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Effects of Dynamic and Static Hip Rehabilitation on Stability and Functional Screening in Dancers

Erin Marie Anderson
University of Nebraska at Kearney, erinmaui@comcast.net

EFFECTS OF DYNAMIC AND STATIC HIP REHABILITATION

ON STABILITY AND FUNCTIONAL SCREENING IN DANCERS

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ABSTRACT

Context
Connections between hip strength and knee mechanics are part of the kinetic chain. Anterior knee pain (AKP) is a symptom of poor biomechanics and strength deficits. Common hip rehabilitation programs perform only static, but dynamic exercises are more functional based.

Objective
Determine if static or dynamic hip exercise increase knee stability and functional mobility while decreasing AKP in dancers.

Design
Randomized control trial.

Setting
Study performed at the University of Nebraska at Kearney.

Subjects
12 college aged dancers (21.75 ± 1.06) that participate in the UNK dance program or dance team. 6 of the 12 perceived to have AKP.

Interventions
Performance of static or dynamic hip rehabilitation exercises, 3 times a week, for 8 weeks.

Measurements
Pre and posttest were conducted 8 weeks apart. Stability of the knee was measured through the Y-Balance System and the BESS tests. Functional mobility was measured by the single and double leg squat analysis. A visual analogue scale was conducted to show perceived knee pain.

Results
Improvement was seen from pretest to post for the Y-Balance System, knee valgus/varus for the single leg squat, and overall scores for the double leg squat. Interactions were found between pain x treatment and pain x testing.

Conclusions
Performing hip rehabilitation exercises will result in increase in knee stability and functional mobility. It was not determined if static or dynamic exercises had a higher increase than the other. Dynamic hip exercises decreased AKP more compared to static.

Key Words
Anterior Knee Pain, Stability, Mobility, Hip Rehabilitation

SIGNITURE PAGE

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DEFINITION OF TERMS

Abduction: Movement away from midline of the body.

Adduction: Movement towards midline of the body.

Balance: Stability produced from equal distribution of weight.

Distal: Farther way from the trunk of the body.

Dynamic Rehabilitation Exercise: Activity used to develop and maintain functional movement for everyday activities.

Flexibility: The ability to move muscles and tendons through a passive range of motion.

Intra-class Correlation Coefficients: Intra-rater test/retest reliability.

Lateral: Direction away from midline of the body, side of the body.

Medial: Close to midline of the body.

Mobility: The ability to move a limb or joint through a range of motion.

Proximal: Closer to the trunk of the body.

Rehabilitation Exercise: Restoration through movement and strengthening someone to their former physical ability.

Stability Rehabilitation Exercise: Activity used to develop and maintain balance.

Squat: An exercise at which one lowers themselves from standing so where the knee is deeply bent, like the action of sitting into and out of a chair.

Valgus: Excessive outwork angle, away from the midline of the body.

Varus: Excessive inward angle, towards the midline of the body.

CHAPTER I

INTRODUCTION

As imperative as it is for all categories of athletes to increase their skeletal muscles' muscular strength to help with their athletic performance,[1] it is just as important to increase the stability of their mobile joints.[2-4] Increasing stability of the knee joints and the strength of muscles that flex and extend or keep the knee joint in the correct plane of motion can help prevent athletic related injuries like anterior cruciate ligament (ACL) tears, meniscus tears, and patellar tendinosis.[2-4] Correct joint kinetics can help prevent applying excessive stress on tendons and ligaments, thus decreasing the chances of acute or chronic lower extremity injuries.[2-4] Clinicians have often used rehabilitation exercises or injury prevention protocols to improve knee joint stability by focusing on the smaller muscles such as obturator externus, gluteus minimums, and transverse abdominis muscle, whose function is to keep the body in the correct plane of motion.[4] The major muscle groups that are often thought of performing knee movement are the quadriceps and hamstring groups, but many other muscles attach and influence the knee though they mainly perform hip movements.[4,5] Some of the muscles that influence the knee joint in this way are the tensor fascia latae (TFL), which attaches to the knee through the iliotibial band, and the sartorius which wraps the upper leg from outer hip to inner knee, like a seatbelt.[5] The gluteus medius influences the knee joint indirectly by controlling internal rotation, abduction, and flexion with its anterior fibers, and external rotation and extension with its posterior fibers.[5] This opposition in the muscle itself helps to stabilize the pelvis while performing hip abduction in the coronal plane. To increase the stretch of these opposing muscles, isometric exercises or high repetition and low weight exercises are utilized as a beneficial way to increase stability.[3]

Mobility of a joint, especially in knee and hip, is also important to prevent athletic related injuries.[2] Due to the circumstance that these injuries often occur when a joint is put into hyper extension or excessive range of motion, that is moved beyond the athlete's considered normal range of motion (ROM) it can obtain naturally,[6] or from lack of appropriate mobility of the joint due to the increases in excessive stiffness on the joint and musculotendinous unit.[4,6] Thus, it can be conferred that if one has appropriate mobility in the joint with adequate muscular strength, they will be able to achieve better dynamic control in the lower extremity.[4] Mobility can be improved upon by working on flexibility and performing correct biomechanics of a motion.[4]

Health care professionals have utilized many different motions to look at a patient's biomechanics and assess mobility of a certain joint. A good example of increasing mobility by performing proper biomechanics is a basic squat.[4] If the knees are going directly over the toes in a squat the movement in safer for the body, than if the knees were to buckle in from adduction and internal rotation at the hip, going more medially. This incorrect motion puts excessive stress over the medial collateral (MCL) and ACL and patella tendon, leading to probable inflammation over the medial side of the knee.[5,6] In a study comparing ten different varsity sports athletes at National Collegiate Athletic Association (NCAA) Division I they concluded that those individuals who tested poorly at the Double or Single Leg Squat Analysis when performing a Functional Movement Systems (FMS) test, were more likely to have a lower extremity injury than those that tested movement of non-poor quality.[7] If incorrect motion is performed regularly during squatting it could lead to a possible injury if the athlete were to land in that same position during an athletic competition. Often, practitioners oversight the importance of functional hip mobility and the relationship it must knee joint stability, instead they focus more on hip strengthening. Functional hip mobility with dynamic hip rehabilitation exercises has more of a correlation with what motions an athlete might encounter in an athletic environment, than static hip rehabilitation exercises that stick to one plane of motion.

While there is a variety of movements and techniques in dance, dancers typically experience a high impact on their knee, which may induce a variety of musculoskeletal issues on the lower extremities.[4] Anterior knee pain is a common injury among dancers from the repetitive stress of plies, jetés, and leaps.[4] Many injuries that cause anterior knee pain are Patellofemoral Pain Syndrome, Chondromalacia Patellae, Osgood-Schlatter's Disease, knee bursitis, and many more.[4] The underlying factors of anterior knee pain are malalignment of the patella in the patellar groove during flexion and extension that causes increased stress on the patellar and quadriceps tendon and often accompanied or caused by muscular imbalance and weakness of the surrounding musculature.[5,6,8] Many of the muscles that can be weakened or imbalanced are the gluteus medias, which attaches to the greater trochanter of the femur and performs hip external rotation, the sartorius that attaches from the outer hip and goes across the anterior thigh to the inner knee, and the adductor group (adductor magnus, brevis, and longus) and gracilis that attaches the pelvis to the inner part of the knee.[5,6] When these muscles are imbalanced the tighter muscle, usually the adductor group can pull the knee in medially, thus causing misalignment, while the looser or weaker muscle, gluteus medias, will not correct for the medial path of the knee and can cause the knee joint to become unstable.[2,4-6,8] This combination commonly causes poor biomechanics, leaving the knee susceptible to injury.[2,4-6,8]

However, there are still limited research on how static and dynamic hip stability rehabilitation exercises influence the functional movements of the lower extremity and improve the knee musculoskeletal issues, like anterior knee pain. The outcomes of this research project may benefit clinicians to have enhanced understanding if static or dynamic hip rehabilitation exercises will decrease level of perceived anterior knee pain. Results will also demonstrate if dynamic or static hip rehabilitation exercises will increase the level of ability for the patient to perform balance and functional movements. Therefore, the purpose of this study is to examine dancers at the University of Nebraska at Kearney that perform 8 weeks (about 2 months) of static or dynamic hip rehabilitation exercises will have a greater influence on knee stability and functional movements. This will be measured through four orthopedic tests: stability testing by the Y-Balance System test, Balance Error Scoring System (BESS) test, and functional movement by the single and double leg squat analysis. A visual analogue scale will be utilized to determine perceived pain of the anterior knee. While observing subjects with anterior knee pain, a common injury for dancers, athletes, and recreationally active individuals, it will be determined if dynamic or static rehabilitation exercises will decrease this perceived pain.

Research Hypotheses

H_1: Static hip rehabilitation exercises will increase knee stability in dancers, tested by the Y-Balance System test and BESS test, compared to the dynamic hip rehabilitation exercises.

H_2: Dynamic hip rehabilitation exercises will increase knee functional biomechanical ability in dancers, tested by single and double leg squat analysis, compared to the static hip rehabilitation exercises.

H_3: Dynamic hip rehabilitation exercises will decrease anterior knee pain in dancers compared to static hip rehabilitation exercises shown by a comparison pre and posttest of subject's perceived pain on a visual analogue scale.

Limitations

- Having a subject population of only college aged dancers is not a representation of other groups.
- Having a subject population of females is not a representation of a male population.
- Time restraint due to COVID-19.
- All testing was performed virtually because the human subjects' research restrictions were still in place.

Delimitations

- All subjects were college aged dancers (aged between 19 and 25 years old).
- All subjects were female.
- There was an equal number of dancers who experienced anterior knee pain in both the stability and dynamic hip rehabilitation exercise subject group.
- There was an equal number of dancers who did not experience anterior knee pain in both the stability and dynamic hip rehabilitation exercise subject group.

Assumptions

- None of the subjects have had a lower body injury other than anterior knee pain in the last 3 months.
- In subjects with anterior knee pain, it was caused by patellofemoral conditions.
- All the participants were only participating in their designated practices or dance classes and no other workout program, at least 4 times a week.
- Participants performed all tests and hip rehabilitation exercises to the best of their ability.

CHAPTER II

REVIEW OF LITERATURE

Importance of Injury Prevention Rehabilitation Exercise

Injury prevention care programs have been utilized by sports medicine programs for numerous years.[1] Rehabilitation exercise programs that have had the greatest success in sustainability of participants continuing the program are integrated.[9] This means that the rehabilitation exercise programs have a subject that is being recurrently “coached” or provided instruction by a clinical professional.[9,10] The greatest decrease in injury rates and time lost from injury occurs with a higher compliance from the patients.[10] Injury prevention programs have been found to improve neuromuscular control and biomechanics of the lower extremities by improving balance, muscle activation, functional performance, strength, and power.[11] Programs that occur during preseason or in season should be performed 2 to 3 times a week for 10-15 minute.[11] Shorter periods of time increase compliance with the rehabilitation program.[11] Programs should progress and become more challenging while maintaining quality and technique of the movements.[11] Sadly, there is a view in the dance community that strength exercise training not related to dance will diminish a dancer’s aesthetic appearance, but supplementary strength exercises have been found to lead to improvements on fitness parameters and reduce incidents of injures.[11]

Common Athletic Injuries in Dancers

Lower extremity injuries make up 66% of all athletic injuries, with the greatest number of injuries occurring at the knee.[11] Some of the most common injures for dancers at lateral ankle sprains, rupture of Achilles tendon, patellar tendonitis, Osgood Schlatter's disease, Chondromalacia patellae, capsular strains of the knee, medical collateral ligament tear, anterior cruciate ligament tear, and meniscal tears.[11] Patellar tendinopathy is caused by and imbalance of the quadriceps muscles, usually an increase of the lateral portion.[12-14] Osgood Schlatter's Disease is an apophysitis of the tibial tubercle occurring in adolescence that enflames over the distal attachment of the patellar tendon.[12,14] Chondromalacia Patellae is a non-specific anterior knee pain, but usually caused by changes of the cartilage on the patella.[12,14]

Anatomical variations in classical ballet dancers, not usually found in the general population, contribute to the mechanisms of knee injuries commonly impeding dancers.[13] Because of the nature of the athletic activity, dancers are extremely flexible compared to the general population. Excessive amounts of flexibility when not matched with correct strengthening of the surrounding muscles can lead to greater chances of injury to joints and tissues.[12,13] Dancers tend to have hyperextended knees, with underdeveloped patellae's stabilization strength that can lead to lateral subluxations. Due to a decrease in the depth of the trochlear notch of the femur and how high the patella sits in the groove, then the quadriceps tendon of the thigh is activated with poor biomechanics of the lower extremity in a valgus angle, the patella may a dislocation or sublux.[13] The normal population has, in a general sense, legs that are straight when observing at them anteriorly, with a slight angle from the hip to the knees. Dancers have been found to have noticeably either varus, which is considered a bow leg where the knees at rest go away from each other, or valgus, knock kneed appearance where the knees are touching at rest.[12] Bowlegged dancers are found to have tight muscle bellies with exceedingly long tendons. These dancers have been found to have great ability in performing high leaps and are very quick.[13] A disadvantage to bowlegs is there is excessive stress on the medial aspect of the knee and can lead to injuries like; medial meniscus tears, decrease in articular cartilage, and tight Iliotibial band pain.[14] “Knock kneed” dancers are the opposite with long, weak muscle bellies and short tendons. These dancers' ability is in their perfection of movement and ability to sustain positions.[13] Dancers who are knock kneed will have excessive pressure on the lateral aspect of the knee causing possible lateral meniscus tears, damage to the articular cartilage, and adductor muscle group tightness. These dancers are also more likely to acquire arthritis at an early age.[14]

Knee Anatomy

The knee joint consists of 3 bones; the femur, tibia, and patella.[15] These 3 bones compose the tibiofemoral joint that create the knee’s hinge motion and patellofemoral joint that moves the patella as the knee performs flexion and extension.[15] There are 4 different ligaments that stabilize the knee joint: medial collateral ligament (MCL), lateral collateral ligament (LCL), anterior cruciate ligament (ACL), and the posterior cruciate ligament (PCL).[5,15,16] The MCL, on the inside of the knee, and LCL, on the outside of the knee, help to stabilize the knee from side movements.[5,15,16] The ACL and PCL are inside of the knee with the ACL attaching to the front, while the PCL attaches to the back.

