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Balance of adults with chronic ankle instability following a 6-week core stability program

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BALANCE OF ADULTS WITH CHRONIC ANKLE INSTABILITY FOLLOWING A 6-WEEK CORE STABILITY PROGRAM

By
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A Thesis

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Dedication

To my parents, Jackie and Scott, and my siblings, Ashley and Jason, for always encouraging me and pushing me to be my best

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I would like to express my deepest gratitude to my thesis committee, Dr. Pletcher, Dr. Mann, and Mrs. Gibbs for all of their guidance and encouragement.

To my friends Sarah, Nicole, Donovan, Matt, and Brad: Thank you for keeping me sane during this time. I wouldn’t want to go through this with anyone else.

Abstract

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BALANCE OF ADULTS WITH CHRONIC ANKLE INSTABILITY FOLLOWING A 6-WEEK CORE STABILITY PROGRAM
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Ankle injuries account for 15-45% of all injuries. They are responsible for causing the longest time loss from sports participation with 60% of high school athletes and 73% of college athletes sustaining at least 1 ankle injury in their career. Mechanoreceptors can be found within the ligaments, joint capsules, and tendons surrounding the ankle as well. The receptors present a feedback response of pressure, which will eventually provide a sense of movement. Using the somatosensory, vestibular and sensory systems, the information is integrated into a control system, allowing for control over posture and coordination. During injury, these receptors are damaged, resulting in postural and coordination deficits. Previous studies have shown the effects of a core program on the reach distance using a 3-point grid or using subjects with previous knee injuries. Other studies have shown deficits in landing using a drop landing test. Many do not focus on landing following a core stability program in conjunction with a balance test in patients with a history of ankle injuries. The effects are clinically relevant because this could prevent re-injury in athletes who are suffering from CAI. Within this thesis, we explored the outcomes of a 6-week core program on the landing stabilization and reach distance of subjects with chronic ankle instability. Overall, this study will allow for clinicians to provide optimal care while decreasing the risk for re-injury.

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Chapter 1

Introduction

Ankle injuries account for fifteen to forty-five percent of all injuries among young athletes, with sixty percent of high school athletes and seventy-three percent of collegiate athletes suffering at least one ankle injury in their careers.[7, 8] Ankle injuries are responsible for the overall longest time loss from sports participation. Long-term problems following an ankle sprain, include: joint degeneration, a reduced quality of life, decrease in physical activity, and the development of chronic ankle instability.[8] During injury, mechanoreceptors found in tendons, ligaments and joint capsules are damaged, resulting in postural and coordination deficits.[2,12] Mechanoreceptors are responsible for feedback regarding joint pressure and tension, which provides a sense of movement and position.[18] Afferent nerve fibers integrate the information with visual and vestibular sensory system into control system that controls posture and coordination.[18] During injury, afferent input is altered, affecting appropriate corrective muscular contractions.[18] Damage to the mechanoreceptors surrounding the ankle joint, functional impairments and chronic instability are subsequent to initial injury.[18] Chronic ankle instability (CAI) has been defined as a condition associated with recurrent sprains and persistent symptoms, including feelings of “giving way,” loss of function and limited movement and continuous ankle pain.[11,12,14,17] Due to the lack of postural control, which has been defined as the ability to maintain stability within a narrow base of support while in a single-leg stance,[14] CAI has led to further lower extremity injuries and functional deficits.

One of the most common issues seen among athletes with chronic ankle instability are balance deficits. Athletes must maintain their postural control while performing certain tasks, such as running and cutting.[9] Dynamic postural control has been defined as maintaining one's center of mass within the base of support during a movement task.[1,17] Patients with CAI are commonly shown to have functional deficits in postural control, such as overcompensating on the uninvolved limb or unable to maintain proper balance.[4] Patients with CAI show deficits in balancing tasks, including center-of-pressure measure, errors when performing balancing tasks, time to stabilization, and the Star Excursion Balance Test (SEBT).[17] In order to maintain proper postural stability, patients must be able to maintain appropriate core stability, which includes the training of the abdominal and lumbopelvic muscles (rectus abdominus, multifidus, internal obliques, external obliques, and transverse abdominus), as well as the gluteal muscles and adductor muscles.[9] Previous literature by Gage et.al[6] indicates that utilizing a core stability training program allows for better activation of the core muscles, which in turn allows for an increase in the feedforward mechanism and improving neuromuscular control of the lower extremities.[6]

