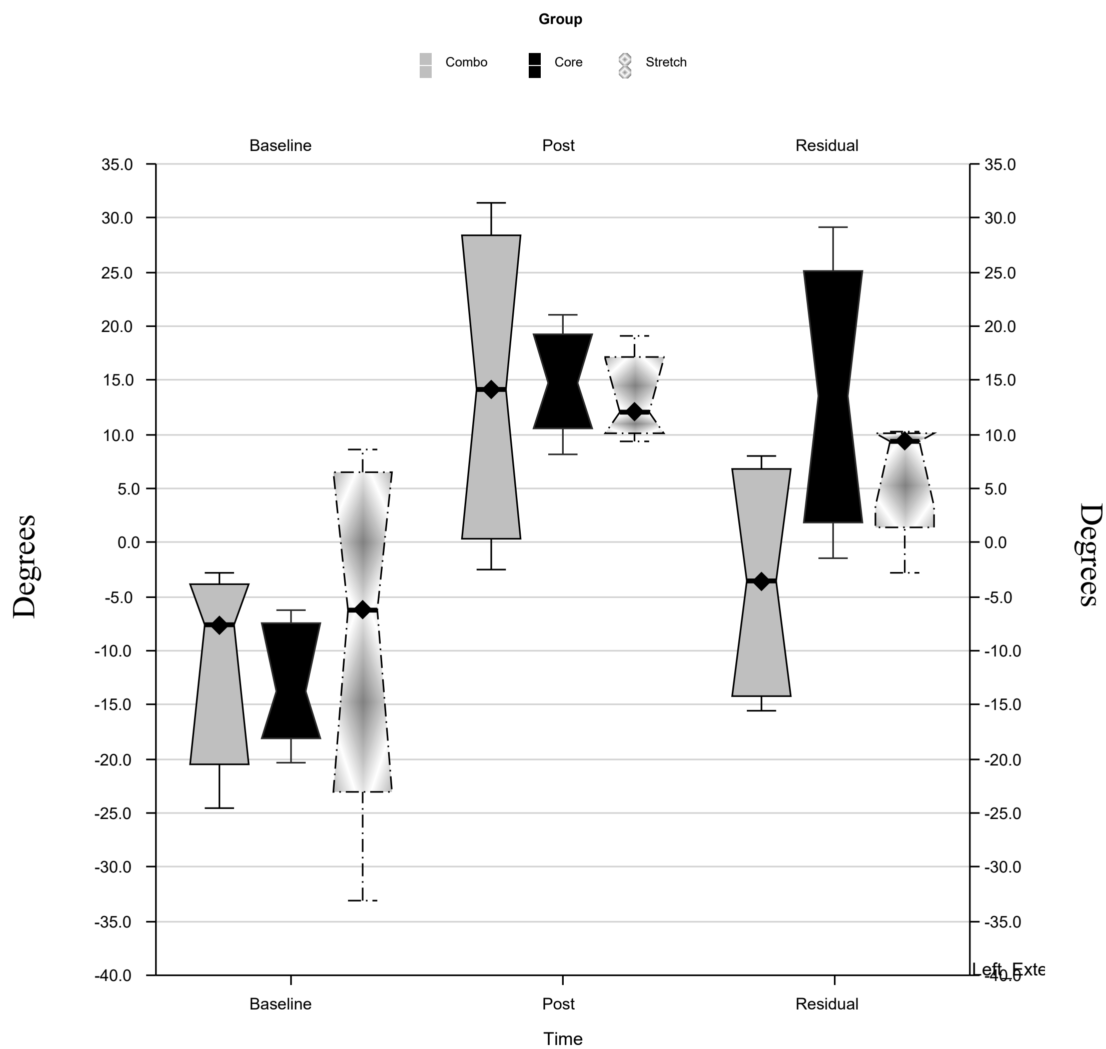


Figure C.1: Group x Time for Left Hip Extension

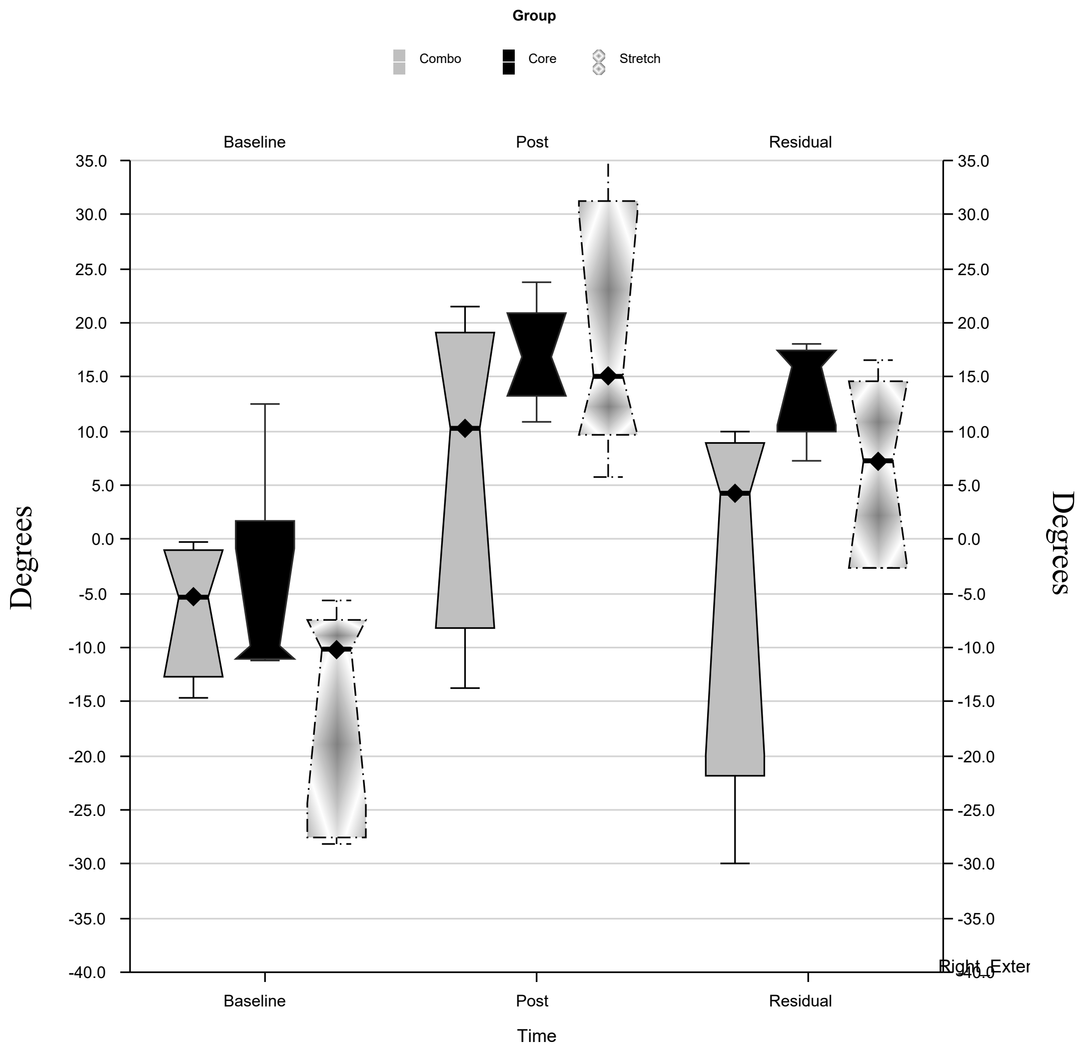


Figure C.2: Group x Time for Right Hip Extension

Table C.1: Group x Time Data for Left Hip Extension

		Mean	SE	95% LCL	95% UCL
	Baseline	-7.8	-7.4	-28.3	12.7
Myofascial Release/Stretch	Post	13.3	-1.7	8.5	18.1
	Residual	6.5	-2.5	-0.3	13.4
	Baseline	-13.0	-2.5	-20.0	-5.9
Motor Control/Strengthening	Post	14.8	-2.2	8.8	20.9
	Residual	-13.5	-5.4	-1.7	28.6
	Baseline	-10.7	-4.8	-25.9	4.5
Combination	Post	14.3	-7.2	-8.7	37.3
	Residual	-3.7	-5.5	-21.2	13.9

Table C.2: Group x Time Data for Right Hip Extension

		Mean	SE	95% LCL	95% UCL
	Baseline	-16.0	-4.8	-29.3	-2.8
Myofascial Release/Stretch	Post	19.4	-5.4	4.5	34.3
	Residual	6.2	-3.9	-4.7	17.1
	Baseline	-5.7	-4.6	-18.3	7.0
Motor Control/Strengthening	Post	17.0	-2.1	11.3	22.7
	Residual	14.2	-1.9	8.8	19.6
	Baseline	-6.4	-3.1	-16.2	3.5
Combination	Post	7.1	-7.5	-16.7	30.8
	Residual	-2.9	-9.2	-32.0	26.3

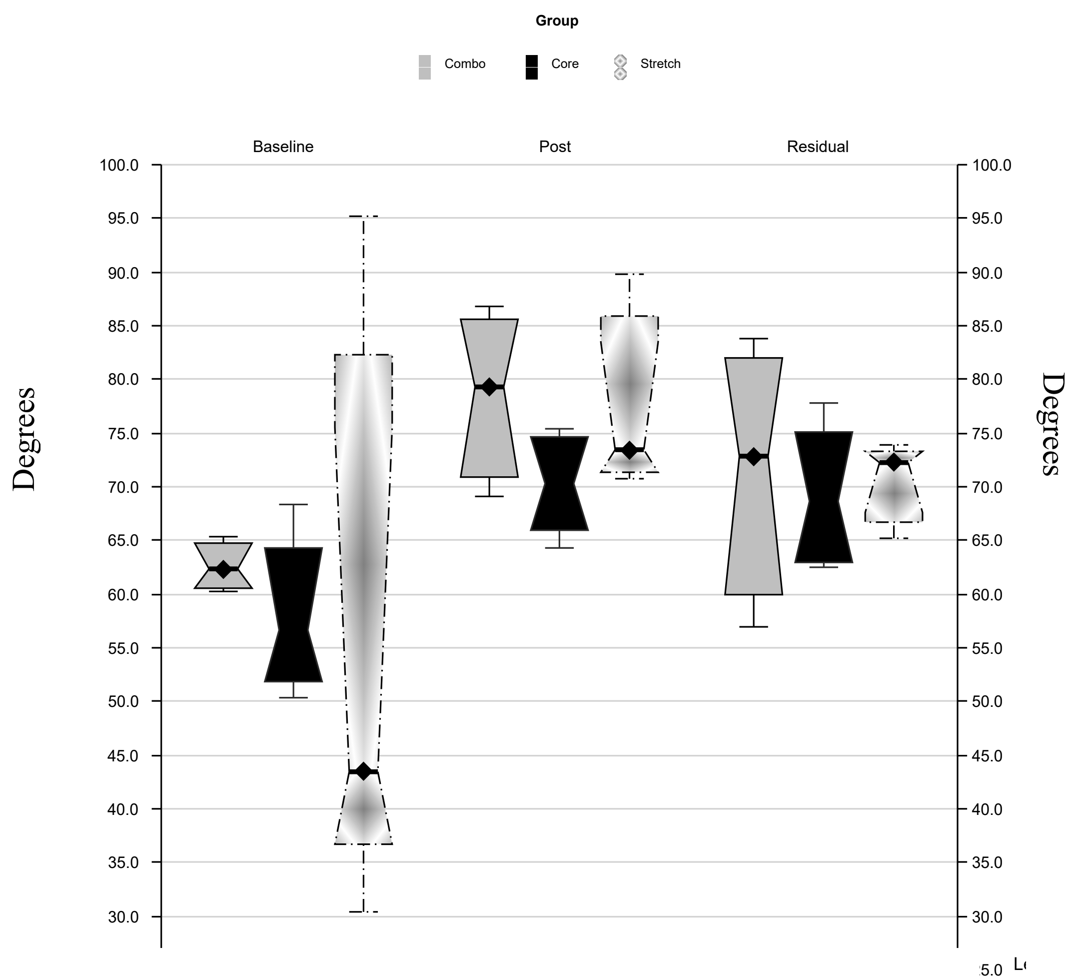


Figure C.3: Group x Time for Left Total Hip Rotation

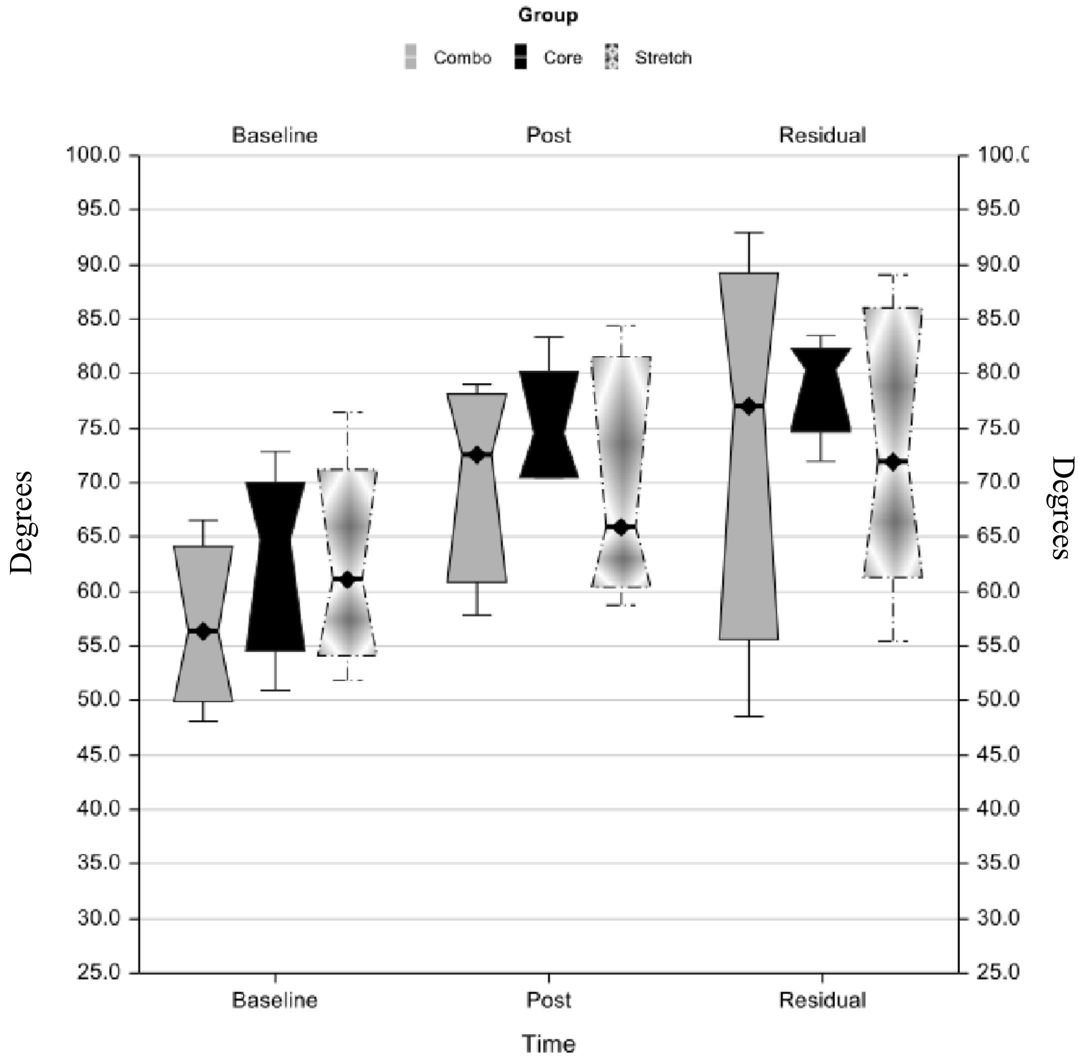


Figure C.4: Group x Time for Right Total Hip Rotation

Table C.3: Group x Time Data for Right Hip Extension

		Mean	SE	95% LCL	95% UCL
	Baseline	-56.3	-11.6	-88.6	-24.1
Myofascial Release/Stretch	Post	-77.6	-3.6	-87.6	-67.5
	Residual	-70.5	-1.6	-75.0	-65.9
	Baseline	-57.8	-3.1	-66.4	-49.2
Motor Control/Strengthening	Post	-70.3	-2.0	-76.0	-64.7
	Residual	-69.0	-2.9	-76.9	-61.0
	Baseline	-62.5	-1.1	-66.0	-59.1
Combination	Post	-78.6	-3.8	-90.8	-66.4
	Residual	-71.6	-5.7	-89.8	-53.4

Table C.4: Group x Time Data for Right Hip Extension

		Mean	SE	95% LCL	95% UCL
	Baseline	-62.3	-4.2	-74.1	-50.6
Myofascial Release/Stretch	Post	-70.0	-5.0	-83.7	-56.3
	Residual	-73.3	-5.9	-89.7	-56.9
	Baseline	-62.8	-3.8	-73.3	-52.2
Motor Control/Strengthening	Post	-75.1	-2.4	-81.8	-68.5
	Residual	-78.9	-2.0	-84.4	-73.4
	Baseline	-56.8	-3.8	-68.9	-44.8
Combination	Post	-70.5	-4.6	-85.2	-55.7
	Residual	-73.9	-9.2	-103.3	-44.5