These ligaments stop the knee from moving too much anterior or posterior. The patellar ligament which attaches to the bottom of the patella to the tibia helps keep the patella in its' groove.[15] Cartilage helps provide cushion at the end of the joint that prevents restriction and helps cushion the joint. Articular cartilage at the end of the femur and tibia. The knee has to menisci which sit on top of the tibia and are made of cartilage.[5,15, 16]

There are many groups of muscles that cause movement of the knee joint. Extension of the knee is performed by the quadriceps femoral group, made up of 4 muscles, and the sartorius, that wraps the thigh like a seatbelt. Flexion is performed by the 3 hamstring muscles and the popliteus that unlocks a fully extended knee.[5,15,16] The knee's two major motions are flexion and extension; the knee can also perform some rotation. This is performed by the hamstring group, gracilis, and sartorius.[15]

Static vs. Dynamic Hip Rehabilitation Exercises

The selection of hip rehabilitation exercises for this study stemmed from two main schools of thought; exercises that the dancers would already be aware of and hip rehabilitation exercises that worked on pelvic stability and glute activation. Hip rehabilitation exercises that the dancers already knew, to a basic degree on how to perform, was due to COVID-19 and having to perform testing and check-ins not in person. Hip rehabilitation exercises were chosen to activate both the gluteus maximus that performs hip extension, hip external rotation, and hip abduction; gluteus medius that performs hip abduction, hip internal and external rotation.[17-19]

The definition of static hip rehabilitation exercises for this study are about rehabilitation exercises that focus on increasing stability of the hip joint. These rehabilitation exercises tend to stay in the same plane of motion, while working the smaller muscles around the hip like the external rotators and gluteus medius (Figures 1-4). These exercises can be performed within a small area and the subject does not need to move off the treatment table which makes them opportunistic for clinicians to use while suggesting rehabilitation exercise for patient who are unable to perform weight bearing exercises.[17] Body positioning is very important with these exercises to activate to correct muscles at the hip and not put excessive strain on the back. The Donkey Kicks mainly activate the gluteus maximus, but also activate the gluteus minimus.[19] Fire Hydrants activate the hip external rotators while also working on stabilizing the lower back.[5,18,19] Glute bridges activate all of the glutes with help of the hip flexors and transversus abdominis.[4.19] Lying Inner thigh lifts were chosen to strengthen the subject's inner thigh muscles, that when weakened can lead to an imbalance of the knee biomechanics.[5,6]

The definition of dynamic hip rehabilitation exercise for this study is about rehabilitation exercises that are performed with increased functional movement. These rehabilitation exercises are performed in multiple different plains of motion and activate, the trunk, core, and other lower extremity muscles as well as the hip muscles.[17,18] The subject is required to move in different directions than just a straight pattern. These hip rehabilitation exercises require balance from the subjects and a safe area to move around in. These muscles increase hip muscle strength like the gluteus maximus and gluteus medius, as well as other lower extremity muscles like quadriceps and hamstring (Figures

5-8).[17-19] Muscle Voluntary Isometric Contraction (MVIC) is a way to measure percent activation of a muscle while performing an exercise. The monster walks and lateral steps both activate the glutes medius (27% MVIC) more than the gluteus maximus (10% MVIC).[17] During both exercises the quadriceps, hip flexors, back and core musculature are also engaged to keep the body, erect.[17,18] Skaters and Jump Squats were selected for exercises to work on biomechanics while jumping/landing and change in body locomotion.[4,5] Dancers perform a lot of jumps into different landing styles like; double leg, single leg, leg parallel, leg turned out.[12-14] It is important for each of these different landings that the knee is going over the toes and not moving valgus or varus.[12-14]

Static Hip Rehabilitation Exercises

Figure 1. Donkey Kicks. The subject will be on all fours, with hands directly under their shoulders and knees under hips. The back and neck should stay flat, parallel to the floor. The subject with engage the lower abdominals, while keeping their knee at 90 degrees, slowly lift the leg straight back towards the ceiling. The subject should lift the leg until they feel like their leg is about to rotate or the back arches. The subject will then return to the starting position and switch legs after all reps are completed on the first leg.

Figue 2. Fire Hydrants. The subject will be on all fours, with hands directly under their shoulders and knees under hips. The back and neck should stay flat, parallel to the floor. The subject will left their leg away from the midline of their body, about 45 degrees while keeping the knee at 90 degrees. The subject needs to make sure that the hip does not hike up as they perform the motion. The subject will then return to the starting position and complete all reps on that side before starting on the other leg.

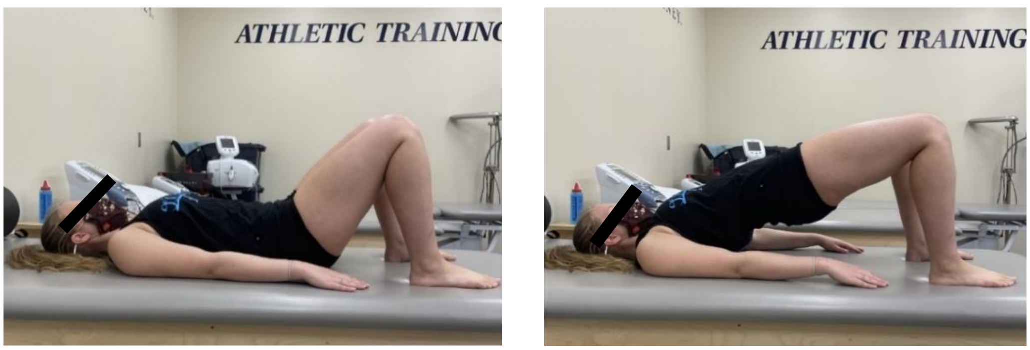


Figure 3. Glute Bridge. The subject will lie face up on the floor, with knees bent so the feet are flat on the floor. They will keep their arms to the side of their body. The subject will activate their glutes and abdominals while they keep their knees, hips, and shoulder in a straight line as they life their hips off the ground. The subject should not overextend their back into an arch. The subject will hold at the top for 3 seconds and then slowly come down, making sure not to drop to the ground.

Figure 4. Lying Inner Thigh Lifts. The subject will lie on their side with their head held by their hand. The subject will cross the top leg over in front so that the foot is flat on the ground, keeping the hips on top of each other, perpendicular to the floor. The subject will the raise their inner thigh up as high as they can without moving their torso or hips. They will complete all the reps and then flip over to their other side to complete the other leg.

Dynamic Hip Rehabilitation Exercises.

Figure 5. Monster Walks. The subject will be in an up-right position with a slight squat about 45-60 degrees knee bend. The subject will have their hands on their waist as they take diagonal steps, forward and out, from the starting position. The subject will take 10 of these steps, alternative legs. This is one set.

Figure 6. Skaters. The subject will start in a small squat with knees and toes under their shoulders. The subject will make a small jump to the left 1/3 to ½ their body height. As they land on their left leg the right leg will cross behind them with the knee bent at 90 so the foot does not touch the floor. They will then complete this on the other side. The combination of both the left and right jump is one repetition.

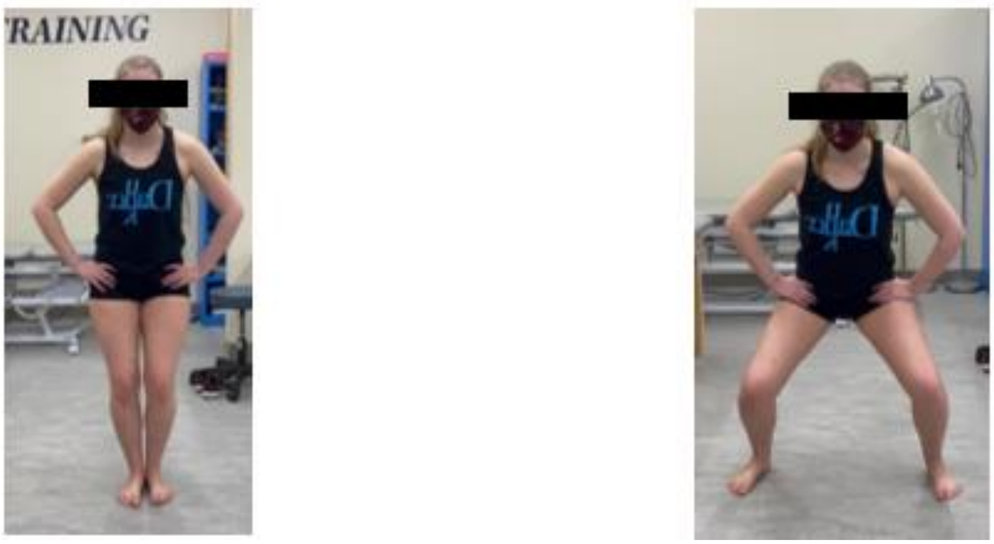
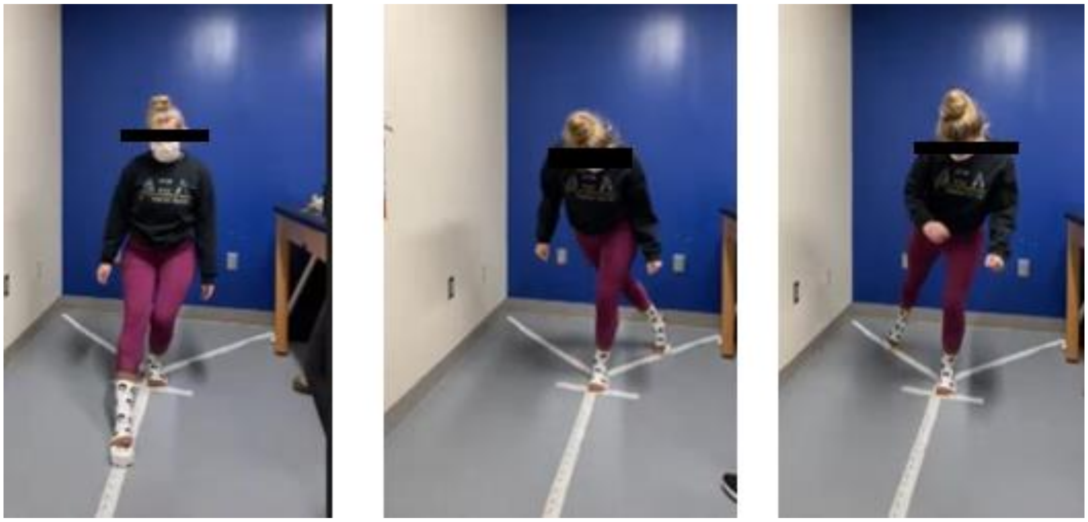


Figure 7. Lateral Walks. The subject will be in an up-right position with a slight squat about 45-60 degrees knee bend. The subject will have their hands on their waist as they take a step 1/3 to ½ their body height to the left side. The subject will then bring their right leg back to their left. The subject will do this 5 times and then repeat going to the right direction with the right leg. This is one set.

Figure 8. Jump Squats. The subject will start in an upright position with knees and toes shoulder width apart, facing forward. The subject will then activate their core as they perform a regular squat. The subject will then jump up and then land back in their squat position. The subject will then return to the upright position. This is one repetition.

Y-Balance System Test

The Y-Balance System test is an orthopedic test utilized to measure dynamic balance, strength, stability, and mobility of the lower extremities.[20] The subject is tested by balancing on a single leg while reaching the other in three different directions: anterior, posteromedial, and posterolateral (Figure 9).



A. Anterior **B. Posteromedial** **C. Posterolateral**

Figure 9. Y-Balance System Test Demonstration. Testing is performed in the anterior (A), posteromedial (B), and posterolateral (C) directions. The subject's balances on one leg and moves the small block along with line until they are no longer able to go any farther. Falling over, picking you standing leg heel up, kicking the block, and putting your moving leg foot down makes the test start over.