Core stability is defined as the ability to control the position and motion of the lumbo-pelvic-hip complex.[2] Core stability relies on the integration of the passive spinal column as well as neural control to ensure that the athlete can perform activities while maintaining proper intervertebral neutral zones.[2] The main role of the stabilizing system is to provide stability to the spine. This allows the lower extremity to adapt to the varying demands of static and dynamic movements, such as cutting for a soccer ball or maintaining position as a linebacker in football.[1] The core can assist in lower extremity stabilization by controlling the forces and motion of the body while allowing optimum transfer and production of the forces.[4] According to Cobb et.al[4], there was a decreased postural stability in individuals with abnormal foot postures, such as pes cavus and hyperpronation, and a positive and negative correlation between core strength and postural stability.[4]

It is unclear whether or not core stability effects the dynamic postural stability of the lower extremities. There have also been disputes about the postural stability of athletes with chronic ankle instability and what measures athletes can take to improve their postural stability, such as improving neuromuscular control as opposed to strengthening the musculature. However, there is minimal research regarding core stability training and the effects it has on postural control in athletes with chronic ankle instability. Therefore, this introduction will serve as an overview of....

1.1 Chronic Ankle Instability Subjective Measures

Long-term problems occur following an ankle injury, with up to thirty percent of first-time ankle sprains developing into CAI.[8,20] In order to determine whether or not a patient is experiencing CAI, subjective measures, including injury history or a self-reported symptom questionnaire, are used.[11]The Foot and Ankle Disability Index (FADI) is a region-specific self-report outcomes assessment designed to evaluate the functional limitations related to the foot and ankle. The FADI contains two components: the FADI, which measures activities of daily living and the FADI Sport, specific for athletes.[7] Hale et.al[7] found the FADI and FADI Sport were sensitive to deficits associated with CAI, reflecting that those with CAI showed more dysfunction. It was also discovered that the FADI Sport is more sensitive to deficits in young, active individuals. CAI is often seen among individuals who are participating in rigorous workouts and athletic events. The FADI Sport would be more sensitive to those individuals who are constantly experiencing the symptoms of CAI on a daily basis, as opposed to those who do not participate in such activities.[7]

Another subjective tool used to determine patients with CAI is the Foot and Ankle Ability Measure (FAAM). The FAAM is a twenty-one item activities of daily living section and eight item sport-specific section questionnaire to measure the change of a patient's status over the course of their recovery. Carcia et.al[3] studied the validity of the FAAM among NCAA athletes. When compared to healthy athletes, those with CAI reflected a lower score on the sports subscale, while subjects who described their ankle as "normal" reported higher functional scores.

1.2 Chronic Ankle Instability and Postural Control

Ankle sprains are among one of the most common injuries in the sports population due to the large amount of forces an ankle encountered on a daily basis. CAI develops following multiple ankle sprains and gives the patient a feeling of instability, due to the ligaments and neural receptors within the ankle being damaged.[18] Delayed muscle reaction time and proprioception deficits at the ankle joint have been shown to be a factor in ankle instability.[19] Mechanoreceptors within the ligaments, joint capsules, and tendons present a feedback response of pressure, providing a sense of movement. Using the somatosensory, vestibular and sensory systems, the information is integrated into a control system, allowing for control over posture and coordination.[18] In order for balance to be maintained, sensory information is sent to the central nervous system with signals being relayed to the muscles of the trunk and lower extremities.[18] During an injury, the receptors are damaged, disrupting postural control within the ankle.[18]

One test that is sensitive detecting athletes with CAI among athletes is the Star Excursion Balance Test (SEBT).[9] The SEBT is a dynamic functional test, which has the patient reach out to maximum distance in eight directions (anterolateral, anterior, anteromedial, medial, posteromedial, posterior, posterolateral, and lateral), while standing on one leg.[18] This test challenges the postural control system as the body's center of mass is moved in relation to its base of support. This test is a useful clinical tool to measure the functional performance following injury.[9] Motte et.al[17] suggest that patients with side to side deficits or reach distances that were less than ninety-four percent of their limb length were up to 2.5 times more likely to sustain a lower extremity injury.[17] Among those with CAI, it was found that the subjects had a decreased reach in the SEBT on their involved leg compared to their uninvolved leg, with a decrease in the lateral direction when compared to the other seven directions. There was also a decrease in reach in the anterolateral, posterior and posteromedial directions, indicating a decrease in proprioception and postural control in those with CAI.[18]