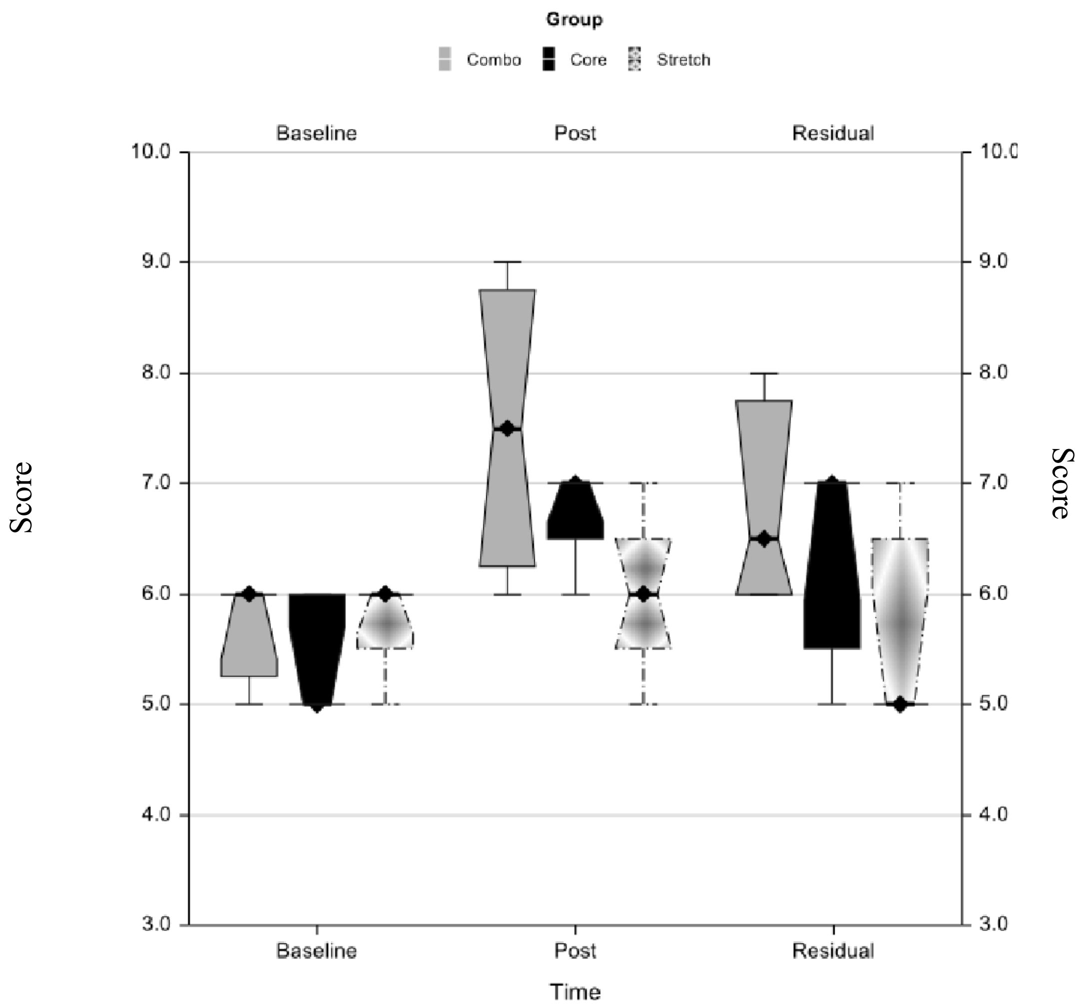


Figure C.5: Group x Time for DLLT

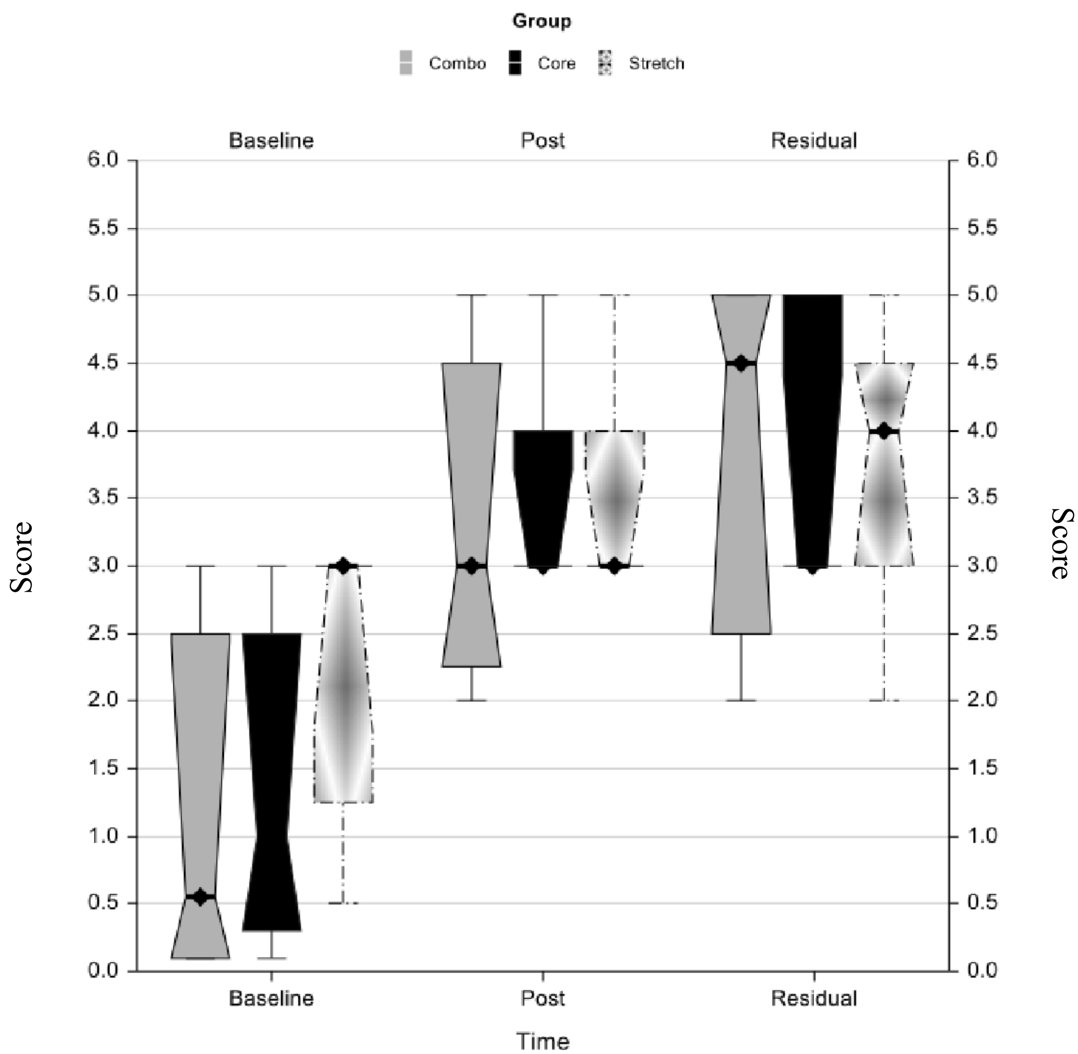


Figure C.6: Group x Time for LAMP

Table C.5: Group x Time Data for DLLT

		Mean	SE	95% LCL	95% UCL
Iyofascial Release/Stretch	Baseline	5.8	0.2	5.2	6.4
	Post	6.0	0.3	5.1	6.9
	Residual	5.6	0.4	4.5	6.7
otor Control/Strengthening	Baseline	5.4	0.2	4.7	6.1
	Post	6.8	0.2	6.2	7.4
	Residual	6.4	0.4	5.3	7.5
Combination	Baseline	5.8	0.3	5.0	6.5
	Post	7.5	0.6	5.4	9.6
	Residual	6.8	0.5	5.2	8.3

Table C.6: Group x Time Data for LAMP

		Mean	SE	95% LCL	95% UCL
Myofascial Release/Stretch	Baseline	2.3	0.5	0.9	3.7
	Post	3.4	0.4	2.3	4.5
	Residual	3.8	0.5	2.4	5.2
Motor Control/Strengthening	Baseline	1.3	0.5	-0.1	2.8
	Post	3.4	0.4	2.3	4.5
	Residual	3.8	0.5	2.4	5.2
Combination	Baseline	1.1	0.7	-1.1	3.2
	Post	3.3	0.6	1.2	5.3
	Residual	4.0	0.7	1.7	6.3

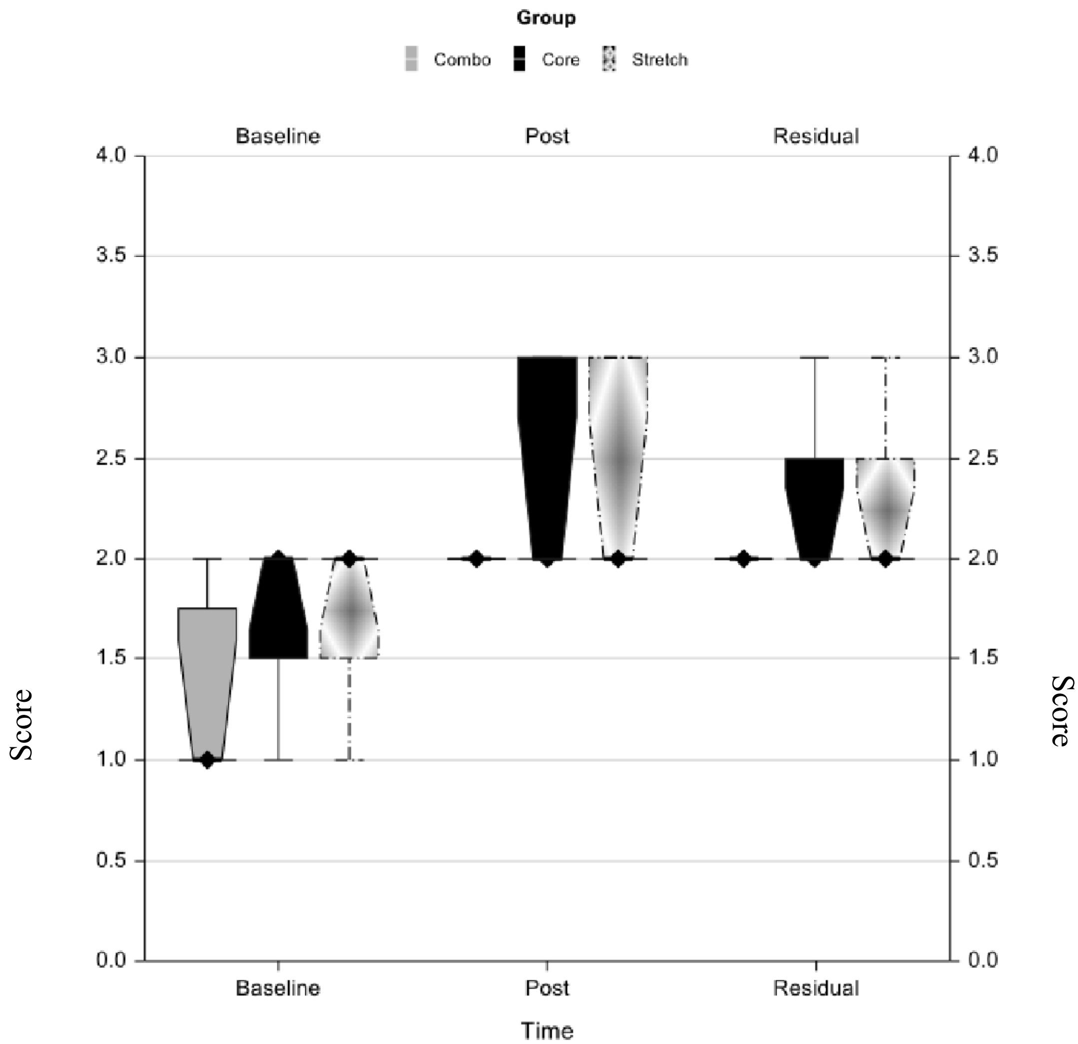


Figure C.7: Group x Time for OHS

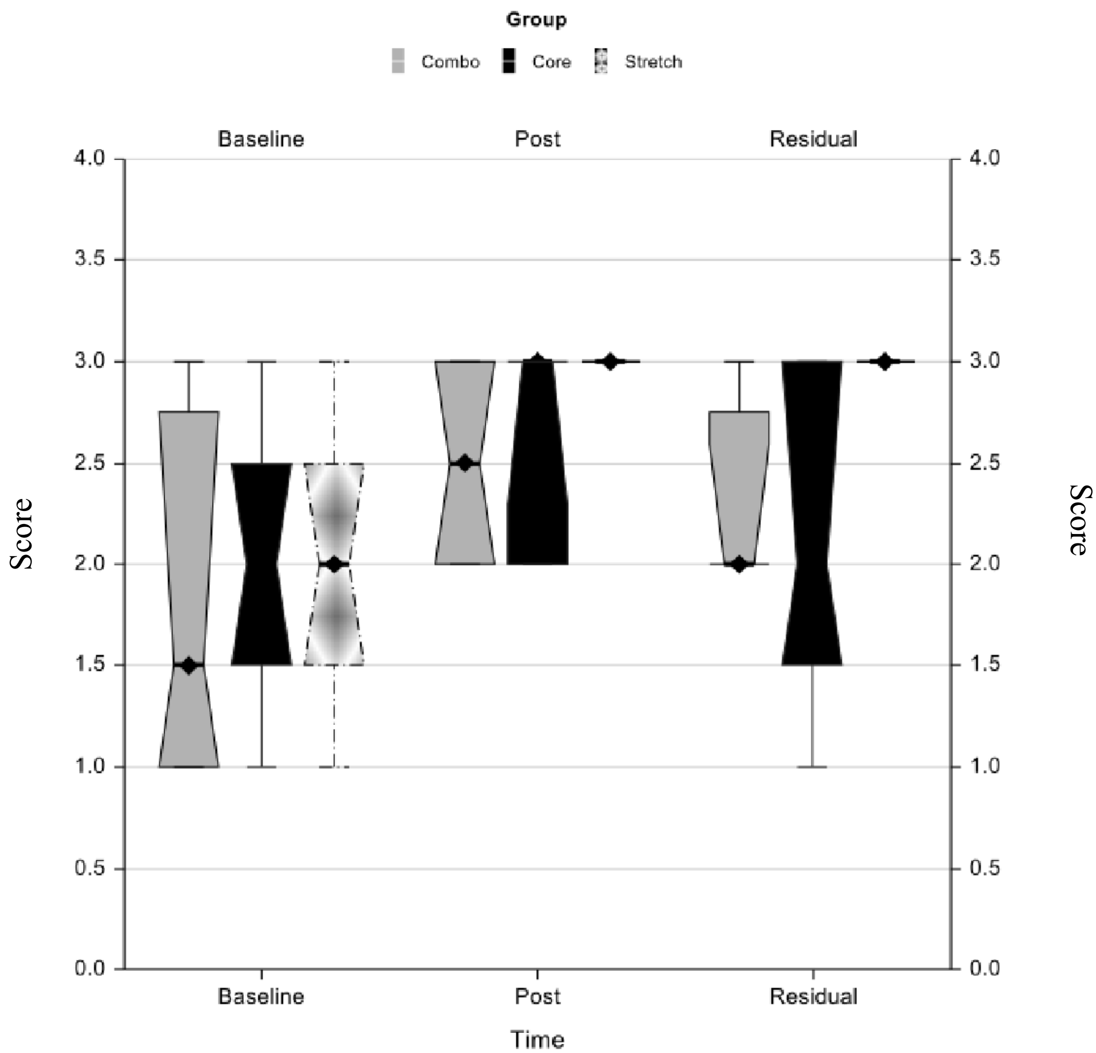


Figure C.8: Group x Time for ASLR

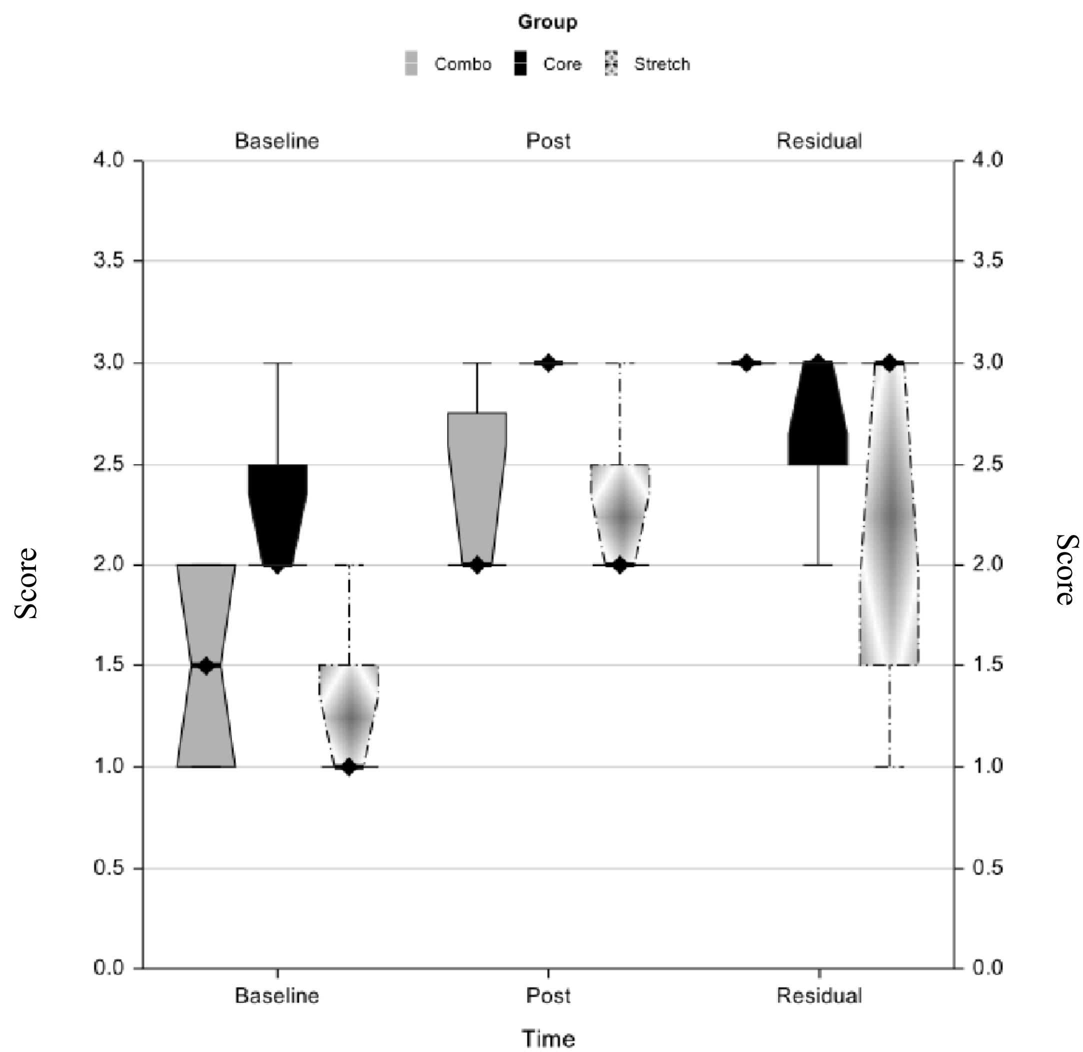


Figure C.9: Group x Time for TPSU

Table C.7: Group x Time Data for OHS

		Mean	SE	95% LCL	95% UCL
Myofascial Release/Stretch	Baseline	1.8	0.2	1.2	2.4
	Post	2.4	0.2	1.7	3.1
	Residual	2.2	0.2	1.6	2.8
Motor Control/Strengthening	Baseline	1.8	0.2	1.2	2.4
	Post	2.4	0.2	1.7	3.1
	Residual	2.2	0.2	1.6	2.8
Combination	Baseline	1.3	0.3	0.5	2.0
	Post	2.0	0.0	0.0	0.0
	Residual	2.0	0.0	0.0	0.0

Table C.8: Group x Time Data for ASLR

		Mean	SE	95% LCL	95% UCL
Myofascial Release/Stretch	Baseline	2.0	0.3	1.1	2.9
	Post	3.0	0.0	0.0	0.0
	Residual	3.0	0.0	0.0	0.0
Motor Control/Strengthening	Baseline	2.0	0.3	1.1	2.9
	Post	3.0	0.0	0.0	0.0
	Residual	2.2	0.4	1.2	3.2
Combination	Baseline	1.8	0.5	0.2	3.3
	Post	2.6	0.2	1.9	3.3
	Residual	2.3	0.3	1.5	3.0

Table C.9: Group x Time Data for DLLT

		Mean	SE	95% LCL	95% UCL
Myofascial Release/Stretch	Baseline	2.0	0.3	1.1	2.9
	Post	3.0	0.0	0.0	0.0
	Residual	3.0	0.0	0.0	0.0
Motor Control/Strengthening	Baseline	2.0	0.3	1.1	2.9
	Post	3.0	0.0	0.0	0.0
	Residual	2.2	0.4	1.2	3.2
Combination	Baseline	1.8	0.5	0.2	3.3
	Post	2.6	0.2	1.9	3.3
	Residual	2.3	0.3	1.5	3.0

Table C.10: Group x Time Data for Norm PF

		Mean	SE	95% LCL	95% UCL
Myofascial Release/Stretch	Baseline	55.0	1.3	51.4	58.7
	Post	56.7	0.4	55.5	57.8
	Residual	55.4	1.0	52.6	58.3
Motor Control/Strengthening	Baseline	56.3	0.5	54.8	57.7
	Post	55.8	0.5	54.4	57.2
	Residual	56.3	0.5	54.8	57.7
Combination	Baseline	56.1	0.6	54.1	57.9
	Post	57.1	0.0	0.0	0.0
	Residual	57.1	0.0	0.0	0.0

Table C.11: Group x Time Data for Norm RP

		Mean	SE	95% LCL	95% UCL
Myofascial Release/Stretch	Baseline	54.8	1.4	50.9	58.7
	Post	157.4	101.2	-123.5	438.2
	Residual	56.2	0.0	0.0	0.0
Motor Control/Strengthening	Baseline	56.2	0.0	0.0	0.0
	Post	54.8	1.4	50.9	58.7
	Residual	52.0	4.2	40.2	63.7
Combination	Baseline	56.2	0.0	0.0	0.0
	Post	56.2	0.0	0.0	0.0
	Residual	56.2	0.0	0.0	0.0

Table C.12: Group x Time Data for Norm BP

		Mean	SE	95% LCL	95% UCL
Myofascial Release/Stretch	Baseline	56.1	4.3	44.3	68.0
	Post	60.0	1.7	55.4	64.6
	Residual	54.4	2.7	46.7	61.9
Motor Control/Strengthening	Baseline	54.9	1.0	52.0	57.7
	Post	54.9	3.9	44.1	65.6
	Residual	52.8	4.3	40.9	64.7
Combination	Baseline	50.7	4.9	36.4	64.9
	Post	50.6	5.2	33.9	67.2
	Residual	49.6	6.3	29.4	69.7

Table C.13: Group x Time Data for Norm VT

		Mean	SE	95% LCL	95% UCL
Myofascial Release/Stretch	Baseline	56.2	1.7	51.5	60.8
	Post	58.5	2.7	51.1	66.0
	Residual	54.3	4.2	42.6	65.9
Motor Control/Strengthening	Baseline	47.6	4.5	35.3	60.0
	Post	50.0	1.9	44.7	55.3
	Residual	46.2	1.9	41.0	51.5
Combination	Baseline	50.9	4.9	35.3	66.4
	Post	56.8	2.5	49.0	64.6
	Residual	56.8	3.5	45.5	68.0