The farthest of the 3 tests will be compared to the other leg, looking for asymmetrical differences between the left and right leg.[20] The scoring system will be the relative (normalized) reach distance percentage. The test takes the highest reach distance divided by the limb length of the one that was reaching, multiplied by 100.[20] Active females with a percentage less than 94% of limb length are found to have a greater risk of injury. The Y-Balance System test has an Intra-class Correlation Coefficient of 0.85 to 0.91 and interrater reliability range of 0.99 to 1.00.[20]

Balance Error Scoring System Test

Postural stability and control will be viewed by the Balance Error Scoring System (BESS) test (Figure 10). The subject will be filmed over Zoom while balancing on one leg on a firm surface barefoot, with the opposite leg out in from of them with the knee bent, not touching their other leg.[21] Subjects will hold the balanced with eyes open, up to 1 minute. Most BESS tests recommend 30 seconds for time to perform each section of the BESS test.[21] Increasing the time to one minute was decided on due to dancers' tendencies in having increased proprioception and coordination on one leg. Dancers are trained to be able to hold their balance on one leg for extended periods of time leading to many of the subjects having perfect scores if the test is only performed for 30 seconds.[22] The examiner will examine for error as the subject is holding the balance. Errors include moving hands-off hips, steps, stumbles, falls, abduction, or flexion of hip beyond 30 degrees, lifting of forefoot or heal off the ground, and stays out of proper testing position for more than 5 seconds.[21]

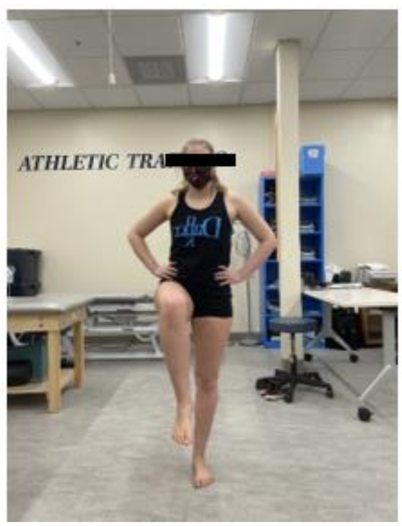


Figure 10. Balance Error Scoring System Test. The subject balances on one leg for one minute with their eyes open, hands-on hips, and leg out in front of them without touching their standing leg. Movements outside of this position are counted for errors.

The interrater and intrarater reliability of the BESS test was determined in the study, "Intrarater and Interrater Reliability of the Balance Error Scoring System (BESS)" performed by Jonathan Finnoff, Valerie Peterson, John Hollman, and Jay Smith, by utilizing the intra-class correlation coefficients (ICC) with 95% confidence intervals. The interrater score was 0.57 and intrarater reliability was 0.74.[23] This study shows that the subcategories of stances that the BESS test has; double leg balance, single leg balance, tandem balance, with or without eyes open, are reliable for evaluation of postural stability.[23] Looking at a total BESS score for all the tests was found to be unreliable.[23]

Single Leg Squat Analysis

The single leg squat analysis is an orthopedic test that assesses neuromuscular control for the Lumbo-Pelvic region.[24] Each subject will start and stop in the same position with their tested leg straight, balanced on one foot. Their arms will be on their hip bones and non-tested leg will be straight but not touching the testing leg. The subject will then perform a single leg squat, going as low as they feel comfortable (Figure 11). [24]

A. Frontal View B. Lateral View

Figure 11. Single Leg Squat Analysis Demonstration. The subject stands on one leg, hands on hips, and performs a single leg squat to the deepest depth of their ability without falling over. The subject will have their leg out Infront of them like pistol squat posture. If the subject falls or has trouble performing the squat that one is not counted.

Examiner will grade them on a scale of 3 being excellent, and 0 being poor or unable to complete test. An excellent is when the subject can perform the single leg squat to hip flexion greater than 65 degrees, hip abduction less than 10 degrees, and knee valgus/varus less than 10 degrees. A good score is when 2 of any of the criteria above are met. Fair is if 1 of the above criteria is met. A poor is if none of the criteria above is met, or the subject loses their balance or falls.[24] The examiner will measure the angles of hip flexion, abduction/adduction, and knee valgus/varus off the Zoom meeting at the lowest point of the squat. Single leg squat analysis does not have a high positive correlation between hip abduction strength (gluteus medius strength) and hip abduction/adduction angle, it is still a reliable test when looking at stability of the lower extremity.[25]

A systematic review of 31 studies identified moderate agreement on measurement for interrater reliability of 0.58 with 95% of the studies having a number between 0.50-0.65.[24] There was a substantial agreement for intrarater reliability of 0.68. 95% of the studies had numbers between 0.60-0.74.[26] There was a larger agreement in interrater reliability when the point rating scales are 3 or larger scales.[26] Though there can be methodological bias when performing a single leg balance test, the test was found to be suitable for clinical evaluation use.[26]

Double Leg Squat Analysis

The purpose of assessing fundamental movements testing is to discover deficits of mobility and stability in an asymptomatic population to prevent injuries.[27] Functional Movement System (FMS) is analyzing the body’s kinetic chain to look for limitations of movement.[27] Double leg squat analysis, will be used to determine movement compensation, knee dysfunction, and assess subject's functional status (Figure 12).[28, 29]

A. Frontal View B. Lateral View

Figure 12. Double Leg Squat Analysis Demonstration. The subject has their feet shoulder with apart and arms above their head in line with their ears. The subjects' squats down as far as they can go, preferable 90 degrees of knee flexion obtained.

The subject will have feet hip distance apart with arms straight overhead.[28] The subject will perform 3 squats facing the camera anteriorly and another 3 squats facing the camera laterally. The examiner will observe the subject's feet and knees watching for movement or compensations. Examples of this could be an overhead squat, if the subject is unable to get past 90° of knee flexion, it could be because of lower back tightness, hip tightness, knee weakness, or the inability for the ankle to dorsiflex to a needed degree. A way to determine if it is the ankle is to have the subject step on a 2 by 4 or plate to prop up their heels. If the subject is then able to do a deep squat the limitation is at the ankle and not at any of the other joints.[27] Knee valgus during the test show weakness in hip abductor and external rotator strength and increased hip adductor tightness, with possible ankle dorsiflexion restrictions.[28] The examiner will also notice the torsos angle, arm position, and head position at the bottom of the squat. One point will be deducted from 10 for every error found during the squat test. A total of 10 points is considered excellent, while 0 is considered poor or unable to perform test. Errors that the examiner will be looking for are; do the foot turn out during the squat, do the knees shift in or out (valgus or varus), do the heels lift up at the bottom of the squat, is there an excessive forward lean, does the low back arch or round during the squat, do the arms fall forward past the ears, does the foot pronate and flatten, is there an asymmetrical weight shift, and lastly does the subject not obtain 90 degrees of knee flexion.[28,29] Clinicians can reliably use a double leg squat analysis test, like the FMS overhead squat test, due to the high intra-rater reliability of 0.84.[30] The test is the most reliable with the same tester performs the pre and posttest, then changing testers.[30]

Visual Analogue Scale

The utilization of the visual analogue scale lower error scores compared to the other scale such as verbal rating scale.[31] The visual analogue when compared to the verbal rating scale is considered to assess a patient's actual experience with pain intensities with less sensitivities to bias.[31,32] During the pre- and post-testing, subjects will draw on 10-cm a line where they believe their pain is (Appendix B).[32,33] The closer to the left side (0-cm) the less pain is perceived, the opposite being for a line closer to the right side (10 cm). Unchanged pain is a score differing 6 mm or less than from the pre-test. Decreased pain is a score at least 7 mm below the pre-test. Increased pain is a pain score 7 mm or more above the pre-test measurement.[32] The intra-rater for the visual analogue scale was a moderate level ranging from 54-73%.[34] Greater intra-rater agreement is reported with those who have greater experience, though moderate agreement with still found with clinicians with no prior experience.[34]

Summary

In summary, an injury prevention program for dancers would be beneficial for decreasing the possibilities of acute and chronic injuries during the season. Not all dancers, however, would be willing to partake in more training outside of their rigorous dance schedules. When prevention of an injury in unable to be obtained, an exercise rehabilitation program is put into place to decrease symptoms of pain of an injury like anterior knee pain. Programs designed to be less time consuming and integrated can increase subject’s compliance. Dancers face many possible knee injuries throughout their careers, many of the injuries are due to poor biomechanics stemming from tight or weak musculature from the hip. Rehabilitation exercise focusing on hip muscular strengthening can be prescribed to help with prevent, correction, and treatment for these injuries. This study is to determine in static or dynamic hip rehabilitation exercises will decrease anterior knee pain, while increasing balance and functional movement. These will be tested through a visual analogue scale, Y-Balance System test, BESS test, single leg, and double leg squat analysis. This will determine if static or dynamic hip rehabilitation will increase knee stability and knee functional biomechanical movement.

CHAPTER III

METHODS

Research Design

A factorial design was used to test the hypotheses. The independent variables were hip rehabilitation exercise groups (static and dynamic hip rehabilitation exercise), pain (symptomatic and asymptomatic anterior knee pain), and testing (pre- and post-hip rehabilitation exercise). The three dependent variables were stability [single leg balance testing with the Y-Balance System test and Balance Error Scoring System (BESS) test], functional movement (single and double leg squat analysis), and anterior knee pain [visual analog scale (VAS)]. Subjects were randomly assigned to static or dynamic hip rehabilitation groups with the equal numbers of subjects in each subgroup, pain, or no pain on their anterior aspect of the knee.

Subjects

The subject population was twelve female volunteers from the dance programs and dance team in the University of Nebraska at Kearney. Agreements with the dance team coaches and dance instructors allowed the dance students to participate if they would like. Decision to participate in the study did not influence their dance performance or course grade. All meetings with those that choose to participate were held without coaches or course instructors present. The subjects were between the ages of 19-25 years with no lower back or lower extremity injuries within the last 3 months other than anterior knee pain. The subjects were not allowed to partake in any extra exercise or weight-lifting other than their designated practice and recreational moderate intensity of activities.

Due to the current COVID-19 pandemic circumstances and collecting data virtually, subjects needed to have access to a computer or smartphone with a video camera to participate in virtual testing and rehabilitation exercise sessions.

Instruments

The Y-Balance System test was used to measure dynamic stability of the lower extremity.[20] The subject balanced on a single leg and were tested in 3 different directions: anterior (Figure 9-A), posteromedial (Figure 9-B), and posterolateral (Figure 9-C). The subject performed these whiles on a Zoom call (Zoom Video Communication, San Jose, CA, USA) with the experimenter that gave guidance and eliminated errors. The subject moved the box with the tip of their big toe, making sure the heel did not touch the floor and their standing leg heel did not come off the ground (Figure 9, Appendix D). The distance was confirmed to the nearest 0.5 of a centimeter of how far the subject could reach in each of the three angles they performed. The test was performed 3 times in each direction. The farthest of the 3 tests was utilized and compared to the other leg, looking for asymmetrical differences between the left and right leg.[20] The scoring system used was the relative (normalized) reach distance percentage. The test took the highest reach distance divided by the limb length of the one that was reaching, multiplied by 100. [20]

BESS test was utilized to look at postural stability and control. The subject balanced on one leg, with the opposite leg out in from of them with the knee bet, not touching their other leg (Figure 10).[21] Subjects held the balance, if they could, with eyes open, up to 1 minute. The choice of 1 minute over the usual 30 seconds for this test was made because dancers tend to have increase proprioception leading to greater balance. The examiner looked for error as the subject held the balance (Figure 10, Appendix D). Errors include moving hands-off hips, steps, stumbles, falls, abduction, or flexion of hip beyond 30 degrees, lifting of forefoot or heal off the ground, and staying out of proper testing position for more than 5 seconds.[21]

The single leg squat analysis is an orthopedic test that assesses neuromuscular control for the Lumbo-Pelvic region.[24] The subject started and stopped in the same position with their tested leg straight, balanced on one foot (Figure 11). Their arms were on their hip bones and non-tested leg straight, but not touching the testing leg. The subject then performed a single leg squat, going as low as they felt comfortable (Figure 11, Appendix D).[24] Examiner graded them on a scale of 3 being excellent, and 0 being poor or unable to complete test. An excellent is when the subject can perform the single leg squat to hip flexion greater than 65 degrees, hip abduction/adduction less than 10 degrees, and knee valgus/varus less than 10 degrees (Figure13 and 14).[24] A good score is when 2 of any of the criteria above are met. Fair is if 1 of the above criteria is met. A poor is if none of the criteria above is met, or the subject loses their balance or falls.[24] The examiner measured the angles of hip flexion, abduction/adduction, and knee valgus/varus from the Zoom video at the lowest point of the squat. The angle of the knee at the lowest point of the squat was measured too.

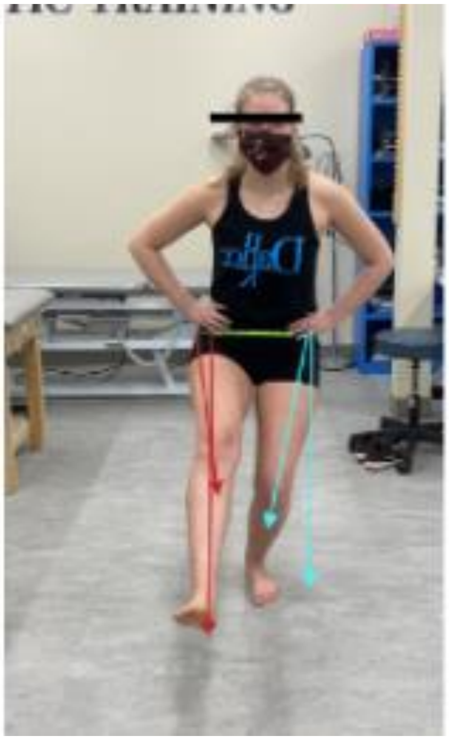


Figure 13. Hip Abduction/Adduction and Knee Valgus/Varus Angle. The blue lines show how the varus or valgus angles of the knee are measured on the supporting leg for the single leg squat analysis. The red shows the angle for the non-supporting leg hip abduction/adduction angle.

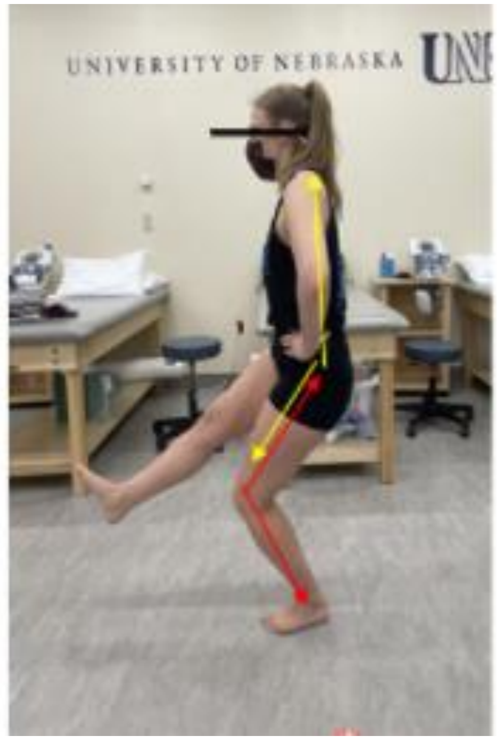


Figure 14. Hip Flexion and Knee Flexion Angle. The yellow lines show how to measure the angle of hip flexion for the single leg squat analysis. The red lines show the angle for knee flexion.

The last physical test, double leg squat analysis, was used to look at movement compensation, knee dysfunction, and assess subject's functional status.[28,29] The subject had their feet, hip distance apart and toes forward, with arms straight overhead (Figure

12, Appendix D).[28] The subject then performed 3 squats facing the camera anteriorly and another 3 squats facing the camera laterally. The examiner observed the subject's feet and knees looking for movement or compensations. Knee valgus during the test showed weakness in hip abductor and external rotator strength and increased hip adductor tightness, with ankle dorsiflexion restrictions.[28] The examiner also looked to see the torsos angle, arm position, and head position at the bottom of the squat. One point was deducted from 10 for every error found during the squat test. A total of 10 points is considered excellent, while 0 is considered poor or unable to perform test.[28,29] Errors that the examiner was looking for are; did the foot turn out during the squat, did the knees shift in or out (valgus or varus), did the heels lift up at the bottom of the squat, was there an excessive forward lean, did the low back arch or round during the squat, did the arms fall forward past the ears, did the foot pronate and flatten, was there an asymmetrical weight shift, and lastly did the subject not obtain 90 degrees of knee flexion.[28,29]

Pre and Post questionnaire about anterior knee pain was given. It asked the subject which leg they felt their pain; right, left, or both (Appendix B). The visual analogue scale was at the bottom of the questionnaire. If there was no indication of any subjects having anterior knee pain, not associated with patellofemoral pain. Stability tests (Y-Balance System test, BESS test) and functional movement (single and double leg squat test) were performed by a Board of Certification (BOC) and Nebraska State Licensed Athletic Trainer. A visual analogy scale, at the bottom of the questionnaire, was utilized to measure and compare anterior knee pain, looking at the distance in millimeters of where the subject perceived their pain for each leg. The scale is a 10-cm long horizontal line on the questionnaire. The subject was asked to draw the line where the subject perceives their anterior knee pain for each leg. The closer to the left (0 cm) the mark is the less pain the subject perceives and the closer to the right (10 cm) the more pain the subject perceives.

Procedures

Subjects were recruited based from participation in the academic dance program and athletics-based dance team at the University of Nebraska at Kearney. Subjects filled-out the informed consent form, informed risk of COVID-19 document, and pre-test questionnaire about their dance experience and perceived anterior knee pain. This was done via Qualtrics to reduce the chance of contact between examiner and subject. After the subject completed the informed consent over email, they completed the pre-testing questionnaire about anterior knee pain, asking the subject which leg they felt their pain; right, left, both, and none. Stability tests and functional movement screens during pre-test and post-test were performed by the primary investigator who is a board certified and Nebraska state licensed athletic trainer via Zoom. To assess the anterior knee pain level, a visual analogy scale was utilized. ere then evenly and randomly assigned to two groups by leg (static or dynamic hip rehabilitation exercise groups) with anterior knee pain in at least on leg and no anterior knee pain in either leg.

Subjects then participated in the pre-test the first week consisting of a series of four stability tests and functional movement screenings. Test was performed on the dancer's scheduled date of their pre-test. They were tested in the Athletic Training Lab

Evaluation room with the Y-Balance System test set up for them to decrease errors. Instructions on how to perform the Y-Balance System test were attached and include instructions on how to set up the subject's camera on their phone on the Tripod provided by the examiner. Zoom calls were recorded and used to avoid a direct contact with subjects during the testing. The primary investigator provided the instructions of each test through Zoom. In between each subject being tested the Y-Balance System test was cleaned with a bleach disinfectant of 9 parts water and 1 part bleach (OSHA blood borne pathogen cleaning/hygiene guidelines). Everything that was or might have been touched by the subject was sprayed with the solution and wiped with a disinfectant wipe (CDC COVID-19 cleaning/hygiene guidelines). The Y-Balance System test was given at least 15 to 20 minutes to dry before the next subject performed their testing. The subject was required to wear a mask during the testing (CDC COVID-19 guidelines).

The first test performed was the Y-Balance System test bilaterally over Zoom where the subject moved their leg in an anterior, posteromedial, and posterolateral direction while balancing on the supporting leg (Figure 9A-C). All stability tests and functional movement screenings were performed barefoot to reduce correction created by footwear. The subject then performed a single leg balance BESS test for 1 minute with eyes open, while the examiner counted biomechanical imbalances, like shifting of hips or knee movement (Figure 10). The next test performed was a single leg squat on both legs with their hands on their hips (Figure 11). The subject performed the test 3 times facing the camera (Figure 11A) and another 3 times with their side facing (laterally) to the camera for both legs (Figure 11B). Then faced to the side, the subject had the leg performing the single leg squat away from the camera. The examiner looked for incorrect biomechanics. The subject then performed a double leg squat with feet shoulder length apart, toes forwards, and arms overhead, same protocol as single leg squat (Figure 12A-B).

After the subject completed the pre-test, they were given their designated hip rehabilitation exercises to be performed the next eight weeks of the study (Table 1 and Table 2). Subjects were then shown through demonstration over Zoom how to perform the hip rehabilitation exercises and did their first day of hip rehabilitation exercises to get feedback on how they performed the hip rehabilitation exercises. The subjects were given the progression of exercise as well as a print-out of the exercises they were to perform. Videos on how to perform each exercise were also available for further clarity. Subjects completed their hip rehabilitation exercises 3 times a week, with each week an increase in reps or sets. The examiner emailed the subjects once a week to remind subjects about performing the exercises and ask how the progression of the exercises was being perceived. Subjects often responded to the emails with thoughts about the hip rehabilitation exercises.

After a total of 8 weeks (about 2 months) the subjects participated in the post-test where they performed all the same tests and questionnaire form as the pre-test. After all the tests occurred, the data was analyzed to evaluate the research questions comparing the pre and post-test of the 4 different subgroups.

Table 1. Static hip rehabilitation exercises weekly schedule

Exercises	Wk. 1	Wk. 2	Wk. 3	Wk. 4	Wk. 5	Wk. 6	Wk. 7	Wk. 8
Donkey Kicks	2/10	2/10	2/12	2/12	3/10	3/10	3/12	3/12
Fire Hydrants	2/10	2/10	2/12	2/12	3/10	3/10	3/12	3/12
Glute Bridge	2/10	2/10	2/12	2/12	3/10	3/10	3/12	3/12
Lying Inner Thigh Lift	2/10	2/10	2/12	2/12	3/10	3/10	3/12	3/12

Table 2. Dynamic hip rehabilitation exercises weekly schedule

Exercises	Wk. 1	Wk. 2	Wk. 3	Wk. 4	Wk. 5	Wk. 6	Wk. 7	Wk. 8
Monster Walks	2/10	2/10	2/12	2/12	3/10	3/10	3/12	3/12
Skaters	2/10	2/10	2/12	2/12	3/10	3/10	3/12	3/12
Lateral Walks	2/10	2/10	2/12	2/12	3/10	3/10	3/12	3/12
Jump Squats	2/10	2/10	2/12	2/12	3/10	3/10	3/12	3/12

Data Analysis

The Y-Balance System test was performed 3 times in each direction. The highest of the 3 scores was used to compute the normalized percentage for each leg compared to the subject's leg length. Leg length was measured bilaterally from greater trochanter of the femur to the bottom of the lateral malleolus. The examiner observed the recorded BESS test a total of 3 times, counting errors. The examiner observed the recorded video of the single leg squat test and determined which of the 3, in the frontal and lateral view, was the perceived optimal squat. From there the examiner measured the hip flexion, knee valgus/varus, hip abduction/adduction, and knee flexion at the lowest part of the squat using a finger goniometer. The examiner watched the recorded video of the double leg squat 3 times to look for biomechanical changes for each subgroup. Overall scores for single leg squat and double leg squat subtracted a number from each total, three for single leg squat and 10 for double leg squat, that did not meet the requirements of each subgroup analyzed. The visual analogue scale was measured in centimeters 3 times with the same girth imperial metric tape measure from the left side to the crossing of the X that the subject drew on the line.

Statistical Analysis

The data from the Y-Balance System test, BESS test, and single and double leg squat functional movement assessment was compared between the no pain group and anterior knee pain group for static hip rehabilitation exercises. The same was done for the dynamic hip rehabilitation exercise group. The static pain group was also compared to the dynamic pain group. All subjects that reported to have perceived anterior knee pain were compared to all the subjects that did not perceive pain. The same was done for the no pain static group and no pain dynamic group.

Separated statistical analysis was conducted to test each hypothesis. Statistics Analysis Software (IBM SPSS Statistics, Chicago, IL) was used for statistical analysis. Alpha level of 0.05 was used to determine the statistical significance.

H_1: Static hip rehabilitation exercises will increase knee stability in dancers, tested by the Y-Balance System test and BESS test, compared to the dynamic hip rehabilitation exercises.

To test H_1, we utilized a 3-way (Pain x Treatment x Testing) ANOVA test on Y-Balance System test in the anterior, posteromedial, and posterolateral direction. The BESS test data utilized a Pearson Chi-Square test.

H_2: Dynamic hip rehabilitation exercises will increase knee functional biomechanical ability in dancers, tested by single and double leg squat analysis, compared to the static hip rehabilitation exercises.

To test H_2, we utilized a 3-way (Pain x Treatment x Testing) ANOVA test on all single leg squat analysis data and the double leg squat analysis score data. All other double leg squat analysis data utilized a Pearson Chi-Square test.

H_3: Dynamic hip rehabilitation exercises will decrease anterior knee pain in dancers compared to static hip rehabilitation exercises shown by a comparison pre and posttest of subject's perceived pain on a visual analogue scale.

To test H_3, we utilized a 3-way (Pain x Treatment x Testing) ANOVA test on visual analogue scale data.

CHAPTER IV

RESULTS

Descriptive Demographic Data

A total of twelve dancers participated in the study concluding to 24 legs being tested (Table 3). No participants participate in both the dance team and dance program, though one subject is on the cheerleading squad at the University of Nebraska at Kearney. Out of the 12 subjects 6 of them expressed no anterior knee pain in either leg, 2 expressed pain in both knees, 2 in the right knee, and 2 in the left knee (Table 4).

Table 3. Descriptive demographic information data (mean ± SD)

	Mean ± SD	Minimum	Maximum
Age (years)	21.75 ± 1.06	20	23
Number of Days of Week Dancing	3.91 ± 1.16	3	6
Hours a Week of Dance	7.42 ± 2.87	3	12
Age Started Dance	7.67 ± 4.74	3	15

Table 4. Reported anterior knee pain based on dance participation

	Dance Program	Dance Team	Total
Right Knee Pain	1	1	2
Left Knee Pain	2	0	2
Both Knee Pain	2	0	2
No Knee Pain	2	4	6

Y-Balance System Test Analysis

The average scores and standard deviations of the anterior Y-Balance System test are shown in Table 5. No interactions were observed (*P*>0.05) in the anterior direction of Y-Balance System test. However, testing had a main effect statistically significant ($F_{1,8}$=10.23, *P*=0.012, Pre-Testing < Post-Testing).

Table 5. Relative anterior Y-Balance System test score results in pre- and post-testing (mean and SD)

	Pre-Testing % Mean [A]	Post Testing % Mean [A]
Total	84.09 ± 7.47	87.04 ± 5.35
Static	82.11 ± 5.78	86.28 ± 4.94
Dynamic	86.06 ± 8.65	87.79 ± 5.85
Pain	79.75 ± 5.76	85.72 ± 5.04
No Pain	86.26 ± 7.42	87.69 ± 1.19
Static Pain	79.67 ± 6.19	85.41 ± 4.37
Static No Pain	83.33 ± 5.56	86.72 ± 5.43
Dynamic Pain	79.83 ± 6.25	86.03 ± 6.32
Dynamic No Pain	89.18 ± 8.22	88.67 ± 5.83

[A] Indicates the statistical significance of (*P*=0.012)

The average scores and standard deviations of the posteromedial Y-Balance System test are shown in Table 6. No interactions were observed (P>0.05) in the posteromedial direction of Y-Balance System test. However, testing had a main effect statistically significant ($F_{1,8}$=5.51, P=0.047, Pre-Testing < Post-Testing).