Table C.14: Group x Time Data for Norm SF

		Mean	SE	95% LCL	95% UCL
Myofascial Release/Stretch	Baseline	56.0	1.1	53.0	59.0
	Post	57.1	0.0	0.0	0.0
	Residual	53.9	3.2	44.9	62.9
Motor Control/Strengthening	Baseline	56.0	1.1	53.0	59.0
	Post	56.0	1.1	53.0	59.0
	Residual	54.9	2.2	48.9	60.9
Combination	Baseline	50.4	4.1	37.5	63.2
	Post	54.4	1.6	49.4	59.4
	Residual	53.1	2.6	44.8	61.3

Table C.15: Group x Time Data for Norm RE

		Mean	SE	95% LCL	95% UCL
Myofascial Release/Stretch	Baseline	53.2	2.1	47.4	59.0
	Post	55.3	0.0	0.0	0.0
	Residual	51.1	4.2	39.4	62.8
Motor Control/Strengthening	Baseline	55.3	0.0	0.0	0.0
	Post	51.1	4.2	39.4	62.8
	Residual	55.3	0.0	0.0	0.0
Combination	Baseline	47.4	7.9	22.3	72.5
	Post	52.7	2.6	44.3	61.0
	Residual	47.4	7.9	22.3	72.5

Table C.16: Group x Time Data for Norm MH

		Mean	SE	95% LCL	95% UCL
Myofascial Release/Stretch	Baseline	55.9	1.5	51.6	60.2
	Post	57.2	1.8	52.3	62.1
	Residual	54.1	3.8	43.6	64.6
Motor Control/Strengthening	Baseline	49.1	3.9	38.4	59.8
	Post	51.8	5.1	37.6	66.0
	Residual	52.7	3.5	43.1	62.3
Combination	Baseline	52.2	5.3	35.4	68.9
	Post	55.6	2.7	47.1	64.0
	Residual	55.6	3.1	45.6	65.5

Table C.17: Group x Time Data for Norm PCS

		Mean	SE	95% LCL	95% UCL
Myofascial Release/Stretch	Baseline	53.7	2.4	46.9	60.5
	Post	57.1	0.8	54.9	59.4
	Residual	55.8	0.8	53.4	58.1
Motor Control/Strengthening	Baseline	54.7	1.7	49.9	59.5
	Post	53.6	1.9	48.2	59.0
	Residual	51.0	3.0	42.7	59.3
Combination	Baseline	54.6	1.3	50.5	58.6
	Post	53.5	1.5	48.6	58.4
	Residual	54.4	2.9	45.2	63.5

Table C.18: Group x Time Data for Norm MCS

		Mean	SE	95% LCL	95% UCL
Myofascial Release/Stretch	Baseline	55.1	1.7	50.5	59.8
	Post	56.5	0.9	54.1	58.9
	Residual	52.2	5.0	38.2	66.1
Motor Control/Strengthening	Baseline	50.5	2.6	43.2	57.7
	Post	50.9	4.2	39.3	62.5
	Residual	52.3	1.8	47.4	57.2
Combination	Baseline	48.2	5.6	30.5	65.9
	Post	54.4	2.4	46.6	62.1
	Residual	51.8	4.9	36.2	67.4