Table 6. Relative posteromedial Y-Balance System test score results in pre- and post-testing (mean and SD)

	Pre-Testing % Mean [B]	Post Testing % Mean [B]
Total	94.74 ± 9.19	100.09 ± 8.26
Static	91.62 ± 8.70	97.34 ± 7.08
Dynamic	97.85 ± 8.94	102.83 ± 8.71
Pain	98.09 ± 9.20	106.20 ± 5.10
No Pain	93.85 ± 9.74	102.10 ± 8.73
Static Pain	93.77 ± 5.95	99.24 ± 4.80
Static No Pain	90.55 ± 9.98	96.39 ± 8.12
Dynamic Pain	100.75 ± 6.24	104.75 ± 3.67
Dynamic No Pain	96.40 ± 10.08	101.87 ± 10.50

[B] Indicates the statistical significance of (P=0.047)

The average scores and standard deviations of the posterolateral Y-Balance System test are shown in Table 5. No interactions were observed (*P*>0.05) in the posterolateral direction of Y-Balance System test. However, testing had a main effect statistically significant ($F_{1,8}$=16.33, *P*=0.004, Pre-Testing < Post-Testing).

Table 7. Relative posterolateral Y-Balance System test score results in pre- and post-testing (mean and SD)

	Pre-Testing % Mean [C]	Post Testing % Mean [C]
Total	95.27 ± 9.58	103.47 ± 7.85
Static	91.69 ± 10.02	101.34 ± 7.83
Dynamic	98.85 ± 7.97	105.59 ± 7.58
Pain	97.26 ± 6.77	101.99 ± 4.93
No Pain	93.77 ± 10.15	99.13 ± 9.50
Static Pain	94.85 ± 11.16	107.25 ± 6.22
Static No Pain	90.10 ± 9.78	98.39 ± 7.06
Dynamic Pain	101.33 ± 6.70	105.15 ± 4.36
Dynamic No Pain	97.61 ± 8.67	105.82 ± 9.06

[C] Indicates the statistical significance of (*P*=0.004)

Balance Error Scoring System Analysis

The average scores and standard deviations of the BESS testing are shown in Table 8. The Pearson Chi-Square Test was used to test our hypothesis. However, there was no statistical significance found when looking at pain (*Value*= 10.361, *df*=7, *P*=0.169), treatment (*Value*=5.543, *df*=7, *P*=0.594), and testing (*Value*=10.130, *df*=7, *P*=0.181)

Table 8. BESS test average scores (mean ± SD)

	Mean Pretest Errors	Mean Post Test Errors
Total	2.79 ± 2.00	1.52 ± 1.17
Static	2.67 ± 2.15	1.25 ± 1.60
Dynamic	2.92 ± 1.93	1.08 ± 1.51
Pain	3.13 ± 1.36	1.25 ± 0.89
No Pain	2.63 ± 2.28	1.13 ± 1.78
Static Pain	3.00 ± 1.15	1.50 ± 1.00
Static No Pain	2.50 ± 2.56	1.13 ± 1.89
Dynamic Pain	3.25 ± 1.71	1.00 ± 0.82
Dynamic No Pain	2.75 ± 2.12	1.13 ± 1.80

Single Leg Squat Test Analysis

The average and standard deviations for the hip flexion angles are shown in Table 9. No interaction nor main effect differences was found looking at groupings of pain, treatment, testing, and comparing between groups ($P>0.05$).

Table 9. Single leg squat analysis hip flexion angle averages (mean ± SD)

	Pretest Angle Mean	Posttest Angle Mean
Total	94.79 ± 23.66	97.79 ± 19.27
Static	87.25 ± 20.62	94.75 ± 14.79
Dynamic	102.33 ± 24.93	100.83 ± 23.18
Pain	91.13 ± 22.86	90.88 ± 11.95
No Pain	96.63 ± 24.57	101.25 ± 21.55
Static Pain	77.00 ± 16.87	86.25 ± 10.97
Static No Pain	92.38 ± 21.35	99.00 ± 15.18
Dynamic Pain	105.25 ± 20.07	95.50 ± 12.48
Dynamic No Pain	100.88 ± 23.23	103.50 ± 27.45

The average and standard deviations of knee varus/valgus angles are shown in Table 10. No interactions were observed but there was statistical significance found for knee angle varus/valgus with testing the main effect difference ($F_{1,8}$ =6.14, P=0.02, Pre-Testing < Post-Testing.

Table 10. Single leg squat analysis knee varus/valgus angle averages (mean ± SD)

	Pretest Angle Mean [F]	Posttest Angle Mean [F]
Total	15.25 ± 8.26	11.79 ± 5.35
Static	15.92 ± 9.56	12.17 ± 4.41
Pain	15.63 ± 9.04	14.63 ± 2.72
No Pain	15.06 ± 8.15	10.38 ± 5.83
Dynamic	14.58 ± 7.10	11.42 ± 6.33
Static Pain	12.50 ± 12.56	13.50 ± 3.00
Static No Pain	17.63 ± 8.12	11.50 ± 5.01
Dynamic Pain	18.75 ± 2.63	15.75 ± 2.23
Dynamic No Pain	12.50 ± 7.84	9.25 ± 6.69

[F] Indicates the statistical significance of (P<0.05)

The average and standard deviations of hip abduction/adduction angle (Figure 19) are shown in Table 11. There was no statistical significance for hip abduction/adduction (*P*>0.05).

Table 11. Single leg squat analysis hip abduction/adduction angle averages (mean ± SD)

	Pretest Angle Mean	Posttest Angle Mean
Total	8.46 ± 7.72	5.92 ± 5.12
Static	6.17 ± 5.34	5.58 ± 2.94
Dynamic	10.75 ± 9.21	6.25 ± 6.77
Pain	8.50 ± 8.19	5.88 ± 2.30
No Pain	8.44 ± 7.75	5.94 ± 6.14
Static Pain	4.75 ± 6.08	6.00 ± 2.00
Static No Pain	6.88 ± 5.22	5.38 ± 3.42
Dynamic Pain	12.25 ± 9.07	5.75 ± 2.87
Dynamic No Pain	10.00 ± 9.80	6.50 ± 8.26

Looking at the overall score of the single leg squat analysis there were no subjects that got a score of 0 and 4 that got a score of 3 for the pretest. The average and standard deviations for the overall scores of the single leg squat are reported in Table 12. There was no statistical significance between the groups of pain, treatment, and testing for scoring between pre and posttest of the single leg squat analysis test (*P*>0.05).

Table 12. Single leg squat analysis score averages (mean ± SD)

	Pretest Score Mean	Posttest Score Mean
Total	1.83 ± 0.70	1.96 ± 0.75
Static	1.83 ± 0.72	2.00 ± 0.74
Dynamic	1.83 ± 0.72	1.92 ± 0.79
Pain	1.63 ± 0.52	1.88 ± 0.64
No Pain	1.94 ± 0.77	2.00 ± 0.82
Static Pain	1.75 ± 0.50	2.00 ± 0.82
Static No Pain	1.88 ± 0.84	2.00 ± 0.76
Dynamic Pain	1.50 ± 0.58	1.75 ± 0.50
Dynamic No Pain	2.00 ± 0.76	2.00 ± 0.93

The average and standard deviations of knee angles were reported in Table 13. Statistical significance determined for testing main effect ($F_{1,8}$=6.14, P=0.038, Post-Testing < Pre-Test) was found.

Table 13. Single leg squat analysis knee flexion angle averages (mean ± SD)

	Pretest Angle Mean [I]	Posttest Angle Mean [I]
Total	96.83 ± 10.49	93.33 ± 9.14
Static	92.92 ± 12.18	89.33 ± 9.77
Dynamic	100.75 ± 6.92	97.33 ± 6.64
Pain	100.63 ± 9.44	95.50 ± 8.18
No Pain	94.94 ± 10.74	92.25 ± 9.64
Static Pain	98.25 ± 13.48	92.00 ± 9.93
Static No Pain	90.25 ± 11.45	88.00 ± 10.09
Dynamic Pain	103.00 ± 3.37	99.00 ± 4.97
Dynamic No Pain	99.63 ± 8.12	96.50 ± 7.50

[I] Indicates the statistical significance of (P=0.038)

Double Leg Squat Test Analysis

No statistical significance was found between the difference observations of the double leg squat test except for the overall double leg score. The subjects had an average overall score of 7.375 for the pretest and posttest of 8.833 (Table 14). No interactions were observed. However, testing main effect difference was observed for the double leg squat overall score ($F_{1.8}$=15.75, P=0.004, Pre-Testing < Post-Testing).

Table 14. Double leg squat average scores (mean ± SD)

	Pretest Score Mean [J]	Posttest Score Mean [J]
Total	7.38 ± 1.41	8.83 ± 1.24
Static	7.50 ± 1.45	8.83 ± 1.47
Dynamic	7.25 ± 1.42	8.83 ± 1.03
Pain	7.50 ± 1.69	9.0 ± 1.31
No Pain	7.31 ± 1.30	8.75 ± 1.24
Static Pain	6.50 ± 1.73	8.25 ± 1.50
Static No Pain	8.00 ± 1.07	9.75 ± 1.46
Dynamic Pain	8.50 ± 1.00	9.75 ± 0.50
Dynamic No Pain	6.63 ± 1.19	8.38 ± 0.92

[J] Indicates the statistical significance of (P=0.004)

Visual Analogue Scale Analysis

The range of perceived pain for the pretest was 8.2 cm to 0 cm (Table 15). There were 8 subjects that reported 0 on the visual analogue scale for the pre and posttest. Ten of the subjects had a lower pain, 2 had a higher pain, and 4 categorized as unchanged pain from the pre to posttest. There was statistical significance in two-way interactions between Pain x Exercise ($F_{1,8}$=6.37, P=0.036, Knee No-Pain Static < Knee Pain Static;

Knee No-Pain Dynamic < Knee Pain Dynamic) and Pain x Testing ($F_{1,8}$= 121.94, P<0.001, Knee Pain Post < Knee Pain Pre).

Table 15. Visual analogue scale average scores (mean ± SD)

	Mean Pretest cm [L]	Mean Posttest cm [L]
Total	1.99 ± 2.34	0.90 ± 1.41
Static [K]	1.79 ± 1.88	0.51 ± 0.64
Dynamic [K]	2.19 ± 2.80	1.29 ± 1.85
Pain [K]	4.74 ± 1.96	1.93 ± 1.93
No Pain [K]	0.62 ± 0.76	0.39 ± 0.68
Static Pain	4.00 ± 1.00	0.93 ± 0.63
Static No Pain	0.69 ± 0.98	0.30 ± 0.57
Dynamic Pain	5.48 ± 2.56	2.93 ± 2.38
Dynamic No Pain	0.55 ± 0.53	0.48 ± 0.81

[K] Indicates the statistical significance of (*P*=0.036)

[L] Indicates the statistical significance of (*P*=0.001)

CHAPTER V

DISCUSSION

Y-Balance System Test

The purpose of this study was to examine dancers at the University of Nebraska at Kearney that performed 8 weeks (about 2 months) of static or dynamic hip rehabilitation exercises to determine which would have a greater influence on knee stability, functional movements, and knee pain scale. The Y-Balance System test analysis showed that testing was statistically significant in the anterior direction with pretest scores being lower than posttest scores. There was no significance when comparing testing in the anterior direction, but the no pain dynamic hip rehabilitation group in the anterior direction was the only grouping to have a lower posttest normative leg length percentage than the pretest, when compared against other groups and the other two directions. The subjects that perceived pain had an overall lower anterior normative percentage score than those that did not perceive pain in the anterior direction for both pre and posttest.

The posteromedial direction was statistically significant for testing with pretest score being lower than posttest score. Though there was no statistical significance with connection to treatment there was an increase in both static and dynamic hip rehabilitation treatments. The dynamic group had a relatively higher pretest of 97.85% compared to the static group of 91.62%. The dynamic group, in the posteromedial direction was the only one to get over 100%, which shows that the subjects were able to move farther than their leg length in that direction. This could lead to the conclusion that the posteromedial direction during the Y-Balance System test had more stability than the other two directions. Statistical significance was found in the posterolateral direction between tests. This demonstrates that there was a significant difference between the normative percentages of the pretest and the posttest, though undetermined which treatment it had more of an effect on due to lack of post hoc significance. The statics hip rehabilitation group had a larger increase of 9.65% compared to the dynamic 6.75%.

Wilson et al. (2018) reported with 73 college aged recreationally active subjects of both genders that the anterior direction of the Y-Balance System test had a lower leg length percentage compared to the posteromedial and posterolateral directions.[35,36] It was also reported that strength of the external rotators muscles of the hip, gluteus medius and gluteus minimus, are predictors in performance on the Y-Balance System test in all directions.[35,36] This demonstrates that the anterior direct is relatively weaker than the posterior directions. There is a strong possibility of a connection between decreased scores in the anterior direction due to decreased activation of the gluteus maximus which can lead to poor biomechanics of the knee that presents, due compensations, as anterior knee pain. This could also be connected to why many knee injuries occur in the sagittal plane. Most movements are performed in a forward motion during athletic activity like running, swimming, and cycling. Dancers, especially ballet dancers, typically work in the coronal plane that moves side to side. This is so the body seems more open to the audience. One subject, from our study conducted, noted that motions in the coronal plane or coronal-sagittal going posteriorly, were perceived by her as more stable due to increased activation of the stabilizer muscles, mainly the glutes. The anterior frontal plain has a lack of activation of the stabilizer muscles and subjects are often utilizing their quadriceps and hip flexors, instead of activating their gluteus maximus to help prevent pelvic drop while jogging or running.[37] Britto et al. (2021) reported that 12 male subjects with anterior knee pain compared to 20 healthy male subjects had delayed activation of the gluteus maximus muscle and activation deficit while performing 15 seconds of running at 11km/h.[37] From this we can infer that those with anterior knee pain might lack activation of the gluteus maximus when they perform forward movements. In conclusion, we saw deficits in normative leg percentage in the anterior direction of the Y-Balance System test compared to the posteromedial and posterolateral directions for both subjects that had anterior knee pain and no anterior knee pain.