APPENDIX D

GRAPHS FOR CHANGE SCORES

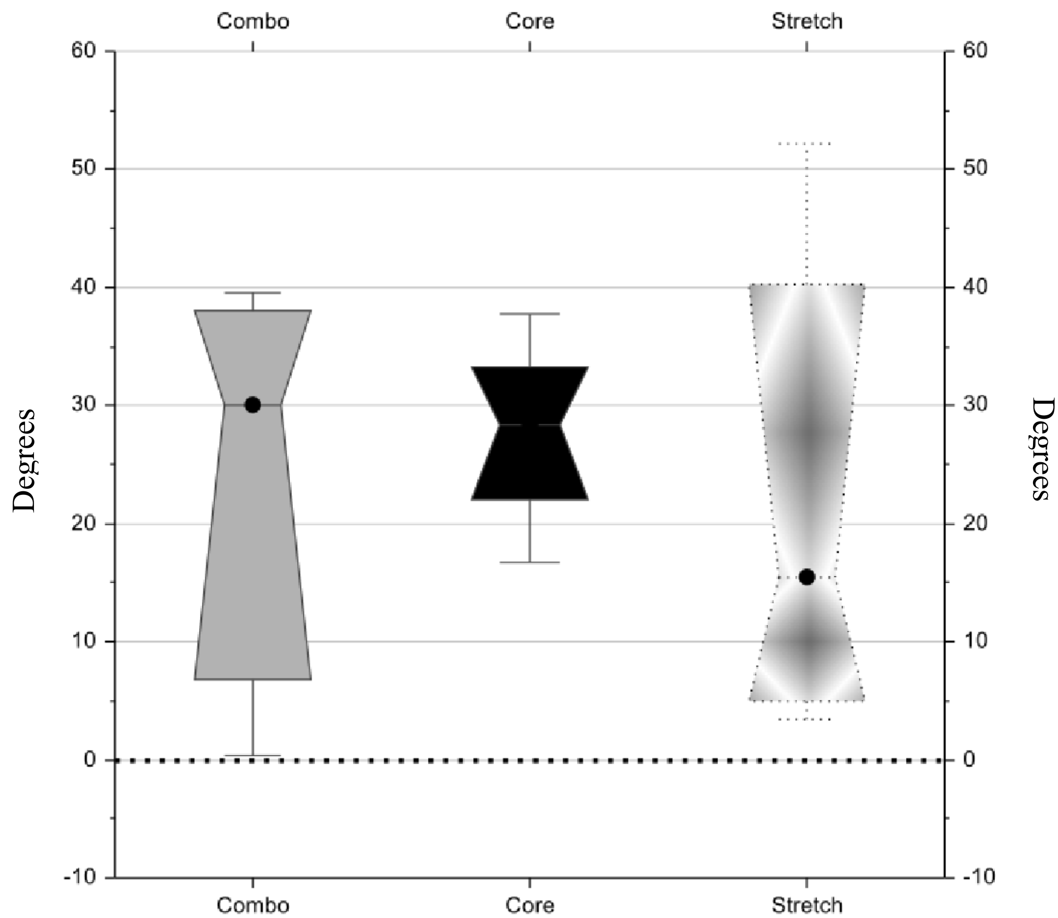


Figure D.1: Post to Baseline Change Left Hip Extension

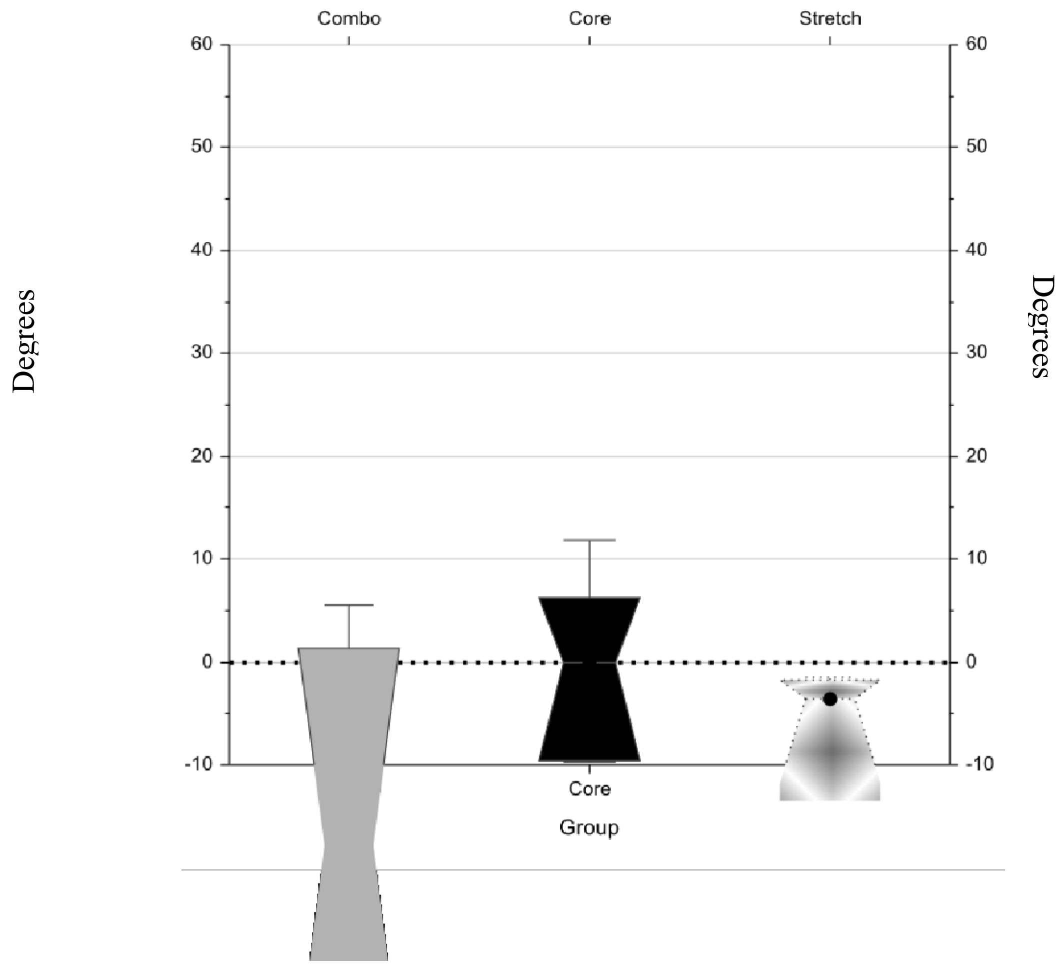


Figure D.2: Residual to Post Change Left Hip Extension

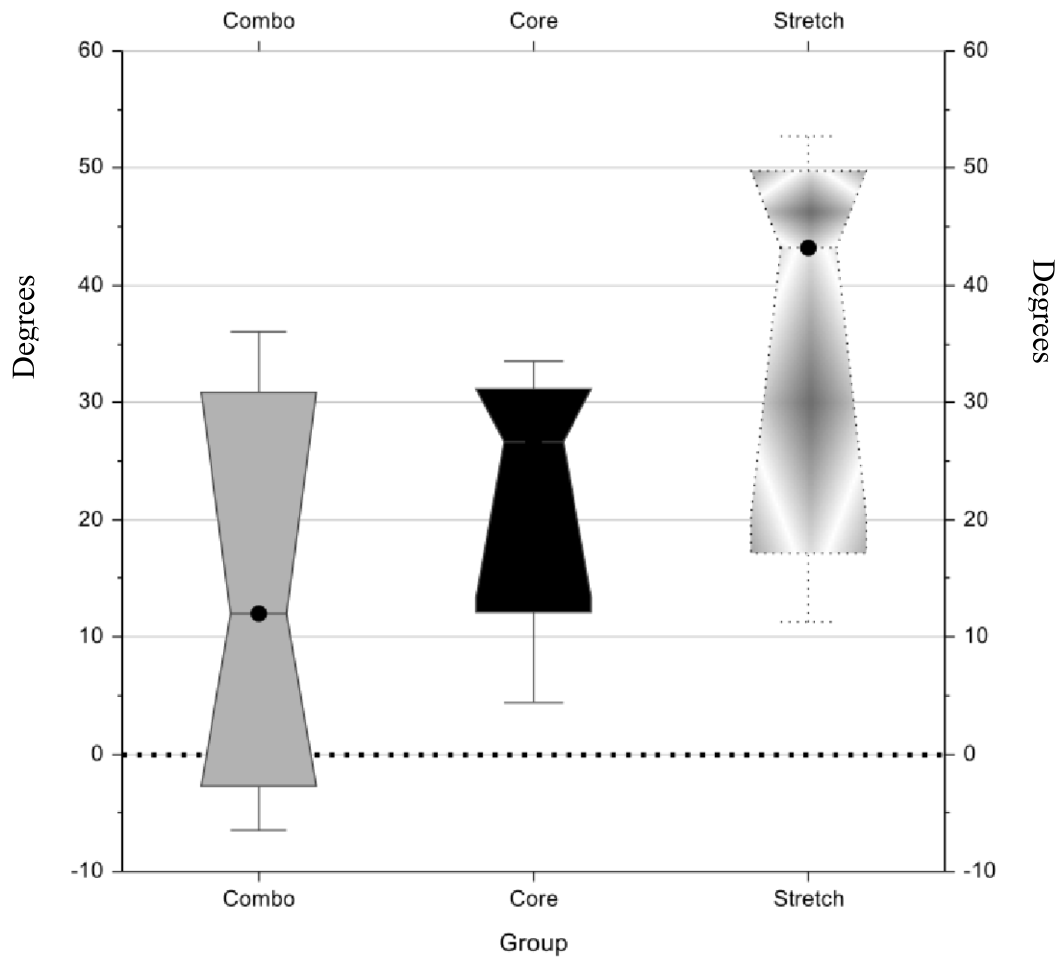


Figure D.3: Post to Baseline Change Right Hip Extension

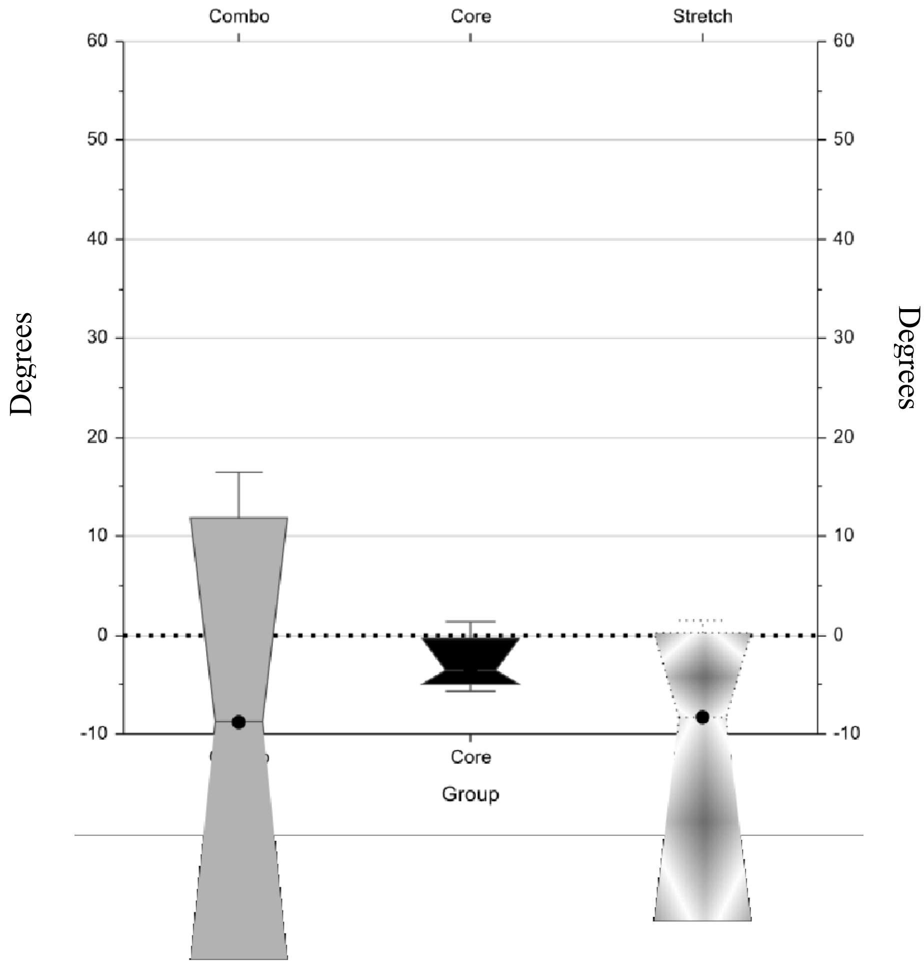


Figure D.4: Residual to Post Change Right Hip Extension

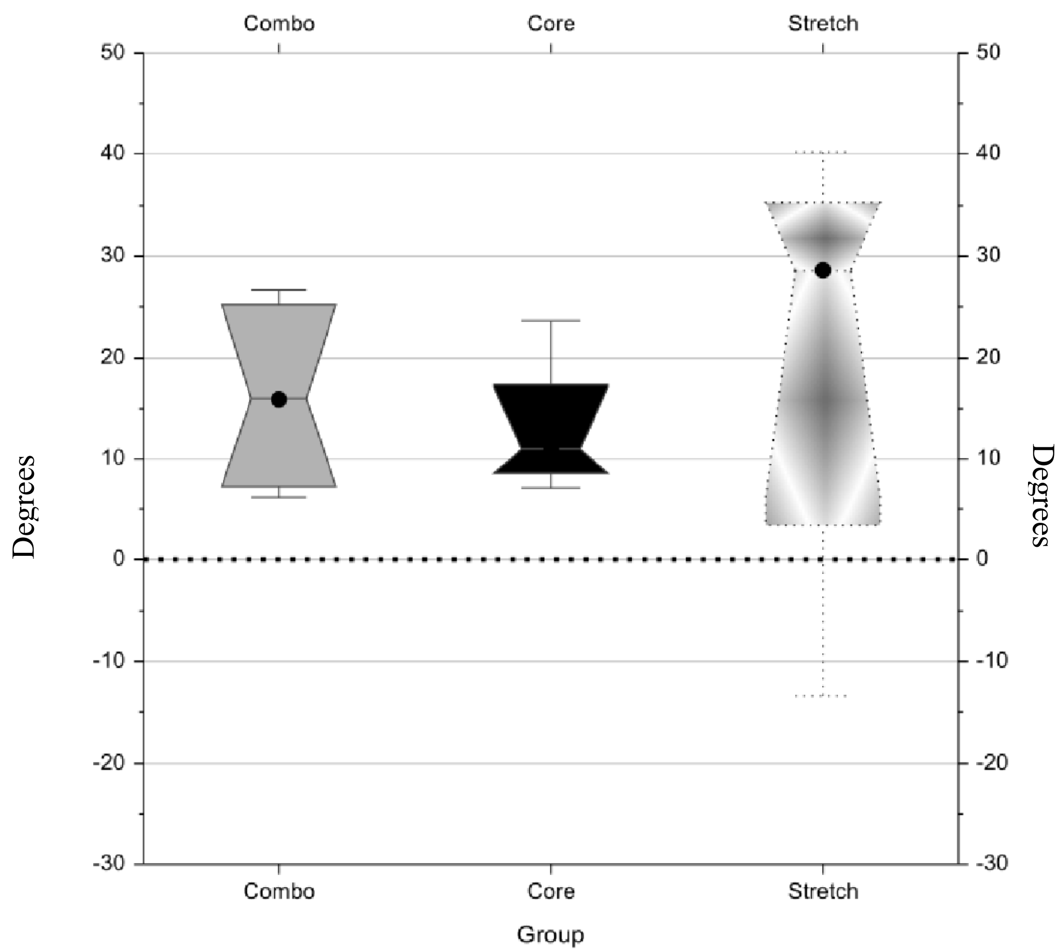


Figure D.5: Post to Baseline Change Left Hip Total Rotation

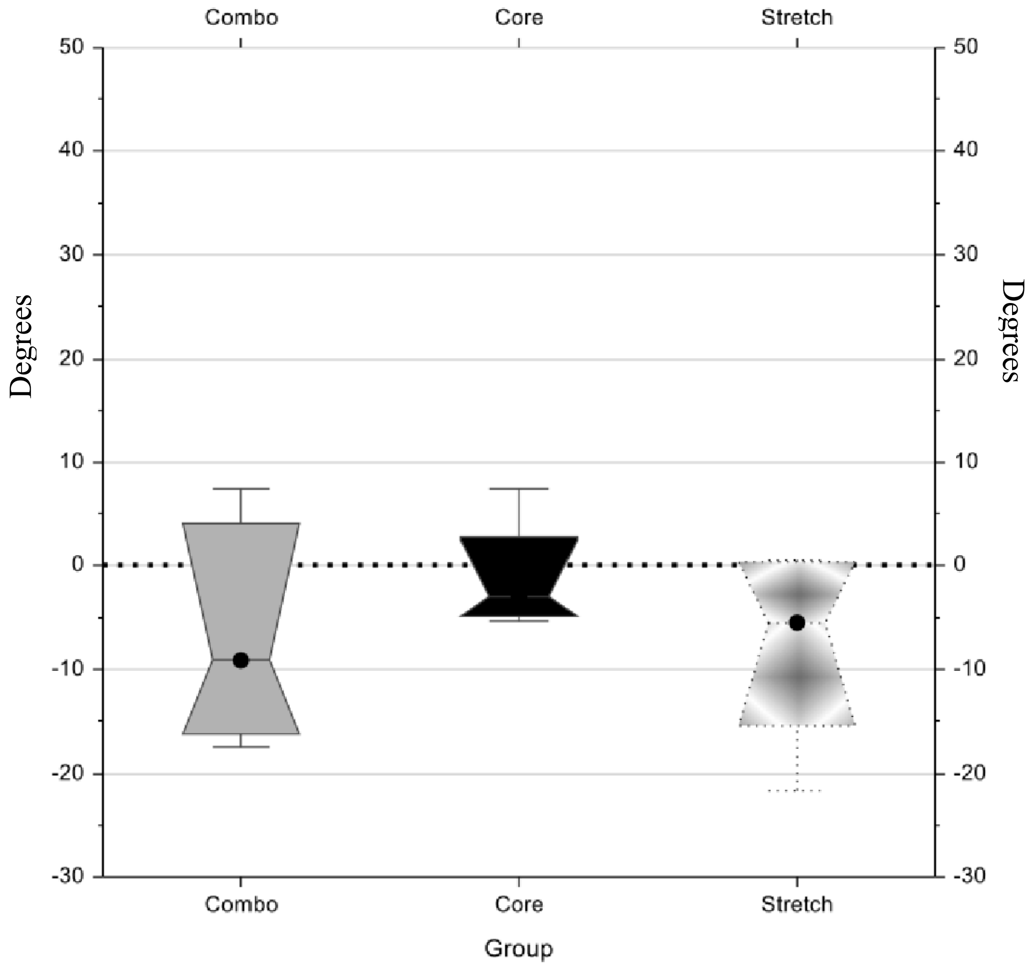


Figure D.6: Residual to Post Change Left Hip Total Rotation

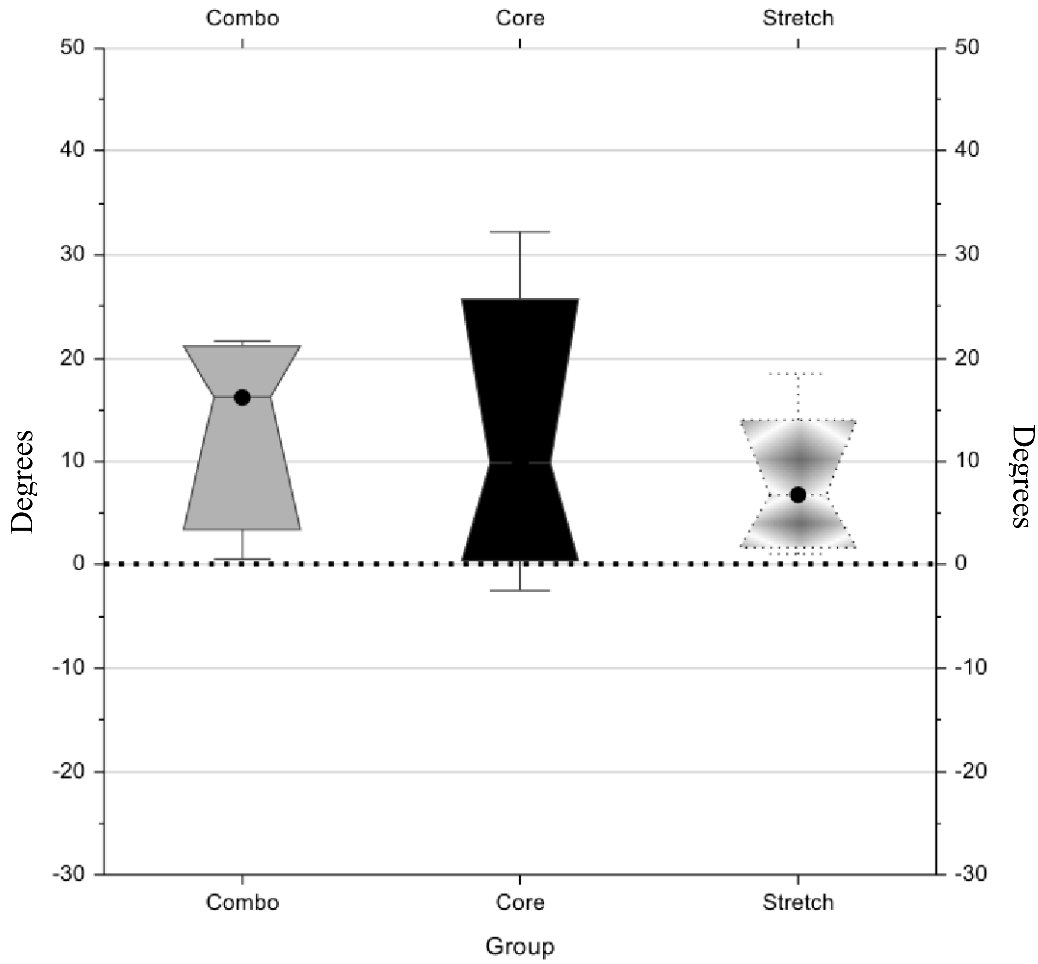


Figure D.7: Post to Baseline Change Right Hip Total Rotation

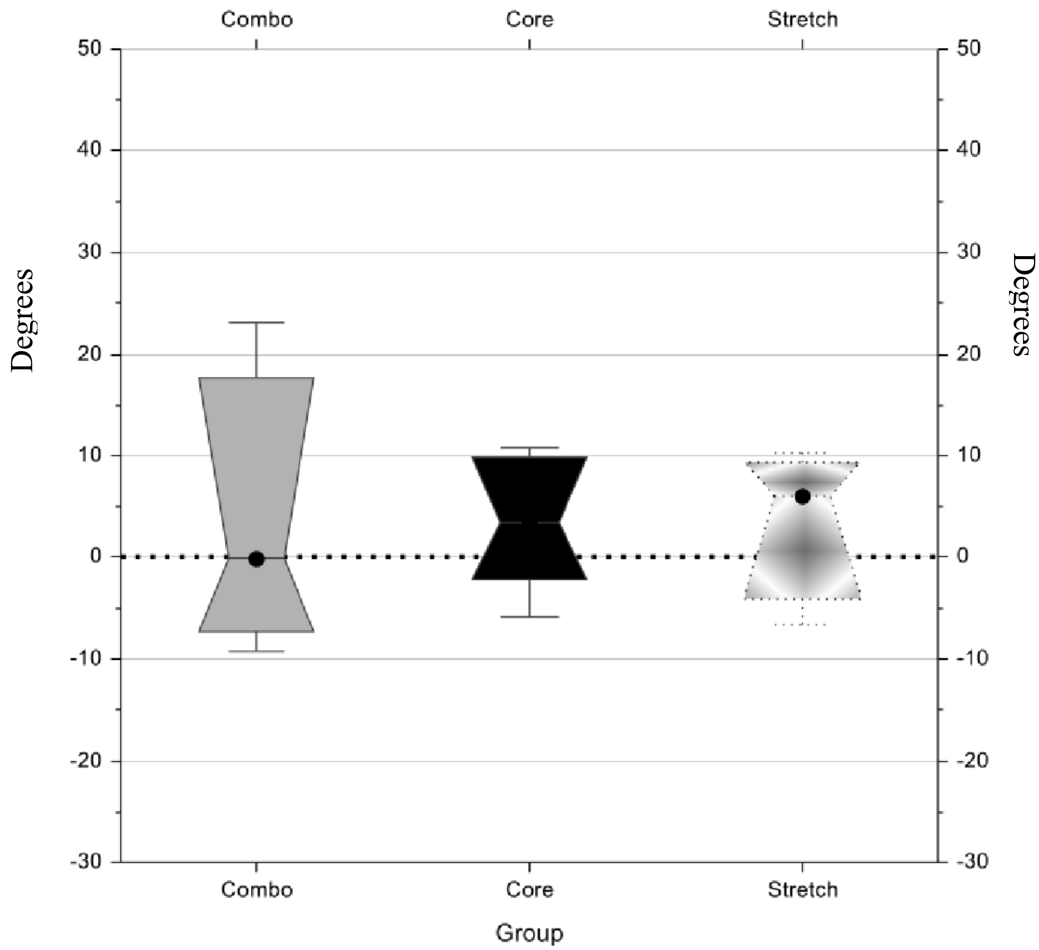


Figure D.8: Residual to Post Change Right Hip Total Rotation

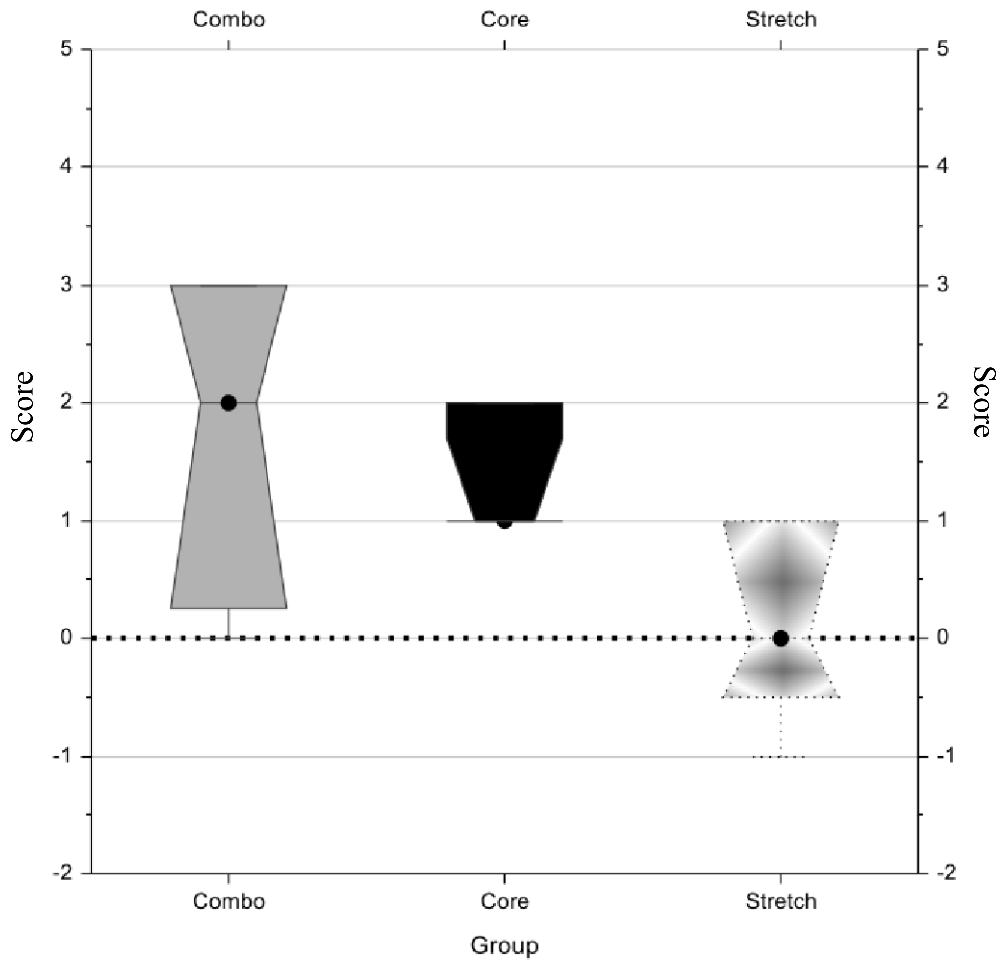