BESS Test

There was no statistical significance found within the BESS test. The test was increased from 30 seconds to 1 minute due to the dancer's proprioception.[21] Tao et al. (2020) reported that 40 recreationally active individuals had an average of 2.23 ± 1.57 for errors while performing a BESS test on a stable surface with no interventions.[38] A low negative correlation was found between hip extension strength and single leg balance.[38] This concludes that those with increased BESS scores had less strength for hip extension.[38] Smith et al. (2018) reported that the 14 participants that were in the hip rehabilitation exercise group that performed exercises 3 times a week found significantly less errors on the BESS test than those in the no intervention group.[36] Smith’s hip rehabilitation exercises utilized a resistance band while performing exercises similar to the static hip rehabilitation group of this study. In conclusion there was a possible change, though not statistically significant from possibly low subject numbers, that those with pain that performed the dynamic hip rehabilitation exercise were able to have a decrease in error during the BESS test corresponding to an increase in knee stability. Overall, those that participate in a hip rehabilitation exercise program will see results in lowering their BESS test error score.

Single Leg Squat Test

Testing main effect differences for valgus/varus angle of the knee with a decrease in angle were observed from pretest to posttest in the current study. There were 2 subjects, both in the dynamic no pain group, that decreased their knee varus angle to under 10 degrees. Though not statistically significant there was no difference between pain and no pain for the pretest when looking at hip varus/valgus angles. When looking at subjects with no pain the average knee varus/valgus angle decreased to 10.38 degrees, within acceptable guidelines, compared to those with pain having an average posttest of 14.63 degrees. Herrington (2014) concluded that individuals with patellofemoral pain, another form of anterior knee pain, have a knee valgus angle while performing single leg squat test greater (13.5 ± 5.7 degrees) than those in the control group (8.4 ± 5.1 degrees) without patellofemoral pain.[39,40] This was assumed due to possibly weakness of the glutes and external rotators of the hip.[39] This study was conducted without intervention of a rehabilitation program.[39] The average hip valgus/varus angle for subjects with no perceived anterior knee pain was 15.06 degrees, this was well over what Herrington determined. The average for subjects that did have pain was 15.63 degrees. Our data is slight contradicting to what Herrington reported, possibly due to low subject numbers. The static pain group had the most similar valgus/varus angle to Herrington at 12.50 degrees for the pretest. The dynamic no pain group at 9.25 degrees for the posttest was closer to Herrington's conclusion and the static pain group average was 13.50 degrees. After the subjects performed the hip rehabilitation exercises the data was more consistent with those found with Herrington's who had no interventions.

Dix et al. (2019) conducted a systematic review looking at the hip muscle strength and knee valgus for single leg squat, double leg squat, and ballistic single and double leg squat in asymptomatic females. Though there were a few conflicting articles about increased or decreased hip strength correlating to knee valgus, it was concluded that single leg ballistic movements, like jumping or hoping, had decreased knee valgus with increased hip strength.[41] This correlation was not consistently seen with single or double leg squat and subjective to certain tasks for ballistic double leg squat.[41] Though there was some improvement of knee valgus angle seen from pretest to posttest, hip strengthening is not a significant enough factor to decrease knee valgus angle to an acceptable degree. A common assumption is that a higher Q-angle that is often seen in the female population affects knee valgus, but Q-angle was found to not be statistically significant with a relation to knee valgus by Pantano et al (2005).[42] Greater pelvic width to femoral length ratio was deemed to be significant predictor to knee valgus while performing a single leg squat and static knee valgus in 20 subjects that were categorized with high or low Q-angles.[42] From this it could be inferred that the main factor of knee valgus angle is subjective to a subject's body structural proportions and a small amount of improvement can be obtained by hip strengthening.

From our data we see that 11 subjects had a larger than 10-degree angle for knee abduction/adduction and only 1 of those subjects did not decrease their angle to under 10 degrees. For the pretest 8 of the subjects with hip abduction/adduction angles above 10 degrees had no perceived anterior knee pain and 3 had perceived anterior knee pain. Nakagawa et al. (2012) analyzed 80 subject that were separated into 4 groups: females with anterior knee pain, female control, male anterior knee pain, and male control, looking at trunk, pelvis, hip and knee kinematics and gluteal muscle activation while performing a single leg squat. Females had a significantly higher hip adduction compared to males and those with anterior knee pain had significantly higher angle than the controls.[40] A small population size in our study, could have contributed to not displaying results with connection between subjects with anterior knee pain having larger hip adduction angles. Both dynamic groups, pain and no pain were able to decrease the overall hip abduction/adduction angle to within acceptable guidelines for the posttest. Willy and Davis (2011) reported from their study that 20 females with excessive hip adduction while running were separated into a control and hip rehabilitation exercise group to work on hip strengthening. They also performed movement education 3 times a week for 6 weeks (about 1 and a half months). They reported that hip abduction (P=0.006), hip internal rotation (P=0.006), and pelvic drop (P=0.02) decreased significantly after the 6 weeks (about 1 and a half months).[43] Though we did not see a statistically significant change in hip abduction there was a substantial change in subjects that were greater than 10 degrees of hip abduction/adduction for the pretest compared to the posttest. This might not be statistically significant due to low subject size.

Double Leg Squat Test

The double leg squat score was significant for testing. There was only 1 subject who had a score of 10 for the pretest, but for the posttest there was 10 subjects. Those with perceived pain did not have the lower score for the pretest as would be expected. Those that did not report perceived anterior knee pain tended to have lower pretest and posttest scores. Severin et al. (2017) reported the assumption that subjects that have perceived pain will have changes in technique while performing actions where the pain is felt.[44] They conducted a study to look at bilateral kinematics for subjects with unilateral anterior knee pain while performing double-leg and single-leg squats on land and in water. There were 20 subjects with unilateral anterior knee pain and 20 healthy individuals as the control group. Movement depths and peak angles were looked as while performing the tasks. They determined that those with anterior knee pain had symmetry bilaterally on land, but asymmetries while in the water, specifically in the frontal plane motions on the limb with anterior knee pain.[44] There is a lack of research connecting anterior knee pain and performance or increasing performance while performing a double leg squat test on land. Most research is looking at ankle mobility in the dorsiflexion direction. In conclusion from these results anterior knee pain might be a factor in performing a double leg squat test, but the body finds ways to change its kinematics to adapt to the pain and the changes might not be visible to an observer. The use of kinematic software could be utilized to pinpoint these biomechanical adaptations in the future.

Visual Analogue Scale

Anterior knee pain of the subjects, recorded by the visual analogue scale was found to be statistically significant for interactions between, pain and treatment, and pain and testing. At the pretest 8 subjects reported 0 cm, those same subjects where the only ones to report 0 cm on the posttest. There was change of 1.76 cm average for the whole subject group. The static group reported a smaller difference at 1.61 cm compared to dynamic difference of 1.97 cm. Overall the subjects that reported anterior knee pain on the questionnaire saw a decrease from pretest to posttest. Subjects that did not report anterior knee pain during the questionnaire but reported it on the visual analogue scale has a decrease in average pain from 0.62 cm to 0.39 cm. The static pain group saw a difference of 1.45 cm while static no pain group had a difference of 0.64 cm. The dynamic pain group had a difference of 2.78 cm while the dynamic no pain group had a difference of 0.65 cm. We expected to see a greater difference in the pain groups because they reported more having more perceived anterior knee pain at the pretest. Ferber et al. (2015) reported that 199 subjects completed their study with patellofemoral pain, another term for anterior knee pain. There protocol considered of patients completing hip, knee, or hip and knee exercises for 6 weeks (about 1 and a half months). They found that after those 6 weeks (about 1 and a half months) there was a significant decrease in the hip exercise group when compared to the knee exercise group.[45] They also found that subjects that participated in both the hip and knee exercises reported a higher score on the visual analogue scale for the posttest than the pretest.[45] The dynamic hip rehabilitation group did see a larger improvement in perceived anterior knee pain when compared to the static hip rehabilitation group. In conclusion, dynamic hip exercises will lead to a decrease in anterior knee pain but performing hip rehabilitation exercises either dynamic or static will decrease anterior knee pain after 8 weeks.

CHAPTER VI

CONCLUSION

The four stability tests and functional movement screenings were most commonly statistically significant when looking at pain and testing. From this we can conclude that there might not have been a significant difference between the static and dynamic hip exercise groups, but there was a change in the performance of the subjects from pretest to posttest. It can be inferred that performing static or hip rehabilitation exercises can increase performance of these stability tests and functional movement, except for the BESS test that found no statistical significance. It also shows us that performing these exercises was able to reduce the perceived anterior knee pain for subjects that had anterior knee pain.

The first hypothesis was static hip rehabilitation exercises will increase knee stability in dancers, tested by the Y-Balance System test and Balance Error Scoring System (BESS) test, compared to the dynamic hip rehabilitation exercises. This hypothesis is inconclusive, possibly due to small sample size. The BESS test was found not have any statistical significance, but there were non-statistical changes from the pretest to post test in error score. The Y-Balance System test was significant in all directions for testing; anterior, posteromedial, and posterolateral. Due to lack of consistent significance between Y-Balance System test and the BESS test, there cannot be a determination that knee stability was increased. Thus, we determine, due to lack of statistical significance, that there is not a statistically significant difference that efficiently improves knee stability between static or dynamic hip rehabilitation exercises.

The second hypothesis was dynamic hip rehabilitation exercises will increase knee functional biomechanical ability in dancers, tested by single and double leg squat analysis, compared to the static hip rehabilitation exercises. This hypothesis is inconclusive, possibly due to small sample size. The single leg squat analysis showed significance for main effects of testing for knee angle varus/valgus. The double leg squat analysis was found to be only statistically significant for main effects of testing for the score. This does not give us a clear sense that dynamic hip rehabilitation exercises increase knee functional biomechanical ability more efficiently compared to static hip rehabilitation exercises.

The third hypothesis was dynamic hip rehabilitation exercises will decrease anterior knee pain in dancers compared to static hip rehabilitation exercises shown by a comparison pre and posttest of subject's perceived pain on a visual analogue scale. This hypothesis is not rejected due to the statistical significance found for interactions between pain and test and pain and treatment. The dynamic hip rehabilitation group with perceived pain had an average decrease of 2.78 cm while the statis hip rehabilitation group with perceived pain was 1.61 cm.

Areas for further research could be completed with the use of the Biodex isokinetic dynamometer and Biodex Balance System. These machines were originally planned to be used for this experiment but due to COVID-19 restrictions on subject-experimenter interactions had to be limited to decrease the risk of the subjects being exposed possibly by the experimenter or vice versa. The Balance System would have been utilized to extract sway index values instead of the BESS test to provide subjective data that can lead to errors from the examiners. The isokinetic dynamometer could provide peak torque for the hip and knee muscles to determine if muscle strength were changed by the static and dynamic exercises. Overall, multiple aspects of this experiment have been changed due to the Center of Disease Control (CDC) guidelines to prevent the spread of COVID-19.

Further investigation on hip rehabilitation exercises for connection between kinetic chain could be performed looking at decreasing common lower extremity injuries like ankle sprain, Achilles' tendonitis, or arch pain. Connection between lower back, non-musculoskeletal, pain and hip rehabilitation exercises could lead to decreasing muscle spasms or sciatic pain by stabilizing the hip and thoracic kinetic chain.

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APPENDIX

APPENDIX A. CONFIDENTIALITY AND INFORMED CONSENT FORM

Consent to Participate in a Research Study
University of Nebraska at Kearney

Study title: Effects of Dynamic and Static Hip Rehabilitation on Stability and Functional Screening in Dancers with Anterior Knee Pain

IRB Number: 111920-1

Investigators:

Erin Anderson, ATC
Principle Investigator, Graduate Student
Dept. Kinesiology & Sport Sciences
Email: andersonem2@lopers.unk.edu

Dr. Kazuma Akehi, Ph.D., LAT, ATC
Faculty Mentor, Associate Professor
Dept. Kinesiology & Sport Sciences
Email: akehik1@unk.edu
Phone: 308-865-8600

Purpose of the research: The purpose of the study is to determine if static or dynamic hip rehabilitation exercises increase knee functional movement and stability while decreasing perceived anterior knee pain.

Procedures: You will visit the UNK (University of Nebraska at Kearney) Athletic Training Lab, Evaluation Room (Cushing 158) dressed in comfortable workout attire (e.g., athletic shorts and a t-shirt).
Baseline Assessment (First day) - This session will take approximately 45-60 minutes.