Figure D.9: Post to Baseline Changes for DLLT

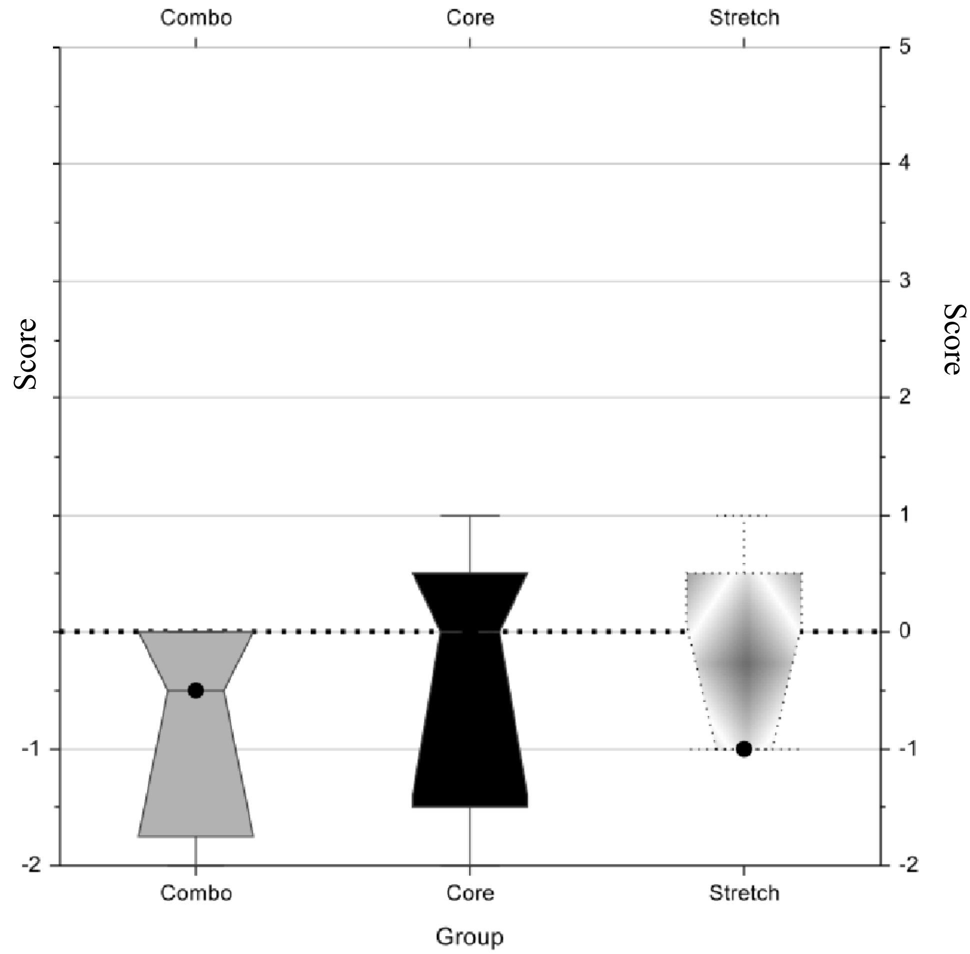


Figure D.10: Residual to Post Changes for DLLT

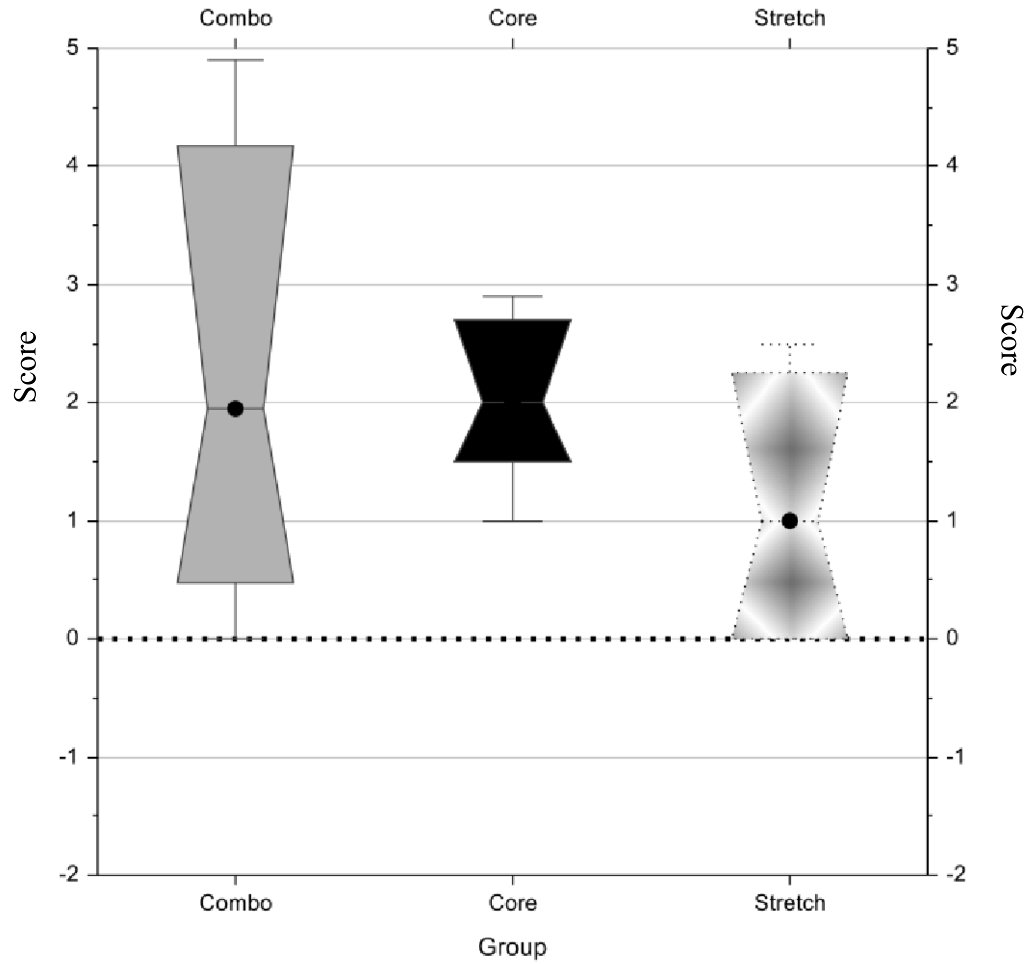


Figure D.11: Post to Baseline Changes for LAMP

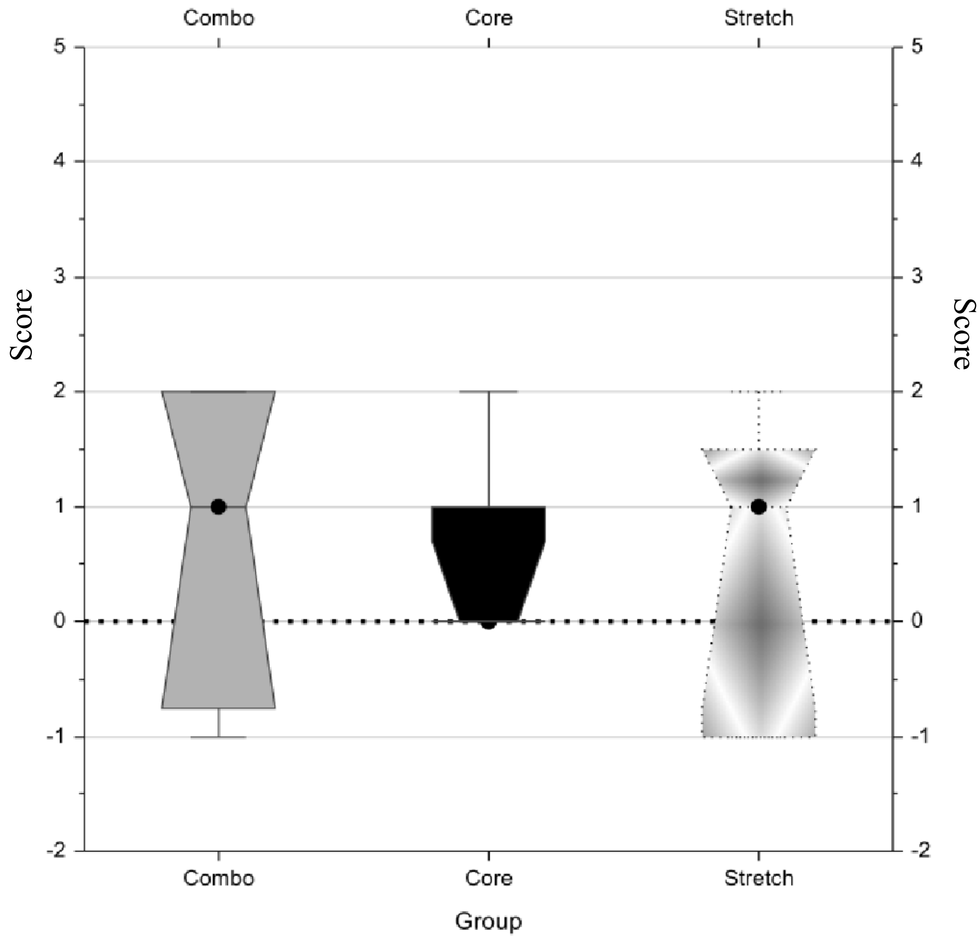


Figure D.12: Residual to Post Changes for LAMP

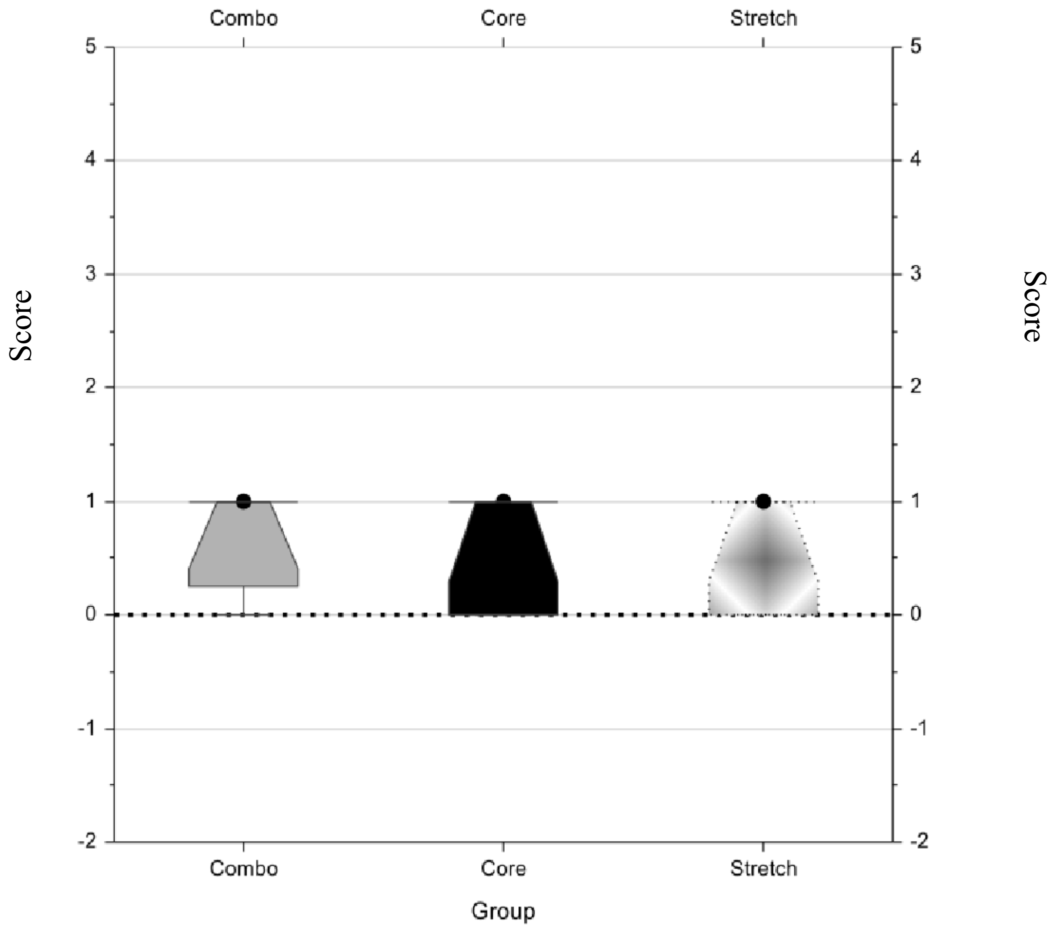


Figure D.13: Post to Baseline Changes for OHS

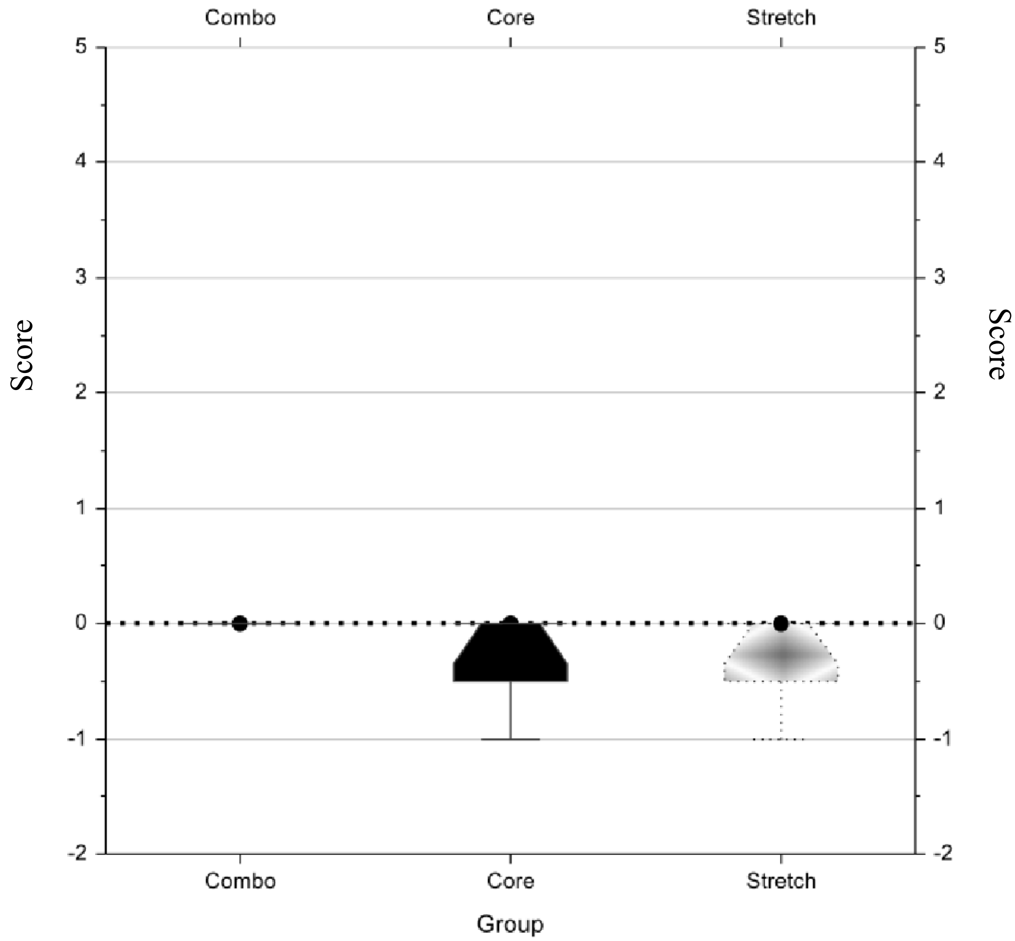


Figure D.14: Residual to Post Changes for OHS

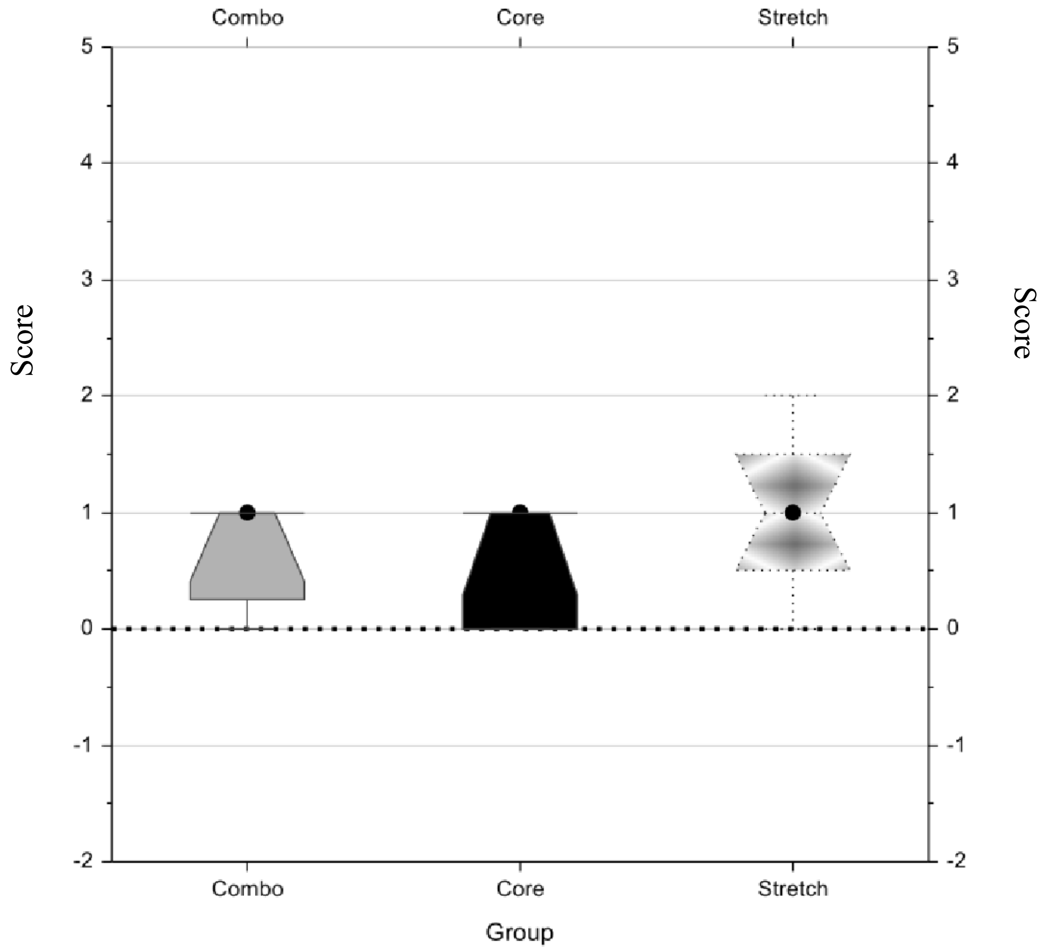


Figure D.15: Post to Baseline Changes for ASLR

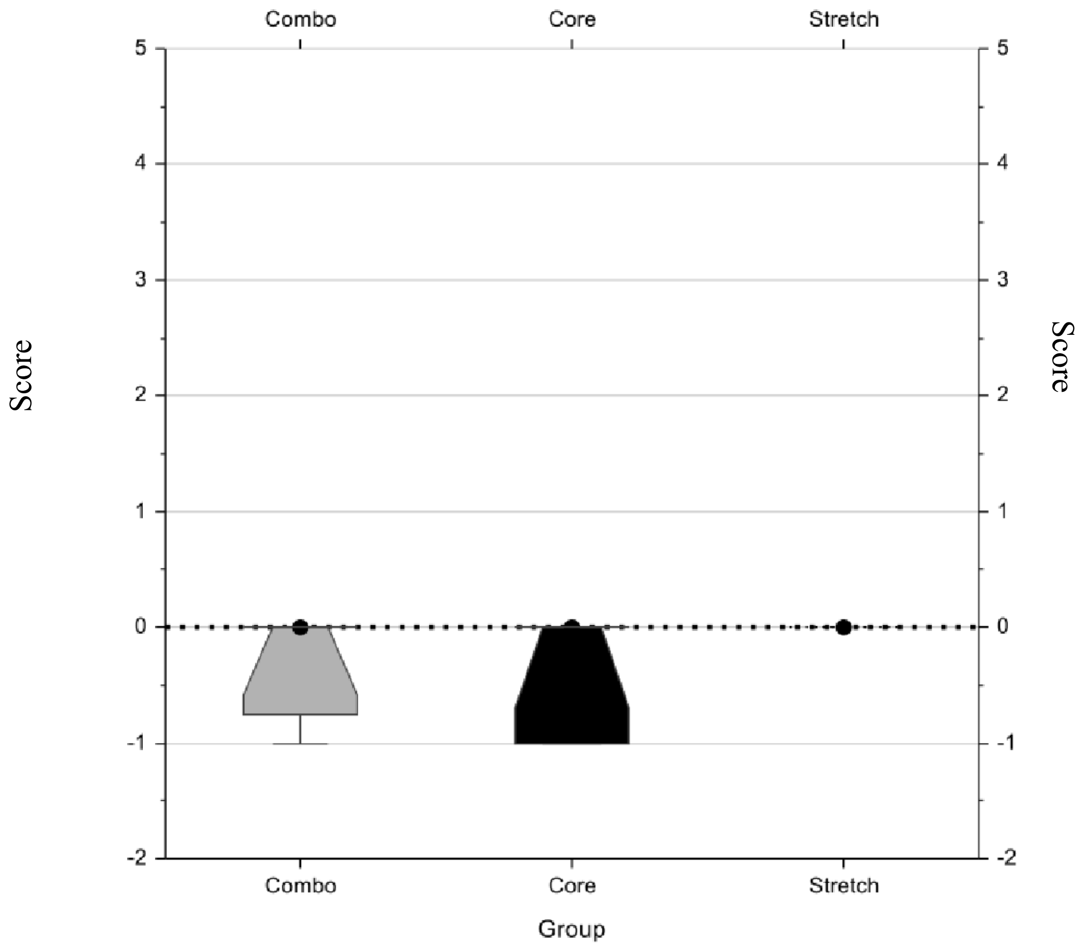


Figure D.16: Residual to Post Changes for ASLR

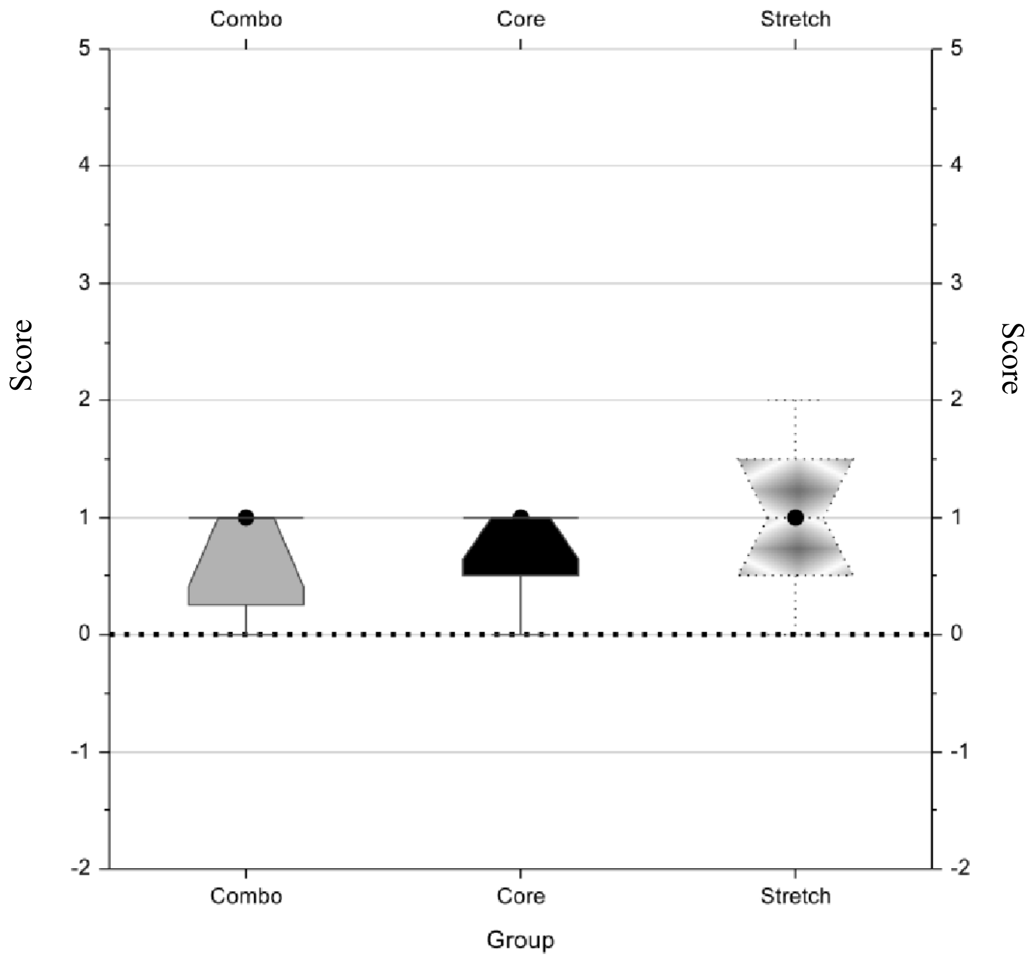


Figure D.17: Post to Baseline Changes for TPSU

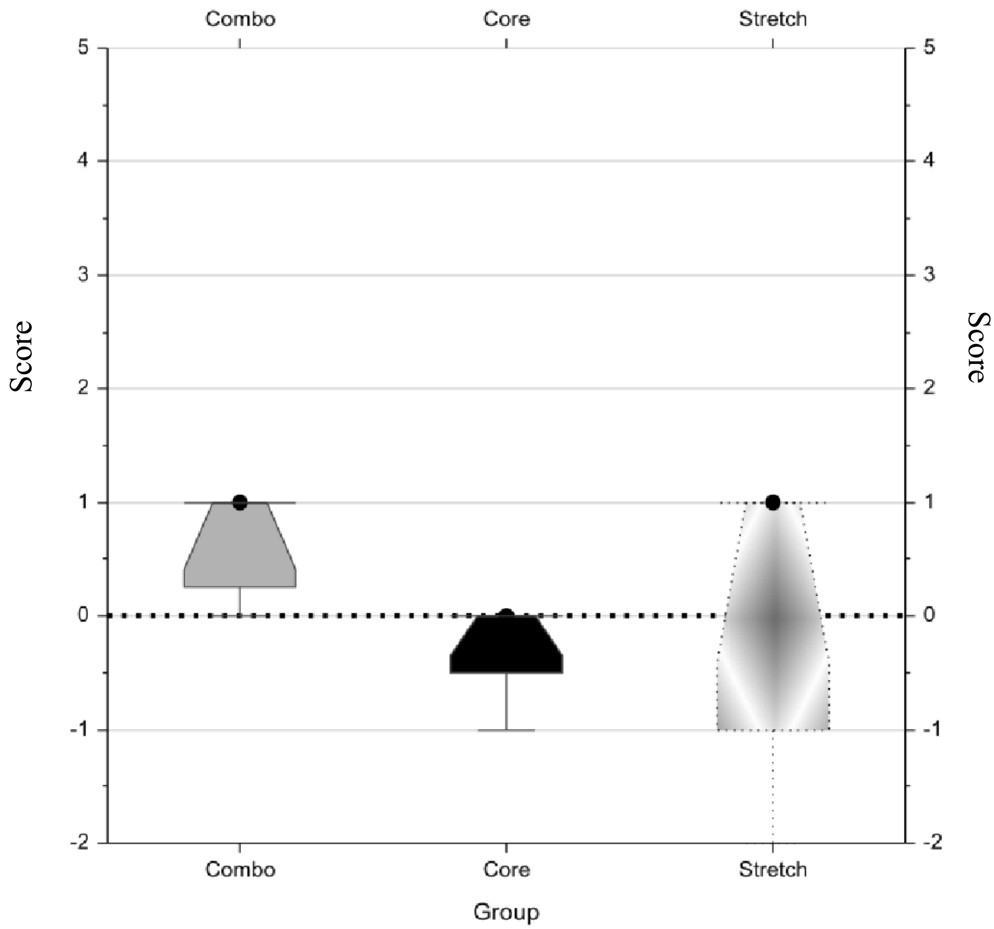


Figure D.18: Residual to Post Changes for TPSU

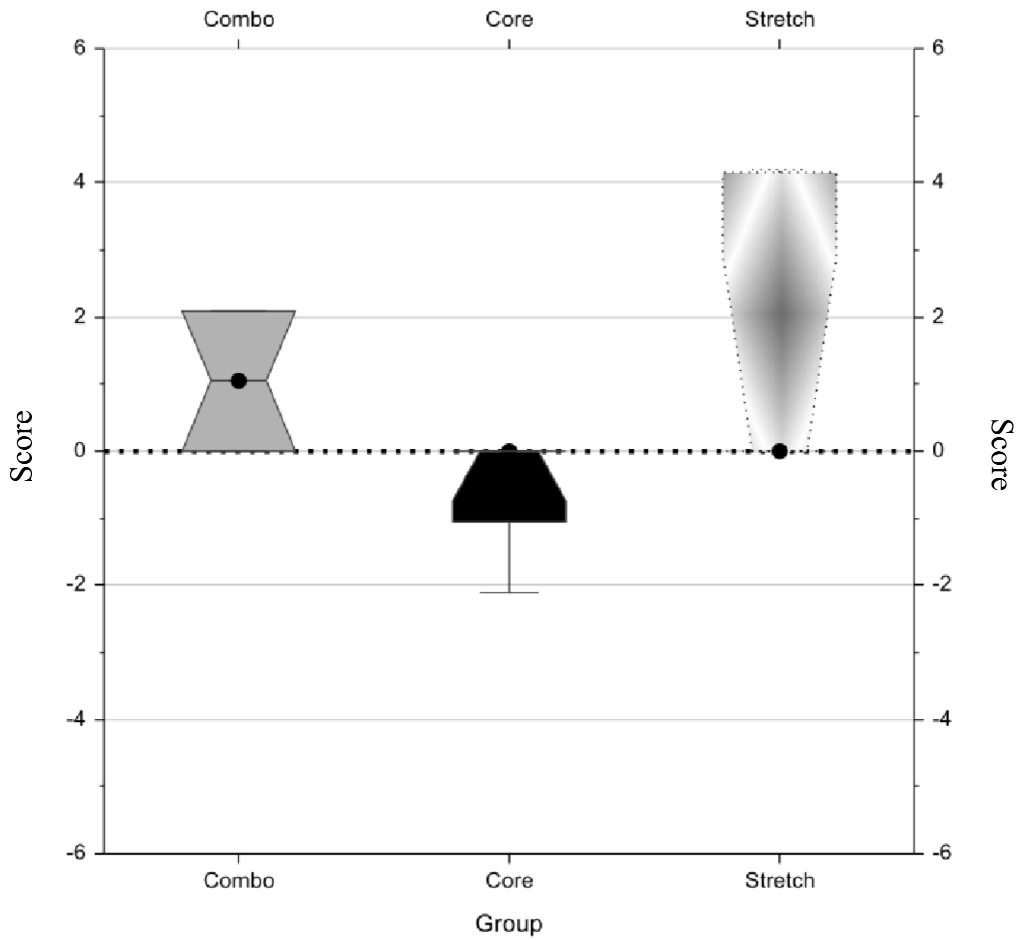


Figure D.19: Post to Baseline Changes for Norm PF

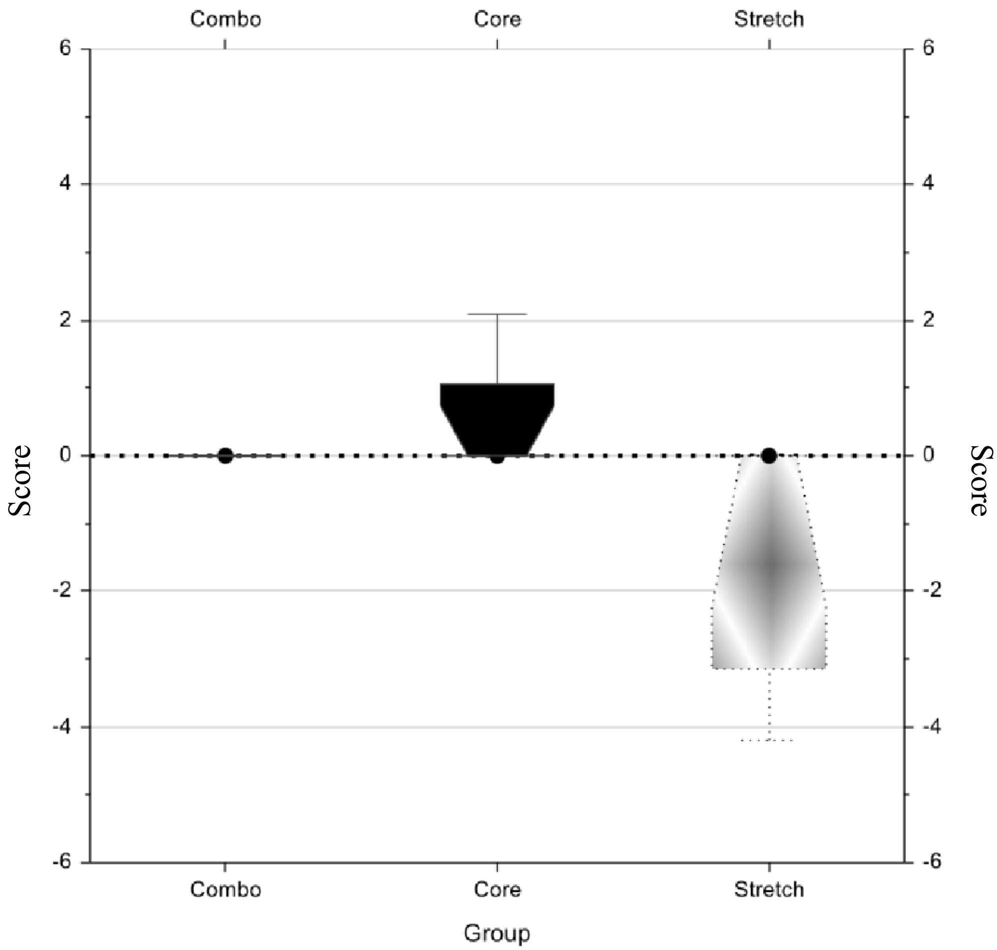


Figure D.20: Residual to Post Changes for Norm PF

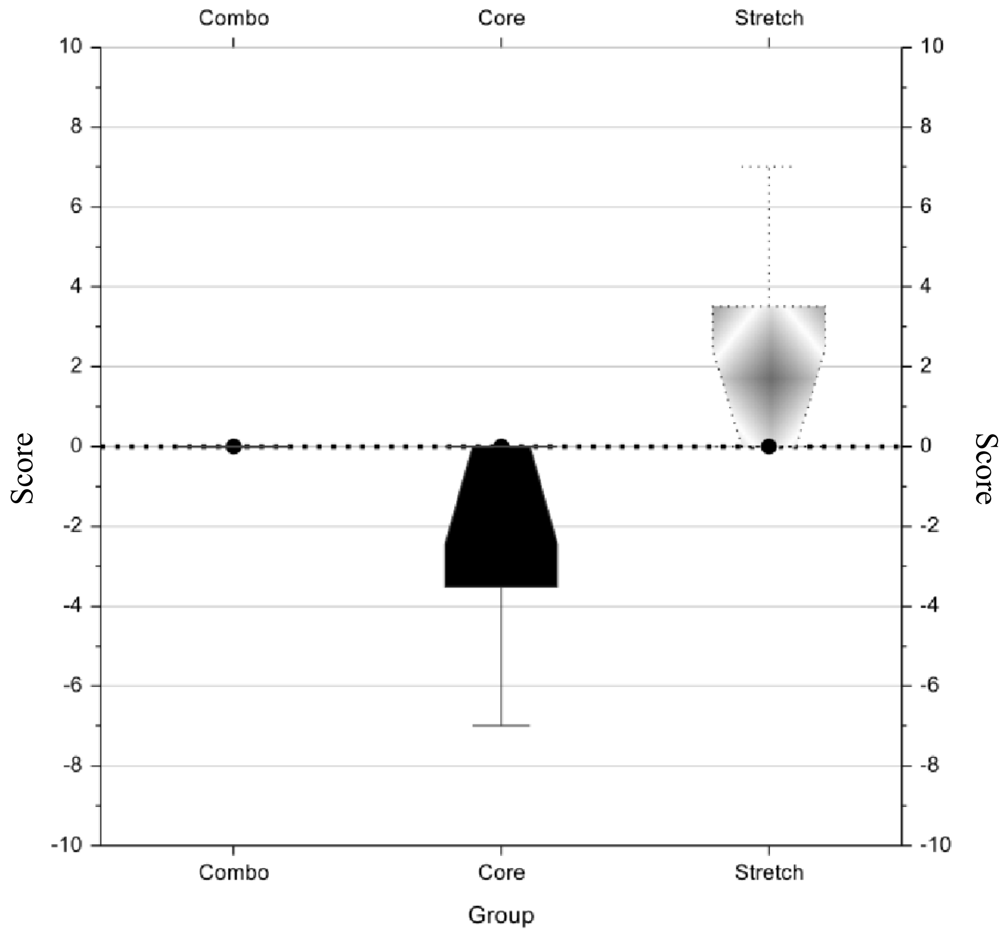


Figure D.21: Post to Baseline Changes for Norm RP

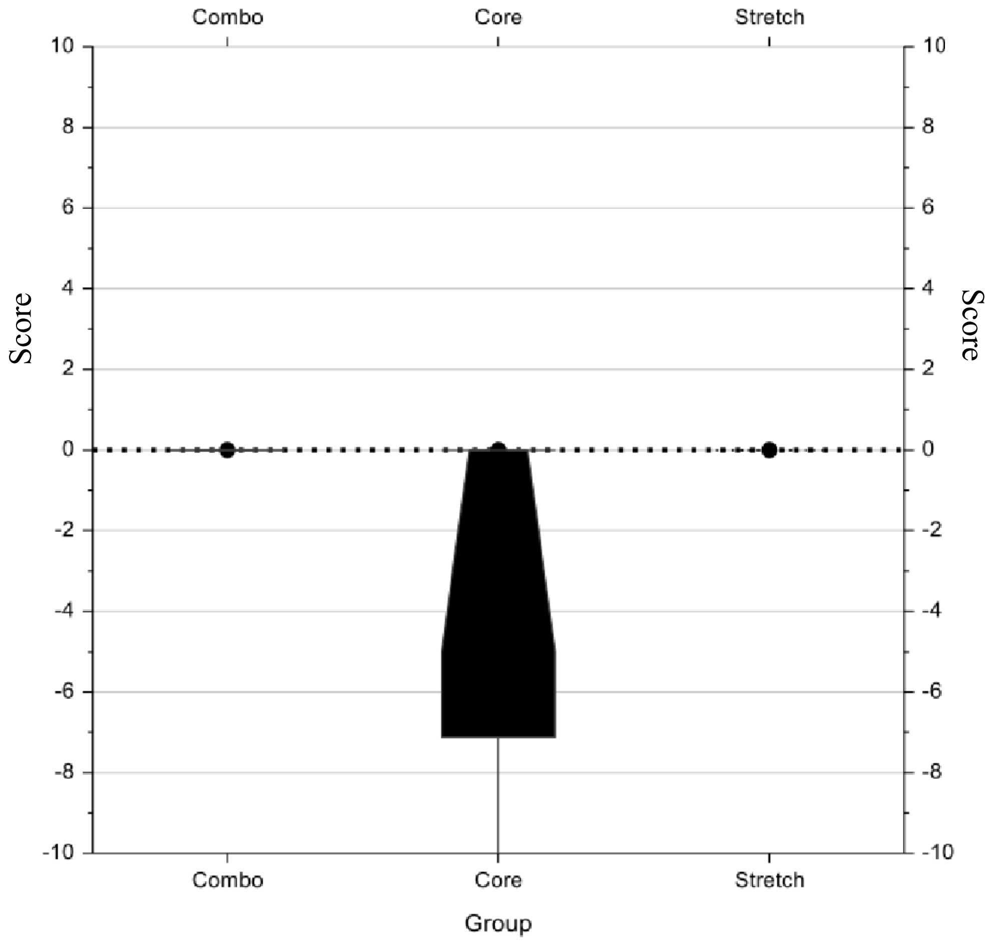


Figure D.22: Residual to Post Changes for Norm RP

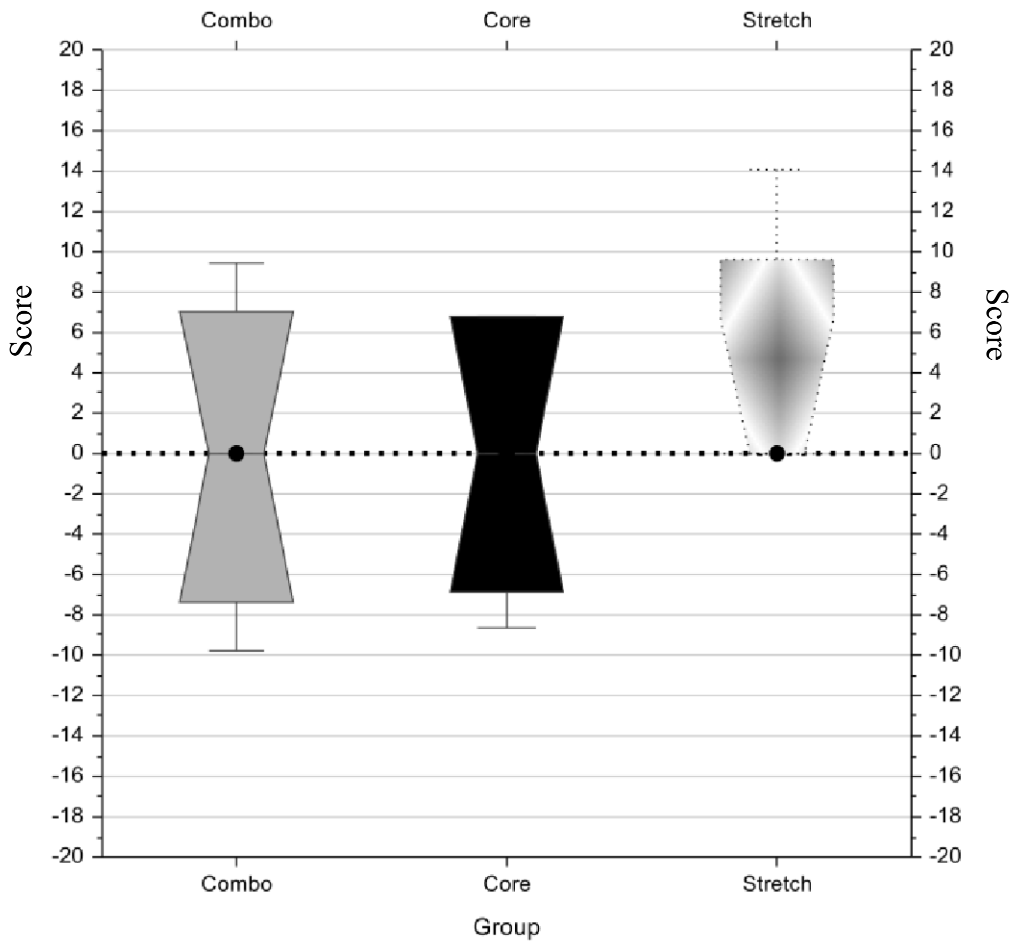


Figure D.23: Post to Baseline Changes for Norm BP

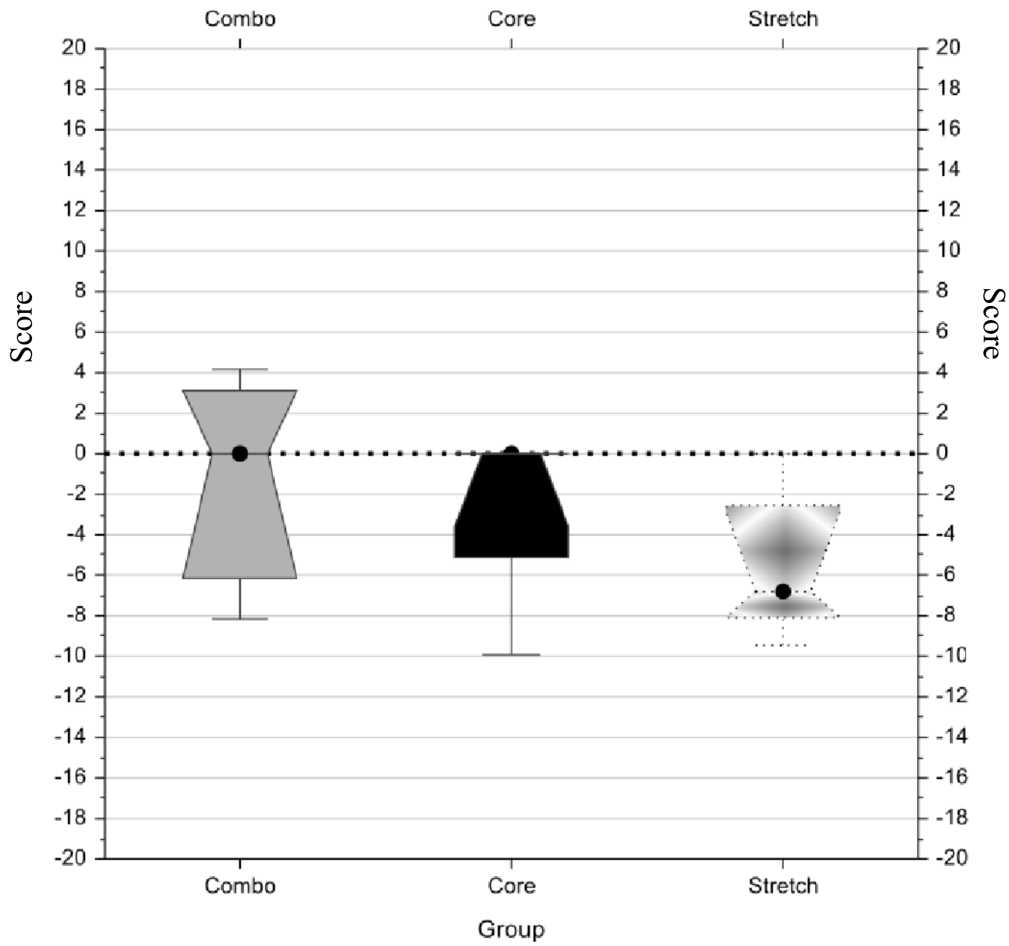


Figure D.24: Residual to Post Changes for Norm BP

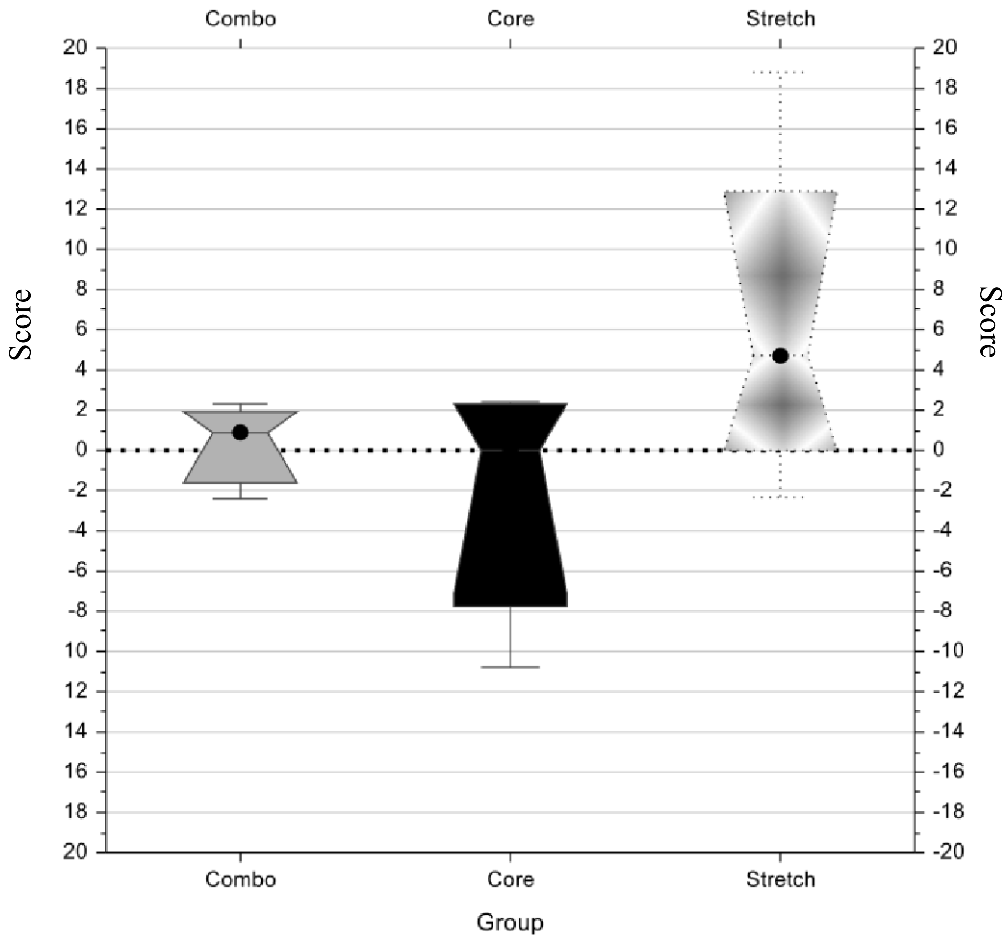


Figure D.25: Post to Baseline Changes for Norm GH

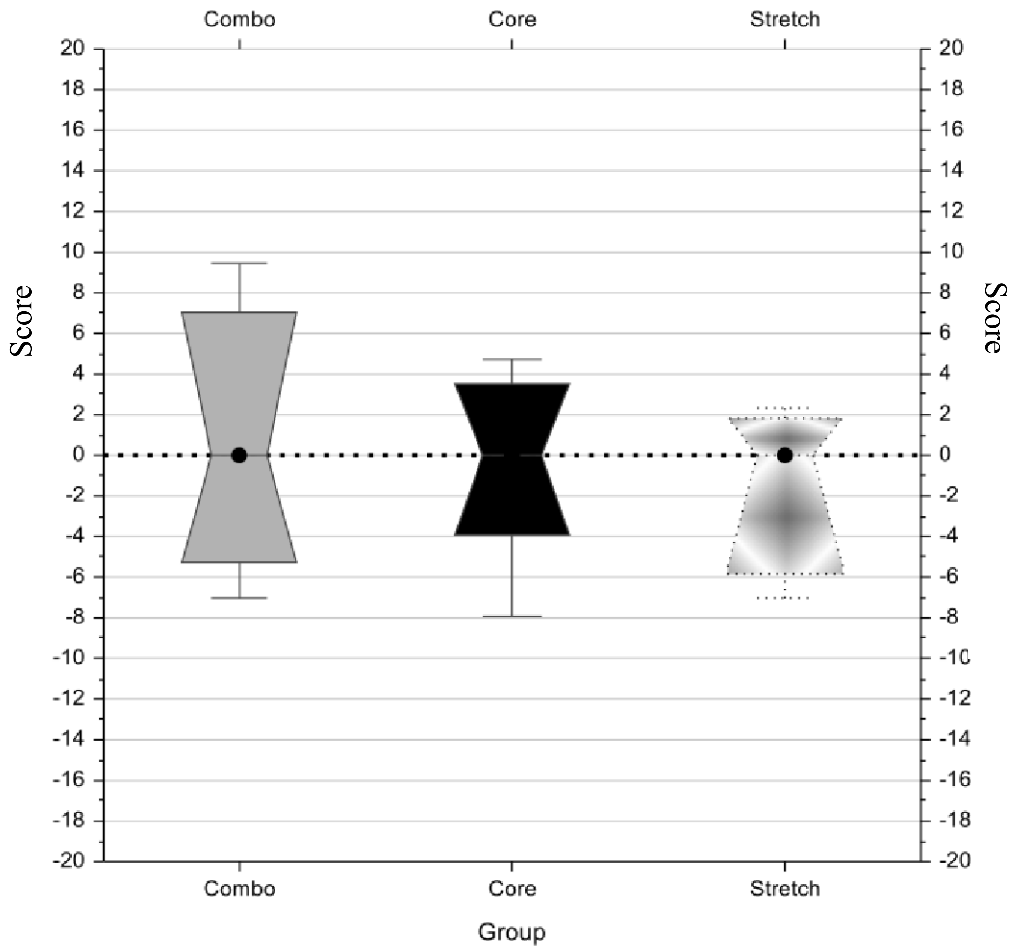


Figure D.26: Residual to Post Changes for Norm GH

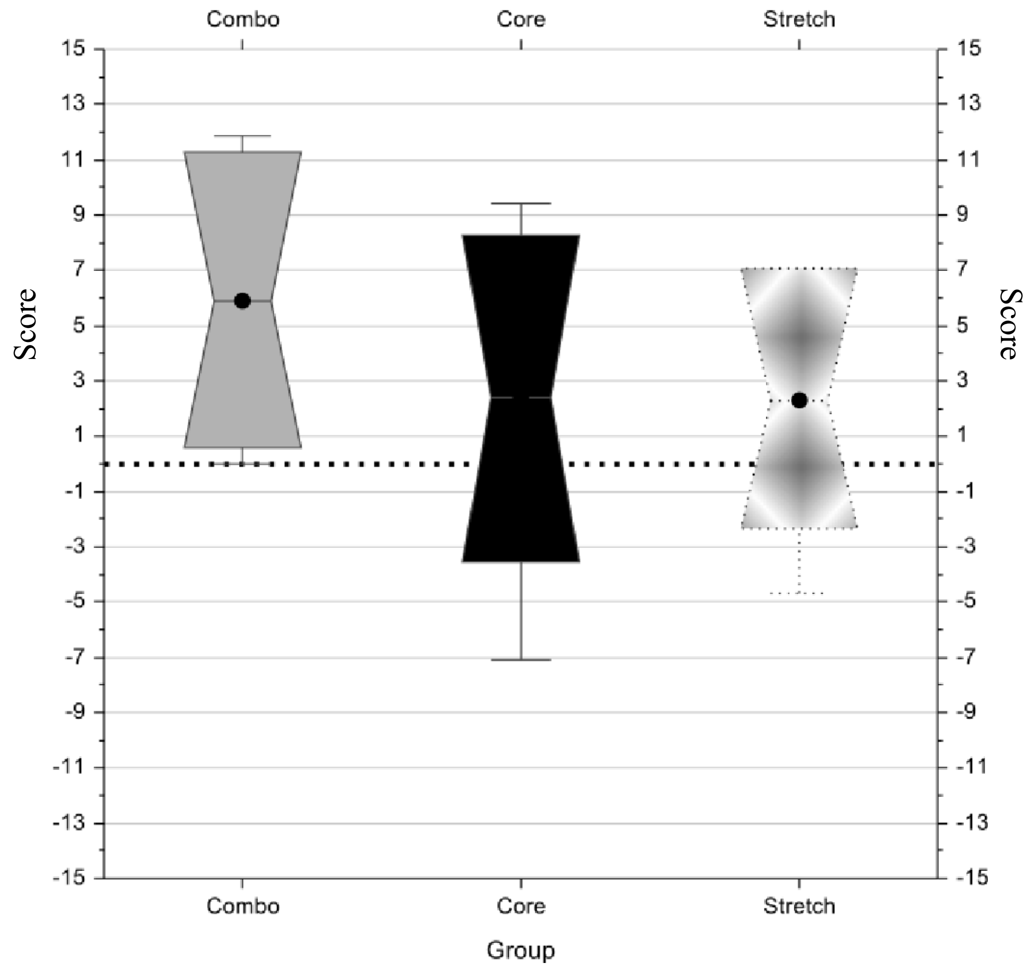


Figure D.27: Post to Baseline Changes for Norm VT

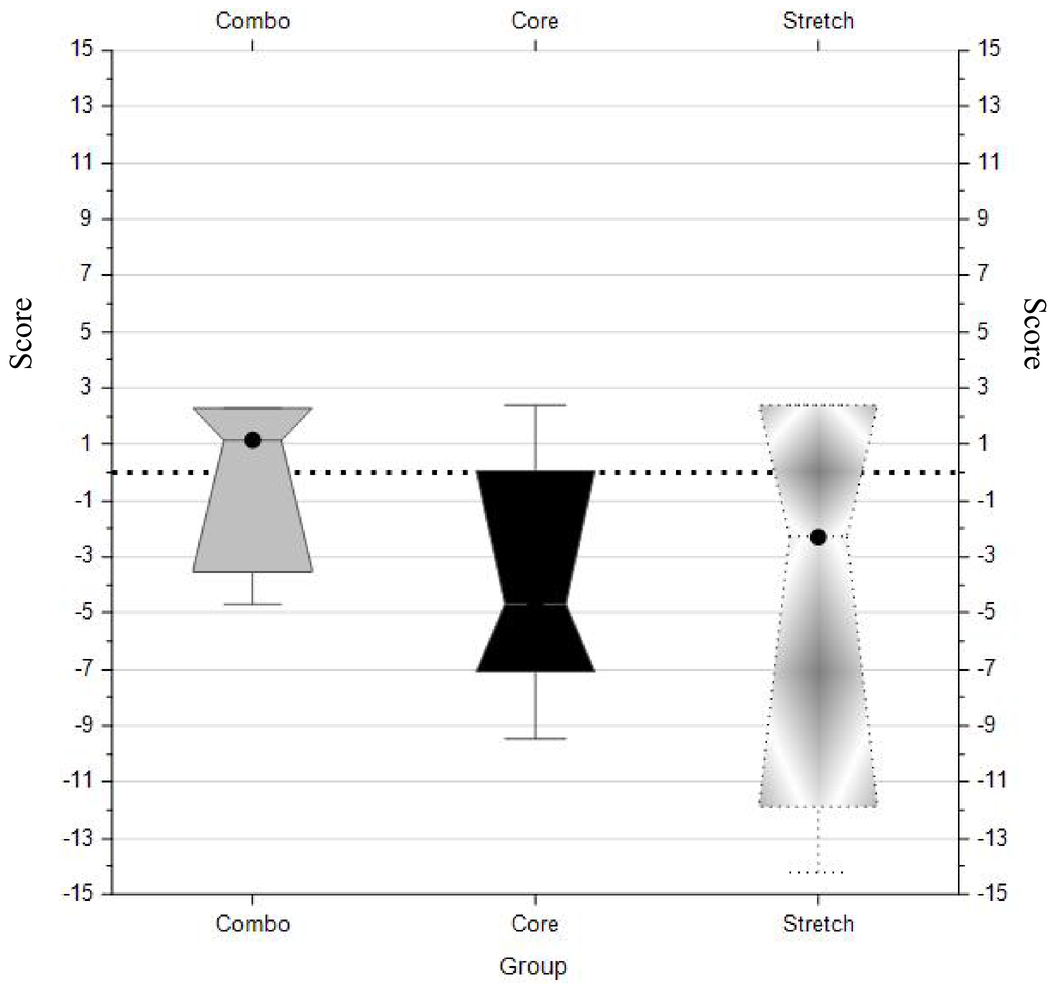


Figure D.28: Residual to Post Changes for Norm VT