- Read and sign the informed consent document prior to test and email signed copy to examiner. Complete the questionnaire with examiner over Zoom and email after testing.
    - To safely participate the current study, you need to be aged 19 years or older, do not have any known lower extremity injury in the last 3 months prior to the data collection, other than anterior knee pain. If you have had a lower extremity injury within the last 3 months, your physician must have cleared you to participate in dance activities to participate in the study.
    - You will need access to a smart phone or computer that can accesses Zoom.
    - Age, height, weight, and level of anterior knee pain will be collected.
- Complete the pre-exercise baseline assessments on the marked floor.

- Y-balance System test: While balancing on one leg you will reach your leg in three different directions (marked on the floor) as far as you can comfortably go without becoming unbalanced or picking your foot off the ground. This will be measured on both legs, 3 times in each direction.
- BESS test: You will balance on one leg with your eyes closed for up to 1 minute on both legs.
- Single leg squat test: You will perform a total of 6 single leg squats on both legs with your hands on your hips and as far as you feel comfortable going. 3 of the squats will be facing the camera and 3 will be facing the side (directions are marked on the floor).
- Double leg squat: You will perform a total of 6 double leg squats with your arms overhead. 3 of the squats will be performed facing the camera and another 3 facing the side (directions are marked on the floor).

- Receive 8-week hip rehabilitation exercises instructions.
    - You will receive the instruction for the 8-week hip rehabilitation exercise that you will perform at your home 3 times a week for 8 weeks (about 2 months). Each exercises session will last 15-20 minutes on your own. This will total to about 45-60 minutes for each of the 8 weeks (about 2 months).
    - Videos of how to perform the exercises will be provided as well as detailed instruction sheets.
    - The first day of exercises will be performed during the pre-test visit to ensure proper technique.

Post-exercise follow-up assessment (after 8th week of rehabilitation exercises) – this session will take approximately 45-60 minutes.

- Your height, weight, and level of anterior knee pain will be collected.
- Post-exercise baseline assessments will be performed as same as the baseline assessment.
    - Y-balance System test, BESS test, single leg squat test, double leg squat will be performed on the mark.

*****Due to the current COVID-19 pandemic circumstances and collecting data in Cushing 158 (Athletic Training Lab Evaluation Room). You also need to have access to a computer or smartphone with a video camera to participate in virtual testing. Further instruction will be provided during the testing and exercise sessions.***

Risks of Participation: In the current proposed study, there a probability greater than minimal physical risks or discomfort. The physical demands of each test and hip rehabilitation exercises are like light physical activity that many of the participants are already accustomed to performing. The rehabilitation exercises progression is in such a way to decrease the amount of soreness the subject may feel. They start off with light of exercise load and it increase every two weeks (Table 1 & 2), enough to increase muscular strength. There is a slight possibility of the stumbling or falling during the testing if you have poor balance. If pain increases or injury occur you will be referred to the Free Open Injury Clinic at UNK and evaluated by a Licensed, Certified Athletic Trainer.

http://www.unk.edu/academics/gradstudies/irb/forms/unantipated%20harm%20or%20injury.pdf

Benefits of Participation: The subject may have a decrease in anterior knee pain, increase in knee stability and functional mobility. This can benefit them by allowing them more pain free motion while dancing.

Following its conclusion, subjects will not be debriefed or receive information about the research project or data. All findings in the current study will be presented at the conference presentation and/or published in peer-reviewed manuscripts. Subjects will be able to access these presented or published materials accordingly.

Confidentiality: All information about you will be kept confidential. Confidentiality will be maintained by coding all information with individual identification numbers. The main list of participants and data will be stored separately and kept in a locked file cabinet in the faculty investigator's (Dr. Kazuma Akehi) office. Only qualified research personnel (i.e., investigator and/or faculty mentor) will have access to this record. The file that contains a link between the subject contact information and ID numbers will be destroyed following data collection. The data collected for this research will be saved if it is scientifically useful: typically, such information is kept for meetings or in publications. All identifiable data will be destroyed once the thesis is completed in May. You will not be identified individually. All information we are interested in at will consist of group information. Zoom videos of testing will be utilized for data collection and will be destroyed in May 2021, once the study has ended.

Contacts: You may contact any of the researchers at the following addresses and phone numbers, should you desire to discuss your participation in the research study and/or request information about the results of the research study. Following is the contact to the PI, Dr. Kazuma Akehi, Cushing 165, Dept. of Kinesiology and Sports Science, University of Nebraska at Kearney, Kearney, NE, 68849, (308) 865-8600, or akehik1@unk.edu.

Participant Rights: Your participation in this research is voluntary. There is no penalty for refusal to participate and you are free to withdraw your consent and participation in this project at any time, without penalty. Participation in this study will not have any effect on standing or performance on the dance team or academic affiliations. If you have any additional questions concerning your rights, you may contact the University of Nebraska at Kearney Institutional Review Board (IRB) at (308) 865-8843. In case of injury or illness resulting from this research study, you are responsible for seeking medical treatment at the UNK Student Health Center or an appropriate provider. Emergency medical treatment will be available by contacting 911. No funds have been set aside by University of Nebraska at Kearney to compensate you in the event of illness or injury.

Consent Documentation: I have been fully informed about the procedures listed here. I am aware of what I will be asked to do and the benefits of my participation. I also understand the following statements:

- I affirm that I am 19 years of age or older.
- I have read and fully understand this consent form and I sign it freely and voluntarily. A copy of this form will be given to me. I hereby give permission for my participation in the research study.

____

Participant Name   Date

____

Participant Signature   Date

I certify that I have personally explained this document before requesting that the participant sign it.

____

Research Investigator Signature   Date

APPENDIX B. PRE/POST QUESTIONAIRE

Demographics

Name: ________________________

Date of Birth: ____________________

Do you participate in the (circle one)?

Dance Team

Dance Program

Both

About how many days would you say you dance a day on average? ______________

About how many days do you dance a week on average? _________________

Since what age have you participated in dance? ___________

Questionnaire

Do you feel like you have pain over the anterior part of your kneecap or around it (circle one)?

Yes

No

If you do experience anterior knee pain, what leg do you feel it in (circle one)?

Right

Left

Both

Mark with an X on the line what level you perceive your pain to be at. The left side is low, and the right side is high.

Right Knee

____

Left Knee

APPENDIX C. PHOTO INFORMED CONSENT

Consent to use photography for purposes of this research.

Photos are used for demonstration of hip rehabilitation exercises.

_____ Yes, I agree to be photographed.

_____ No, I do not agree to be photographed.

Print Legal Name: ____

Signature: ____

Date of Signature (mm/dd/yr.): ____

Consent to use of photographs for publications, presentations or for educational purposes.

I give permission for the photographs made of me as part the research to be used in publications, presentations or for educational purposes.

_____

_____ Yes

_____ No

Print Legal Name: ____

Signature: ____

Date of Signature (mm/dd/yy): ____

APPENDIX D. FIGURES

Figure 1. Donkey Kicks. The subject will be on all fours, with hands directly under their shoulders and knees under hips. The back and neck should stay flat, parallel to the floor. The subject with engage the lower abdominals, while keeping their knee at 90 degrees, slowly lift the leg straight back towards the ceiling. The subject should lift the leg until they feel like their leg is about to rotate or the back arches. The subject will then return to the starting position and switch legs after all reps are completed on the first leg.

Figue 2. Fire Hydrants. The subject will be on all fours, with hands directly under their shoulders and knees under hips. The back and neck should stay flat, parallel to the floor. The subject will left their leg away from the midline of their body, about 45 degrees while keeping the knee at 90 degrees. The subject needs to make sure that the hip does not hike up as they perform the motion. The subject will then return to the starting position and complete all reps on that side before starting on the other leg.

Figure 3. Glute Bridge. The subject will lie face up on the floor, with knees bent so the feet are flat on the floor. They will keep their arms to the side of their body. The subject will activate their glutes and abdominals while they keep their knees, hips, and shoulder in a straight line as they life their hips off the ground. The subject should not overextend their back into an arch. The subject will hold at the top for 3 seconds and then slowly come down, making sure not to drop to the ground.

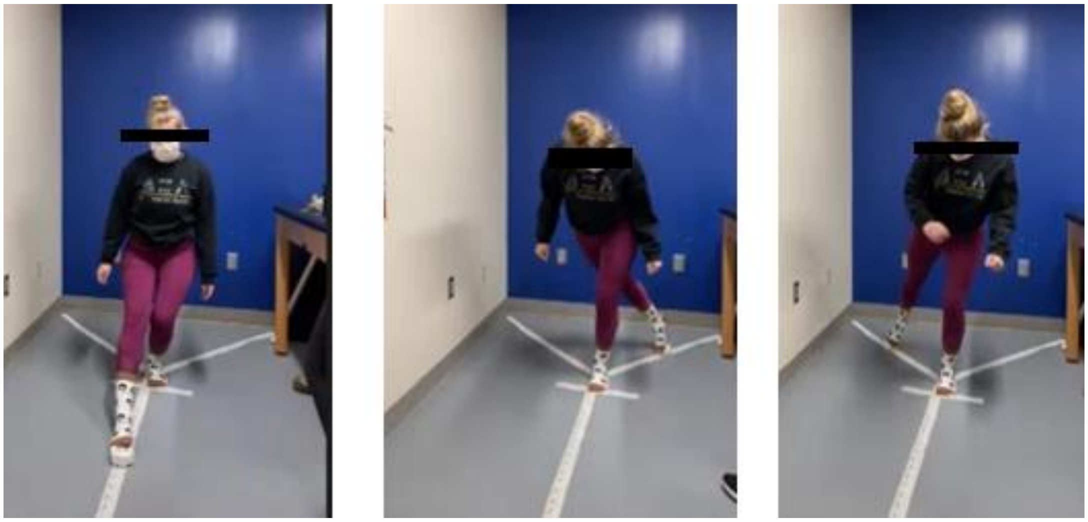
Figure 4. Lying Inner Thigh Lifts. The subject will lie on their side with their head held by their hand. The subject will cross the top leg over in front so that the foot is flat on the ground, keeping the hips on top of each other, perpendicular to the floor. The subject will the raise their inner thigh up as high as they can without moving their torso or hips. They will complete all the reps and then flip over to their other side to complete the other leg.

Figure 5. Monster Walks. The subject will be in an up-right position with a slight squat about 45-60 degrees knee bend. The subject will have their hands on their waist as they take diagonal steps, forward and out, from the starting position. The subject will take 10 of these steps, alternative legs. This is one set.

Figure 6. Skaters. The subject will start in a small squat with knees and toes under their shoulders. The subject will make a small jump to the left 1/3 to ½ their body height. As they land on their left leg the right leg will cross behind them with the knee bent at 90 so the foot does not touch the floor. They will then complete this on the other side. The combination of both the left and right jump is one repetition.

Figure 7. Lateral Walks. The subject will be in an up-right position with a slight squat about 45-60 degrees knee bend. The subject will have their hands on their waist as they take a step 1/3 to ½ their body height to the left side. The subject will then bring their right leg back to their left. The subject will do this 5 times and then repeat going to the right direction with the right leg. This is one set.

Figure 8. Jump Squats. The subject will start in an upright position with knees and toes shoulder width apart, facing forward. The subject will then activate their core as they perform a regular squat. The subject will then jump up and then land back in their squat position. The subject will then return to the upright position. This is one repetition.



D. Anterior **E. Posteromedial** **F. Posterolateral**

Figure 9. Y-Balance System Test Demonstration. Testing is performed in the anterior, posteromedial, and posterolateral direction. The subject's balances on one leg and moves the small block along with line until they are no longer able to go any farther. Falling over, picking you standing leg heel up, kicking the block, and putting your moving leg foot down makes the test start over.

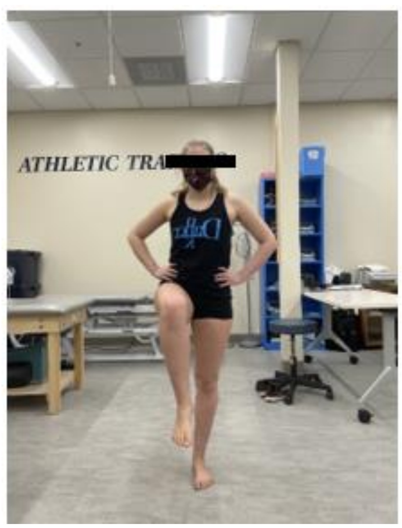


Figure 10. Balance Error Scoring System Test. The subject balances on one leg for one minute with their eyes open, hands-on hips, and leg out in front of them without touching their standing leg. Movements outside of this position are counted for errors.

Figure 11. Single Leg Squat Analysis Demonstration. The subject stands on one leg, hands on hips, and performs a single leg squat to the deepest depth of their ability without falling over. The subject will have their leg out Infront of them like pistol squat posture. If the subject falls or has trouble performing the squat that one is not counted.

Figure 12. Double Leg Squat Analysis Demonstration. The subject has their feet shoulder with apart and arms above their head in line with their ears. The subject's squats down as far as they can go, preferable 90 degrees of knee flexion obtained.