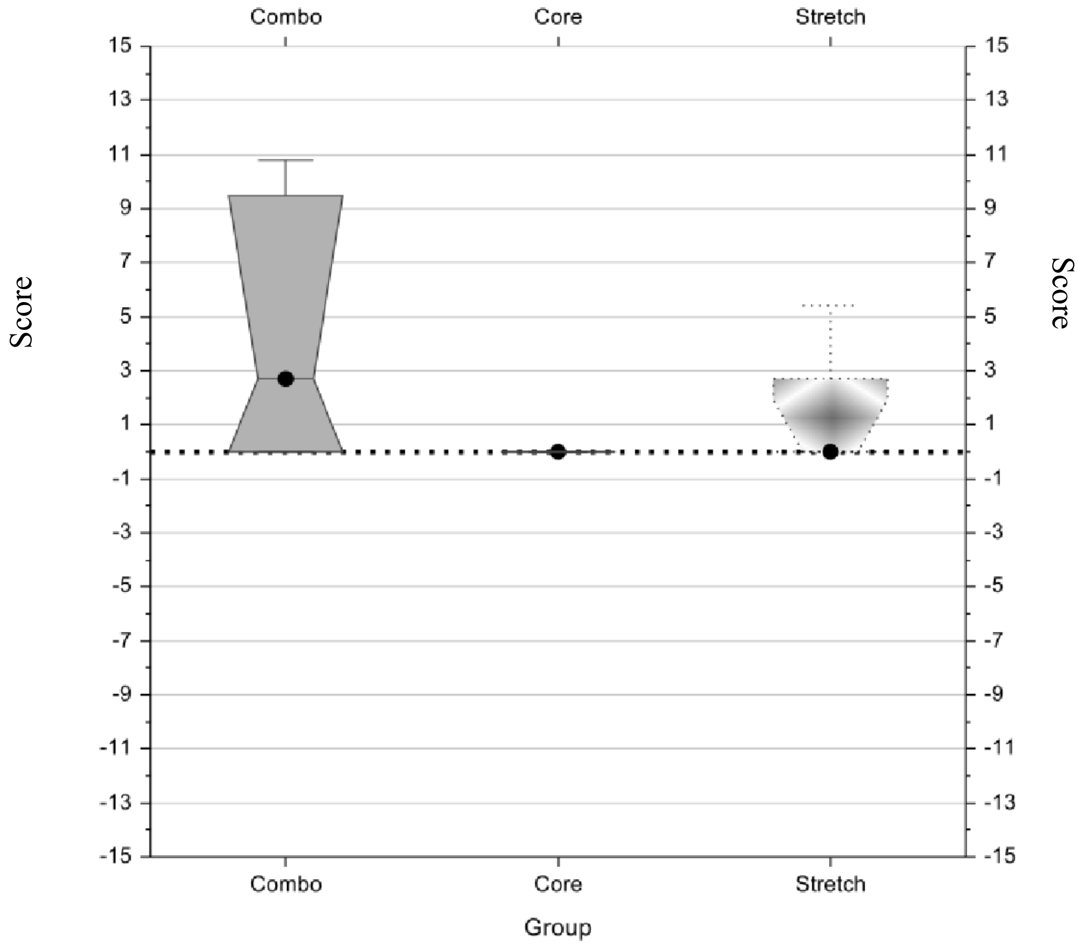


Figure D.29: Post to Baseline Changes for Norm SF

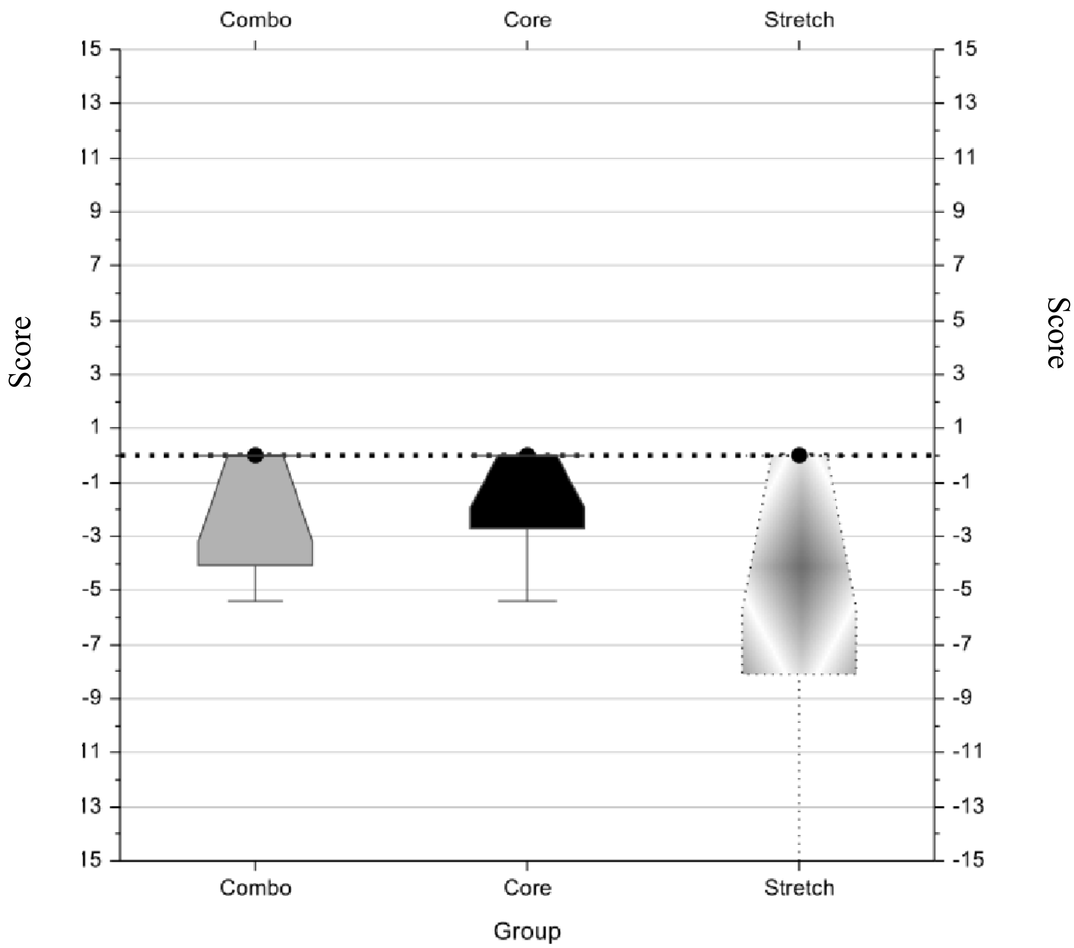


Figure D.30: Residual to Post Changes for Norm SF

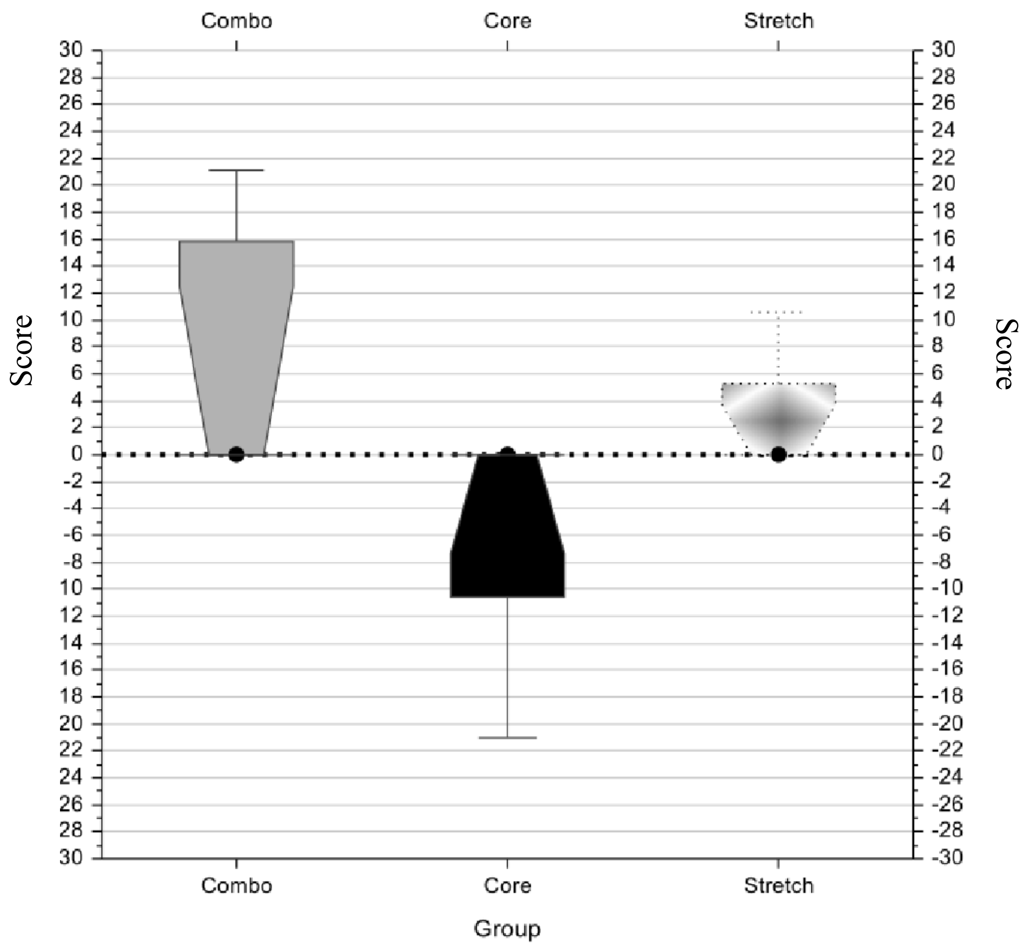


Figure D.31: Post to Baseline Changes for Norm RE

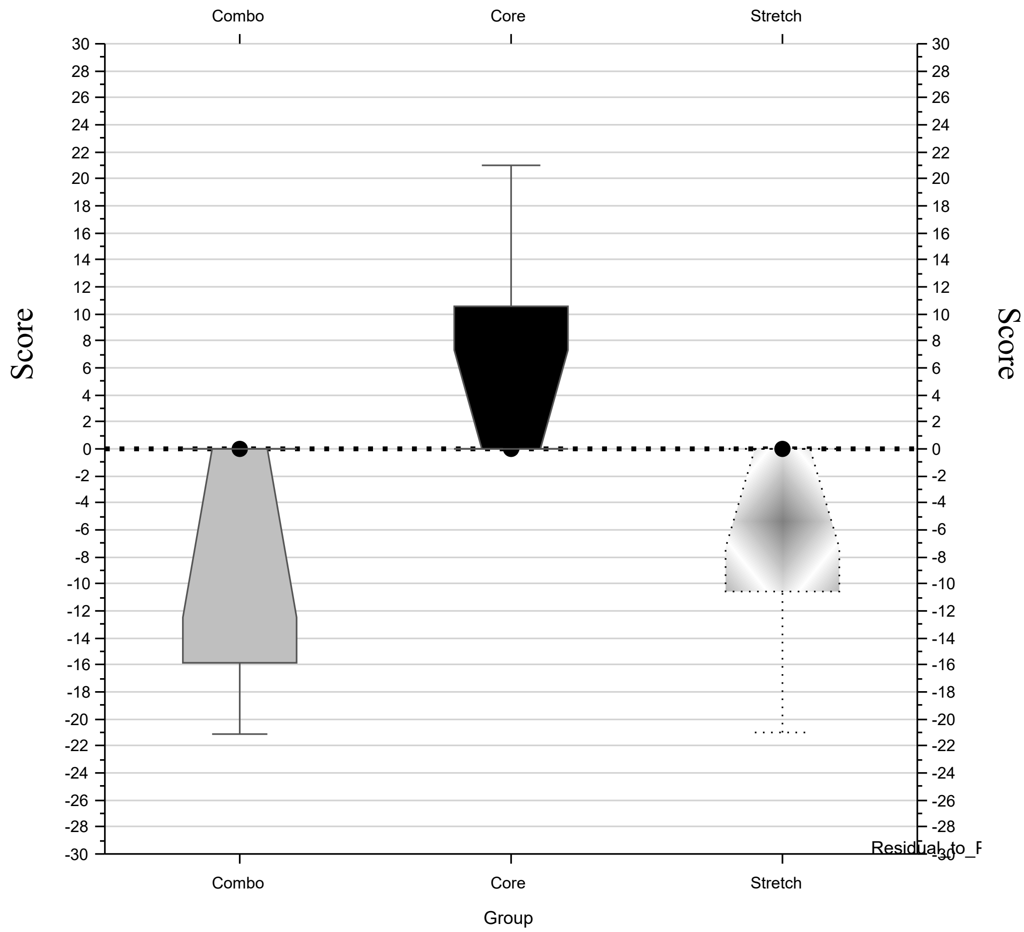


Figure D.32: Residual to Post Changes for Norm RE

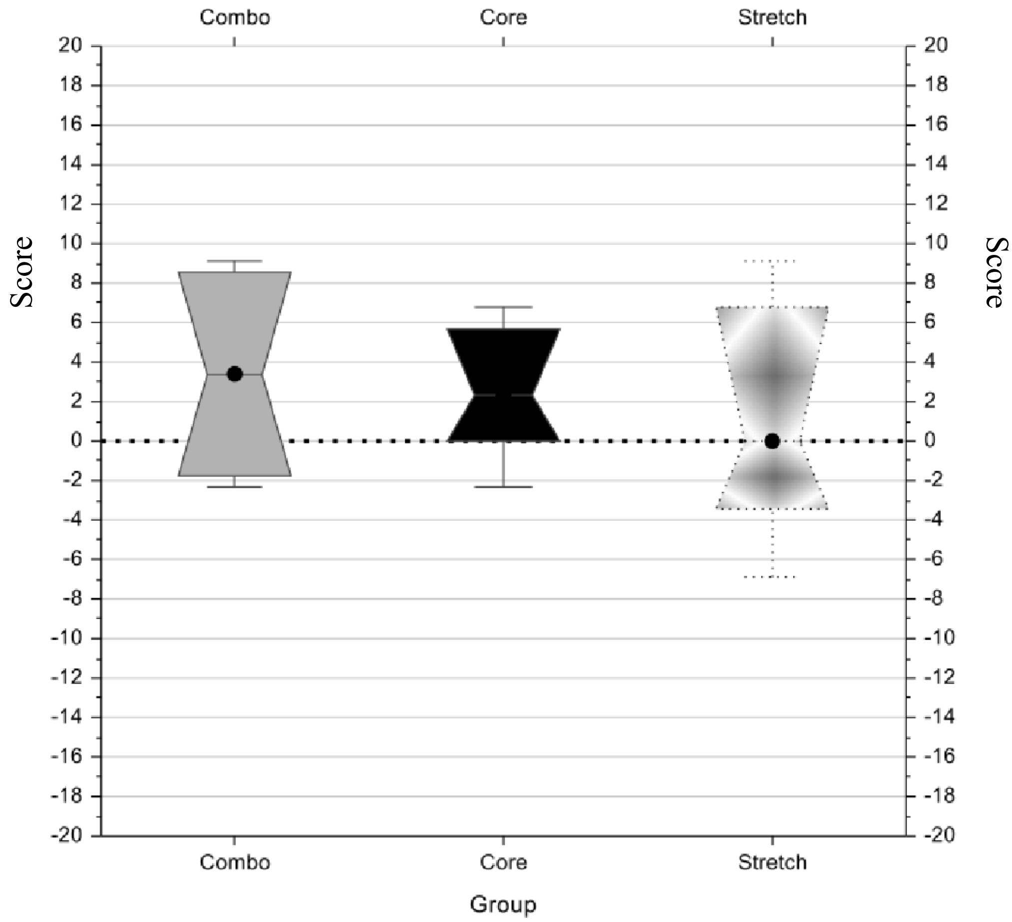


Figure D.33: Post to Baseline Changes for Norm MH

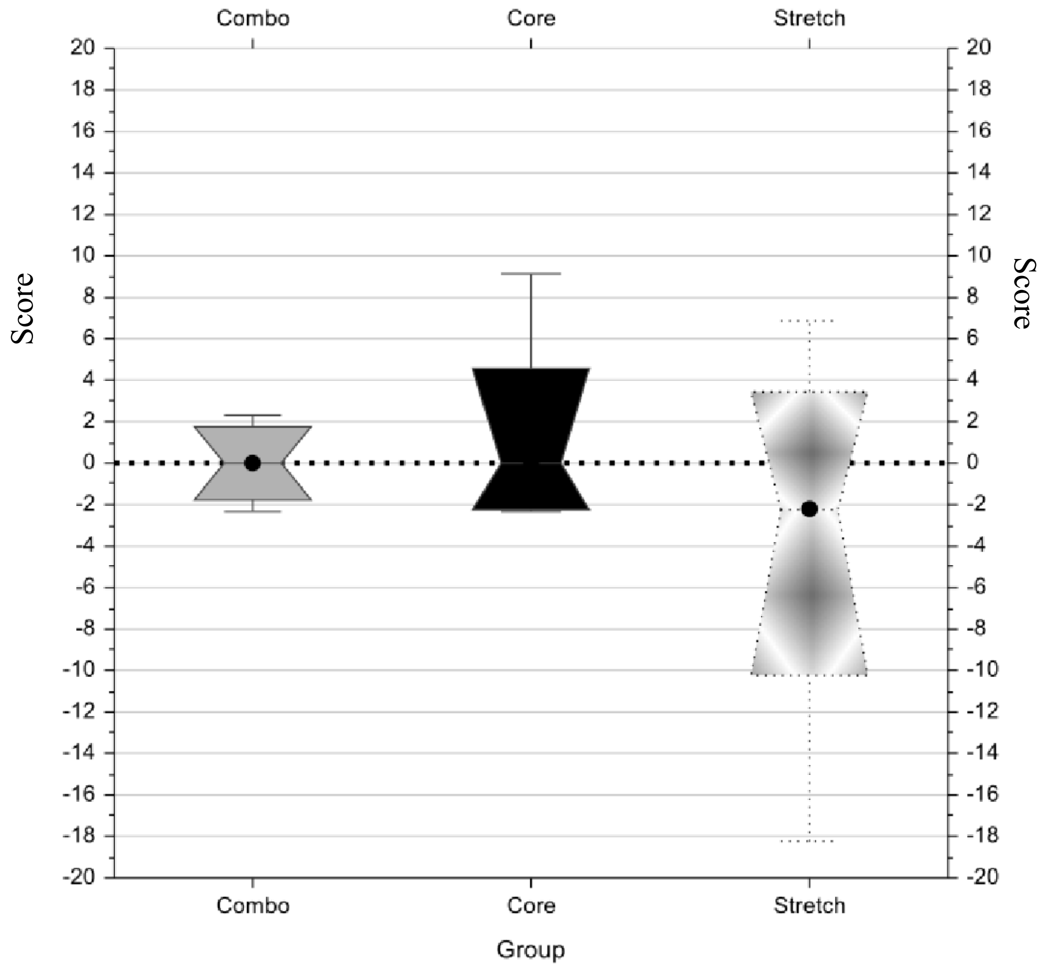


Figure D.34: Residual to Post Changes for Norm MH

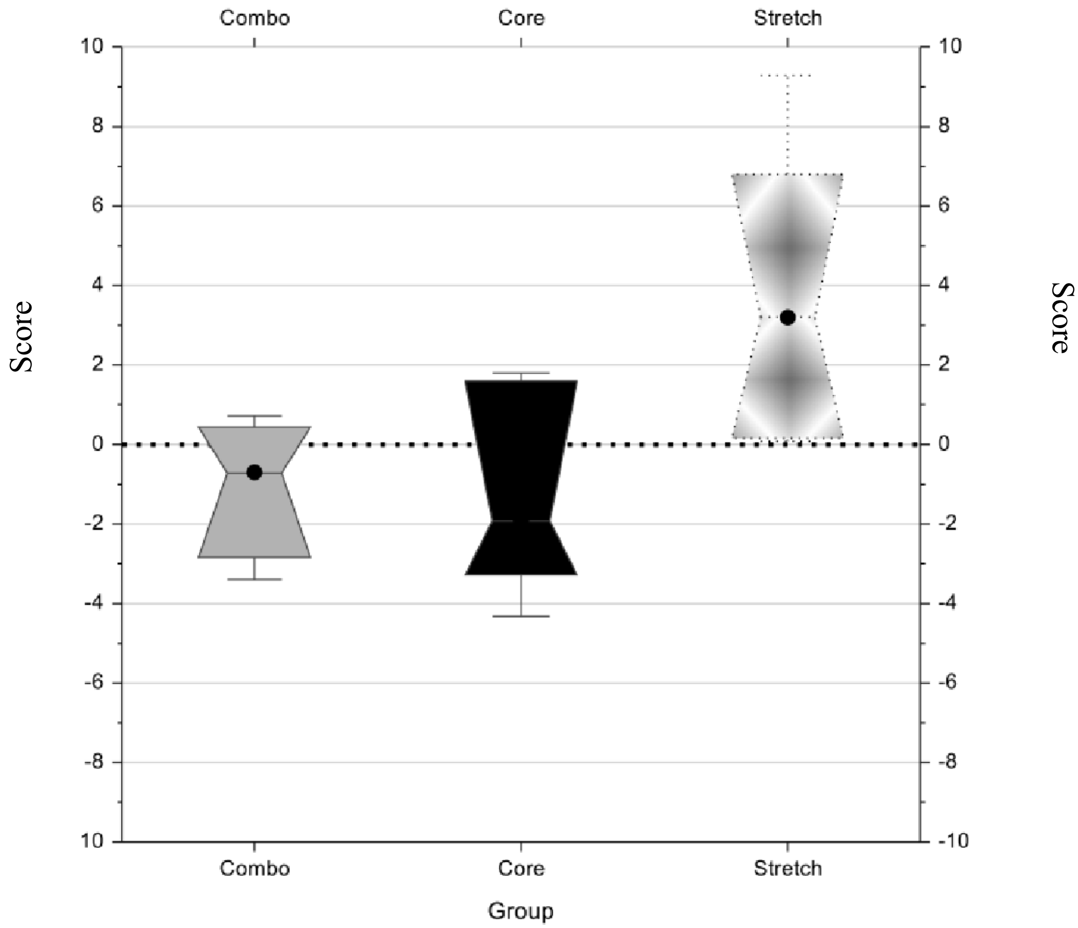


Figure D.35: Post to Baseline Changes for Norm PCS

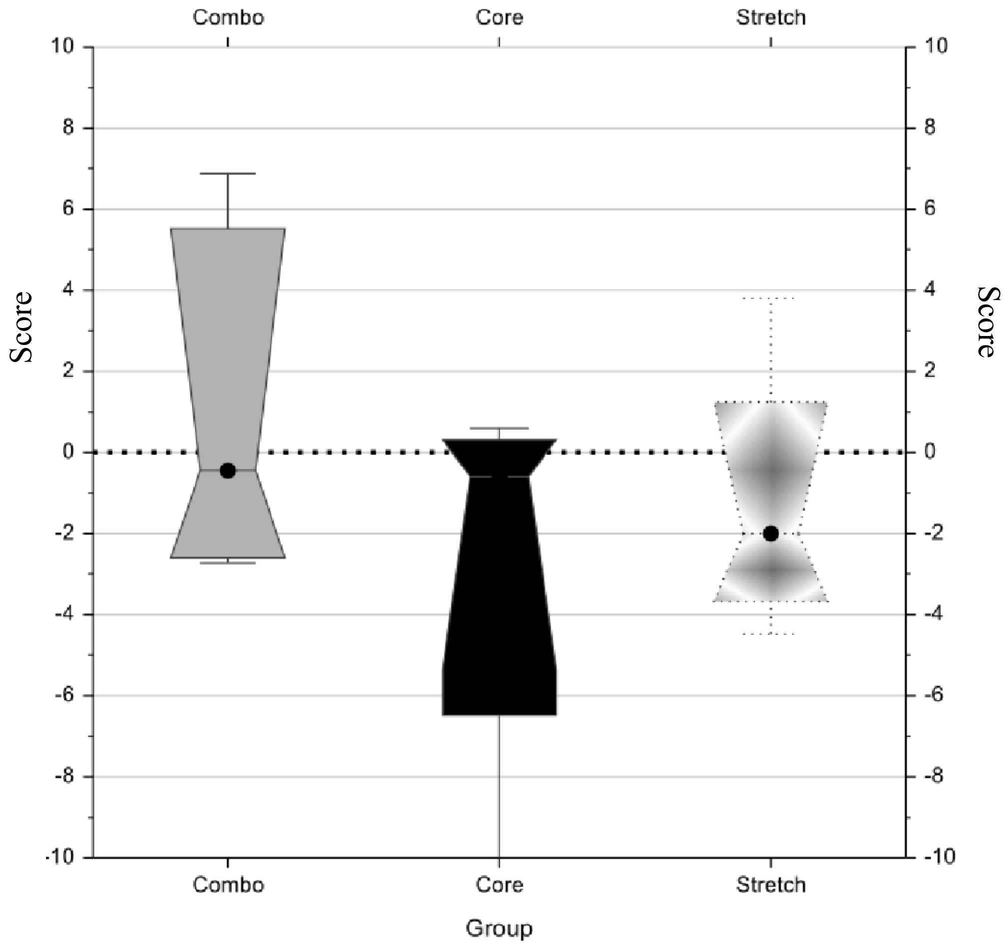


Figure D.36: Residual to Post Changes for Norm PCS

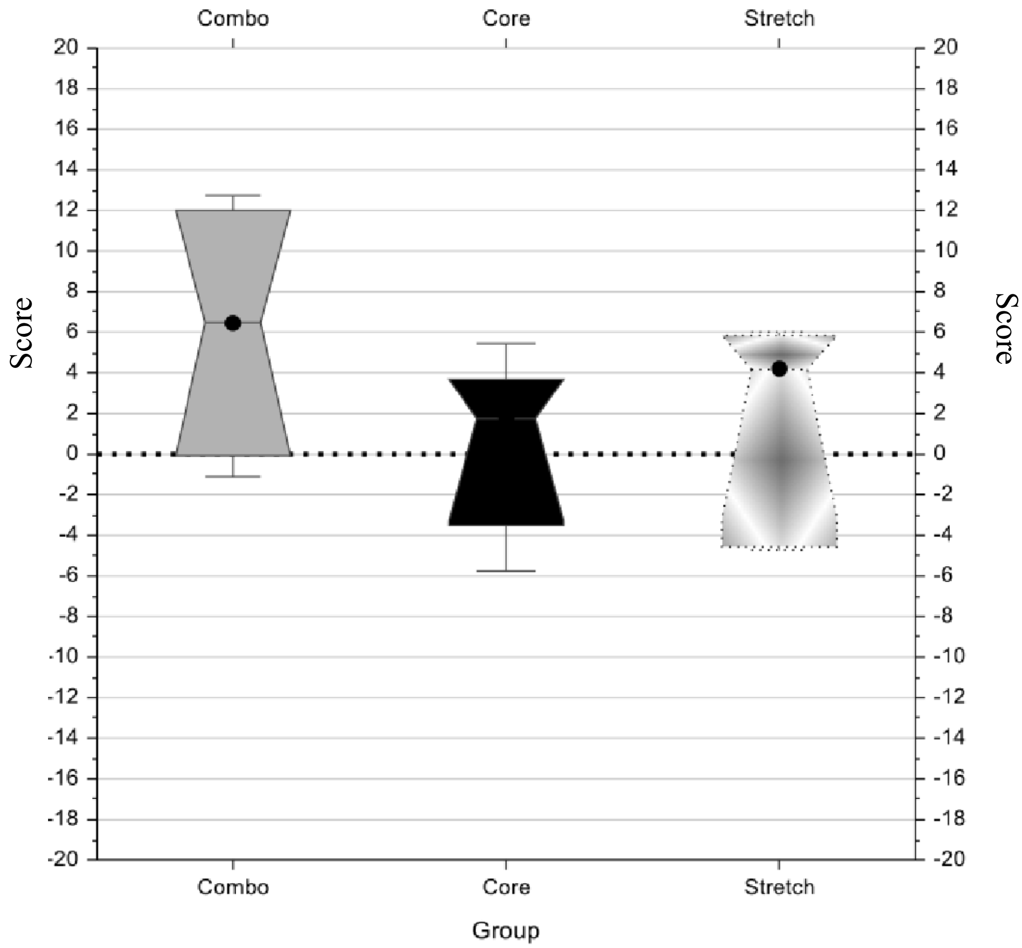


Figure D.37: Post to Baseline Changes for Norm MCS

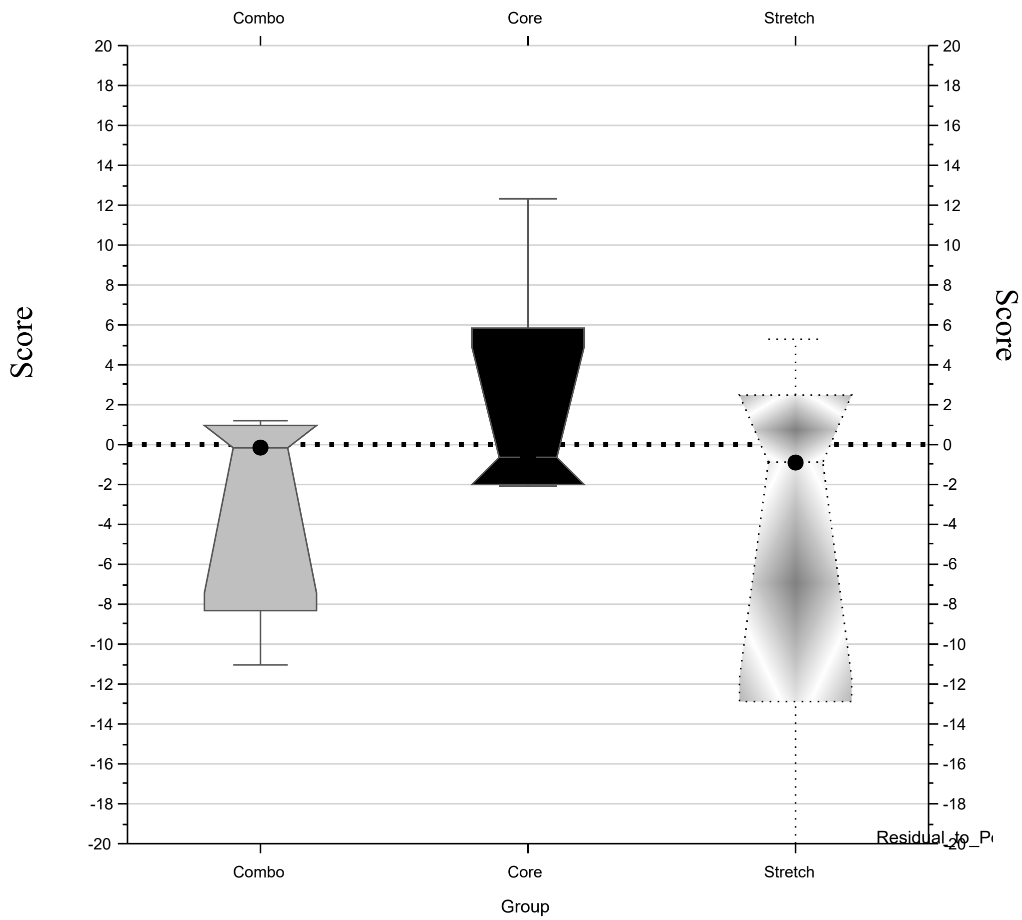


Figure D.38: Residual to Post Changes for Norm MCS

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BIOGRAPHICAL INFORMATION

Mayrena Isamar Hernandez is an Athletic Training student at the University of Texas at Arlington. Throughout her undergraduate career at UTA, Mayrena has worked under Dr. Cynthia Trowbridge in various research projects that involved stretching, myofascial release, cryotherapy techniques, and core stability, and received a Kinesiology Research Day Award in 2015 as a result of her work in these projects.

Mayrena will earn her Honors Bachelors of Science in Athletic Training in May 2016. She plans to pursue a Master's in Public Health with an emphasis in nutrition at Kansas State, while serving as a graduate assistant athletic trainer to their track and field team. Mayrena will continue to research core stability and implement her findings into her own practice as an athletic trainer in the future.