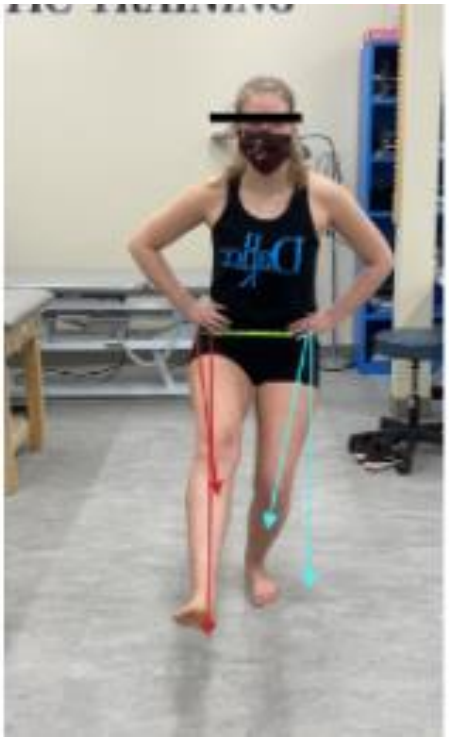


Figure 13. Hip Abduction/Adduction and Knee Valgus/Varus Angle. The blue lines show how the varus or valgus angles of the knee are measured on the supporting leg for the single leg squat analysis. The red shows the angle for the non-supporting leg hip abduction/adduction angle.

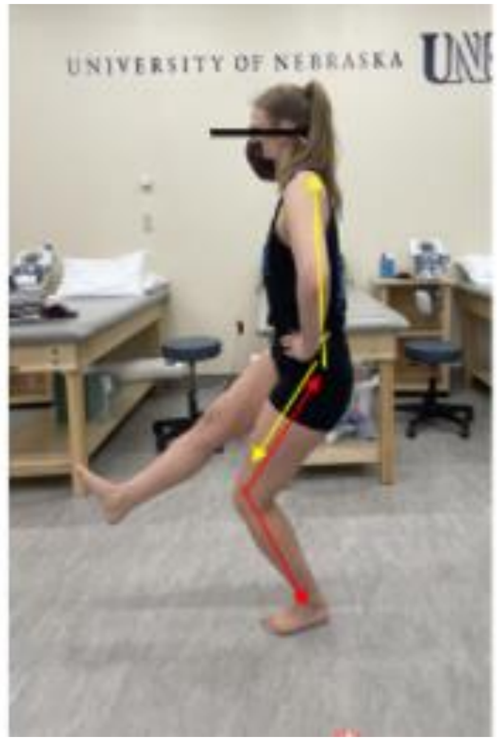


Figure 14. Hip Flexion and Knee Flexion Angle. The yellow lines show how to measure the angle of hip flexion for the single leg squat analysis. The red lines show the angle for knee flexion.

APPENDIX E. TABLES

Table 1. Static hip rehabilitation exercises weekly schedule

Exercises	Wk. 1	Wk. 2	Wk. 3	Wk. 4	Wk. 5	Wk. 6	Wk. 7	Wk. 8
Donkey Kicks	2/10	2/10	2/12	2/12	3/10	3/10	3/12	3/12
Fire Hydrants	2/10	2/10	2/12	2/12	3/10	3/10	3/12	3/12
Glute Bridge	2/10	2/10	2/12	2/12	3/10	3/10	3/12	3/12
Lying Inner Thigh Lift	2/10	2/10	2/12	2/12	3/10	3/10	3/12	3/12

Table 2. Dynamic hip rehabilitation exercises weekly schedule

Exercises	Wk. 1	Wk. 2	Wk. 3	Wk. 4	Wk. 5	Wk. 6	Wk. 7	Wk. 8
Monster Walks	2/10	2/10	2/12	2/12	3/10	3/10	3/12	3/12
Skaters	2/10	2/10	2/12	2/12	3/10	3/10	3/12	3/12
Lateral Walks	2/10	2/10	2/12	2/12	3/10	3/10	3/12	3/12
Jump Squats	2/10	2/10	2/12	2/12	3/10	3/10	3/12	3/12

Table 3. Descriptive demographic information data (mean ± SD)

	Mean ± SD	Minimum	Maximum
Age (years)	21.75 ± 1.06	20	23
Number of Days of Week Dancing	3.91 ± 1.16	3	6
Hours a Week of Dance	7.42 ± 2.87	3	12
Age Started Dance	7.67 ± 4.74	3	15

Table 4. Reported anterior knee pain based on dance participation

	Dance Program	Dance Team	Total
Right Knee Pain	1	1	2
Left Knee Pain	2	0	2
Both Knee Pain	2	0	2
No Knee Pain	2	4	6

Table 5. Relative anterior Y-Balance System test score results in pre- and post-testing (mean and SD)

	Pre-Testing % Mean	Post Testing % Mean
Total	84.09 ± 7.47	87.04 ± 5.35
Static	82.11 ± 5.78	86.28 ± 4.94
Dynamic	86.06 ± 8.65	87.79 ± 5.85
Pain	79.75 ± 5.76	85.72 ± 5.04
No Pain	86.26 ± 7.42	87.69 ± 1.19
Static Pain	79.67 ± 6.19	85.41 ± 4.37
Static No Pain	83.33 ± 5.56	86.72 ± 5.43
Dynamic Pain	79.83 ± 6.25	86.03 ± 6.32
Dynamic No Pain	89.18 ± 8.22	88.67 ± 5.83

Table 6. Relative posteromedial Y-Balance System test score results in pre- and post-testing (mean and SD)

	Pre-Testing % Mean	Post Testing % Mean
Total	94.74 ± 9.19	100.09 ± 8.26
Static	91.62 ± 8.70	97.34 ± 7.08
Dynamic	97.85 ± 8.94	102.83 ± 8.71
Pain	98.09 ± 9.20	106.20 ± 5.10
No Pain	93.85 ± 9.74	102.10 ± 8.73
Static Pain	93.77 ± 5.95	99.24 ± 4.80
Static No Pain	90.55 ± 9.98	96.39 ± 8.12
Dynamic Pain	100.75 ± 6.24	104.75 ± 3.67
Dynamic No Pain	96.40 ± 10.08	101.87 ± 10.50

Table 7. Relative posterolateral Y-Balance System test score results in pre- and post-testing (mean and SD)

	Pre-Testing % Mean	Post Testing % Mean
Total	95.27 ± 9.58	103.47 ± 7.85
Static	91.69 ± 10.02	101.34 ± 7.83
Dynamic	98.85 ± 7.97	105.59 ± 7.58
Pain	97.26 ± 6.77	101.99 ± 4.93
No Pain	93.77 ± 10.15	99.13 ± 9.50
Static Pain	94.85 ± 11.16	107.25 ± 6.22
Static No Pain	90.10 ± 9.78	98.39 ± 7.06
Dynamic Pain	101.33 ± 6.70	105.15 ± 4.36
Dynamic No Pain	97.61 ± 8.67	105.82 ± 9.06

Table 8. BESS test average scores (mean ± SD)

	Mean Pretest Errors	Mean Post Test Errors
Total	2.79 ± 2.00	1.52 ± 1.17
Static	2.67 ± 2.15	1.25 ± 1.60
Dynamic	2.92 ± 1.93	1.08 ± 1.51
Pain	3.13 ± 1.36	1.25 ± 0.89
No Pain	2.63 ± 2.28	1.13 ± 1.78
Static Pain	3.00 ± 1.15	1.50 ± 1.00
Static No Pain	2.50 ± 2.56	1.13 ± 1.89
Dynamic Pain	3.25 ± 1.71	1.00 ± 0.82
Dynamic No Pain	2.75 ± 2.12	1.13 ± 1.80

Table 9. Single leg squat analysis hip flexion angle averages (mean ± SD)

	Pretest Angle Mean	Posttest Angle Mean
Total	94.79 ± 23.66	97.79 ± 19.27

Static	87.25 ± 20.62	94.75 ± 14.79
Dynamic	102.33 ± 24.93	100.83 ± 23.18
Pain	91.13 ± 22.86	90.88 ± 11.95
No Pain	96.63 ± 24.57	101.25 ± 21.55
Static Pain	77.00 ± 16.87	86.25 ± 10.97
Static No Pain	92.38 ± 21.35	99.00 ± 15.18
Dynamic Pain	105.25 ± 20.07	95.50 ± 12.48
Dynamic No Pain	100.88 ± 23.23	103.50 ± 27.45

Table 10. Single leg squat analysis knee varus/valgus angle averages (mean ± SD)

	Pretest Angle Mean	Posttest Angle Mean
Total	15.25 ± 8.26	11.79 ± 5.35
Static	15.92 ± 9.56	12.17 ± 4.41
Pain	15.63 ± 9.04	14.63 ± 2.72
No Pain	15.06 ± 8.15	10.38 ± 5.83
Dynamic	14.58 ± 7.10	11.42 ± 6.33
Static Pain	12.50 ± 12.56	13.50 ± 3.00
Static No Pain	17.63 ± 8.12	11.50 ± 5.01
Dynamic Pain	18.75 ± 2.63	15.75 ± 2.23
Dynamic No Pain	12.50 ± 7.84	9.25 ± 6.69

Table 11. Single leg squat analysis hip abduction/adduction angle averages (mean ± SD)

	Pretest Angle Mean	Posttest Angle Mean
Total	8.46 ± 7.72	5.92 ± 5.12
Static	6.17 ± 5.34	5.58 ± 2.94
Dynamic	10.75 ± 9.21	6.25 ± 6.77
Pain	8.50 ± 8.19	5.88 ± 2.30

No Pain	8.44 ± 7.75	5.94 ± 6.14
Static Pain	4.75 ± 6.08	6.00 ± 2.00
Static No Pain	6.88 ± 5.22	5.38 ± 3.42
Dynamic Pain	12.25 ± 9.07	5.75 ± 2.87
Dynamic No Pain	10.00 ± 9.80	6.50 ± 8.26

Table 12. Single leg squat analysis score averages (mean ± SD)

	Pretest Score Mean	Posttest Score Mean
Total	1.83 ± 0.70	1.96 ± 0.75
Static	1.83 ± 0.72	2.00 ± 0.74
Dynamic	1.83 ± 0.72	1.92 ± 0.79
Pain	1.63 ± 0.52	1.88 ± 0.64
No Pain	1.94 ± 0.77	2.00 ± 0.82
Static Pain	1.75 ± 0.50	2.00 ± 0.82
Static No Pain	1.88 ± 0.84	2.00 ± 0.76
Dynamic Pain	1.50 ± 0.58	1.75 ± 0.50
Dynamic No Pain	2.00 ± 0.76	2.00 ± 0.93

Table 13. Single leg squat analysis knee flexion angle averages (mean ± SD)

	Pretest Angle Mean	Posttest Angle Mean
Total	96.83 ± 10.49	93.33 ± 9.14
Static	92.92 ± 12.18	89.33 ± 9.77
Dynamic	100.75 ± 6.92	97.33 ± 6.64
Pain	100.63 ± 9.44	95.50 ± 8.18
No Pain	94.94 ± 10.74	92.25 ± 9.64
Static Pain	98.25 ± 13.48	92.00 ± 9.93
Static No Pain	90.25 ± 11.45	88.00 ± 10.09
Dynamic Pain	103.00 ± 3.37	99.00 ± 4.97

Dynamic No Pain	99.63 ± 8.12	96.50 ± 7.50

Table 14. Double leg squat average scores (mean ± SD)

	Pretest Score Mean	Posttest Score Mean
Total	7.38 ± 1.41	8.83 ± 1.24
Static	7.50 ± 1.45	8.83 ± 1.47
Dynamic	7.25 ± 1.42	8.83 ± 1.03
Pain	7.50 ± 1.69	9.0 ± 1.31
No Pain	7.31 ± 1.30	8.75 ± 1.24
Static Pain	6.50 ± 1.73	8.25 ± 1.50
Static No Pain	8.00 ± 1.07	9.75 ± 1.46
Dynamic Pain	8.50 ± 1.00	9.75 ± 0.50
Dynamic No Pain	6.63 ± 1.19	8.38 ± 0.92

Table 15. Visual analogue scale average scores (mean ± SD)

	Mean Pretest cm	Mean Posttest cm
Total	1.99 ± 2.34	0.90 ± 1.41
Static	1.79 ± 1.88	0.51 ± 0.64
Dynamic	2.19 ± 2.80	1.29 ± 1.85
Pain	4.74 ± 1.96	1.93 ± 1.93
No Pain	0.62 ± 0.76	0.39 ± 0.68
Static Pain	4.00 ± 1.00	0.93 ± 0.63
Static No Pain	0.69 ± 0.98	0.30 ± 0.57
Dynamic Pain	5.48 ± 2.56	2.93 ± 2.38
Dynamic No Pain	0.55 ± 0.53	0.48 ± 0.81

APPENDIX F. TIMELINE

First Committee Meeting	September 3rd
• **Describe Research Plan**	
• **Proposed Research Objectives**	
• **Program of Study Form Signatures**	
Literary Review Research	September 5th
Apply for Candidacy.	September 25th
Second Committee Meeting	October 23rd
• **Approvals of:**	
• **Literature Review**	
• **Statement of Research Questions**	
• **Research Objectives**	
• **Procedures for Each Objective**	
Formal Research Approval	November 3rd
IRB Approval	November 29th
Research Collection	Feb 22nd – April 19th
• **Pre-Testing**	Feb 22nd-26th
• **Post-Testing**	April 19th -23rd

Research Data Analytics	April 23rd -30th
Write Thesis Results and Conclusion	April 26th-May 5th
Third Committee Meeting • **Inform Progress and Modifications to Program**	May 3rd-7th
Thesis Defense • **Copies Given to Defense at Least 2 Weeks Before.** • **Oral Defense** • **Submit First 10 Pages 3 Weeks Prior to Graduation** • **All forms Completed.** • **All Copies Given to Office of Graduate Studies 2 weeks Before Graduation.** • **Submit PDF File of Thesis to ProQuest CSA's UMI Dissertation Publishing**	July 8th