Postural control is defined as the inability to maintain stability over a narrow base of support while in a single-stance position.[9,12] Postural control consists of dynamic tasks that require constant stabilization of the entire lower extremity throughout the whole exercise.[15] many subjective tests frequently test postural stability in periods of quiet and even surfaces, failing to elicit dynamic postural stabilization.[22] Time to stabilization is defined as the time required to minimize resultant ground reaction forces of a jump landing to within a range of the baseline.[22] Single-leg stabilization tests are challenging and closely mimic athletic performance by having the athlete land from a height.[22] Time to stabilization is an example of an objective postural control measure[22] and depends on proprioceptive feedback and preprogrammed muscle patterns in addition to reflexive and voluntary muscle responses.[22] It has been suggested that CAI is often associated with poor postural control, with patients showing functional deficits due to insufficiencies in proprioception.[5,14] Due to the damage to the feedback system, individuals with CAI land differently from a jump when compared to those with stable ankles. Single-leg jump-landing tests may challenge the postural control system and allow clinicians to identify unstable landing patterns when proper dependent measures are used for analysis.[19]

Lofvenberg et.al[13] suggests there is a delayed reaction time in patients with CAI due to damage to the neuromuscular control system. While standing on a trap door, subjects were asked to remain relaxed. One side of the trap door was released and EMG measured the amount of time it took for the peroneus longus and tibialis anterior to contract. It was found that the CAI group had a longer reaction time when compared to the control group.[13] This suggests that patients with CAI have a neuromuscular deficit which can lead to further injury.

Ross et.al[19] used time to stabilization testing to evaluate the stability of subjects with CAI after a single-leg landing. Researchers found that subjects with no previous history of ankle injury had a longer stabilization time when compared to those with CAI.[19] Wikstrom et.al[21] focused on the dynamic postural stability deficits found in those with ankle instability. They found there to be a significantly higher, or worse, dynamic postural stability in the anterior/posterior and vertical plane while completing a jump-landing protocol.[21] Due to the increased (worse) scores, this would suggest that those with ankle instability perform differently when compared to those with "stable" ankles.[21] This study also found there to be greater proximal preparatory muscle activity, suggesting a defense mechanism to help stabilize the already weakened ankle.[21] It is also noted that subjects with ankle instability land in a more dorsiflexed position, which braces the lateral ankle ligaments.[21] Using a jump-landing stabilization has been found to be clinically useful in in detecting differences between those with stable ankles and those without.

1.3 Core Stability and Postural Control

Core stability is the motor control and muscular capacity of the lumbo-pelvic complex, and is one of the factors related to lower extremity injuries.[9] The abdominal muscles, which include the rectus abdominus, transverse abdominus, internal obliques and external obliques, contract to add stabilization to the spine.[9] The paraspinals and gluteal muscles add posterior stabilization to the spine.[2] Prior to movement, contraction occurs, which allows the lower extremity to have a stable base for motion.[9] Normal function of the stabilizing system is to provide sufficient stability to the spine to match instantaneously varying demands due to the changes in spinal posture and static and dynamic loads, as well as maintaining equilibrium.[1,5] CAI subjects use proximal muscles, such as the gluteals, hip flexors, abdominals and erector spinae, to compensate their distal neuromuscular deficits. Subjects with a history of lower extremity injuries require greater trunk muscle recruitment to stabilize the body during dynamic tasks compared to healthy subjects.[1,5] It is suggested that core muscle function has a reported influence on structures in the low back to the ankle.[23] the knee and ankle movements depend on the hip moment to preserve the forward component of the acceleration of the center of mass during the jump task Willson et.al[23] suggests that patients with a history of ankle sprains and hypermobility have a delayed latency of activation of the ipsilateral glueteal muscle, creating a deficit.

A meta-analysis by Willson et.al[23] provided evidence that the core plays a vital role in the function of the lower extremities. It is suggested that the central nervous system creates a stable foundation for movement of the lower extremities through activation of the transverse abdominus and the multifidus.[23] During activity the transverse abdominus was the first muscle activated when preparing for movement.[23] One study found there to be a delayed onset of firing patterns in the ipsilateral and contralateral gluteus maximus in patients with chronic ankle instability due to fatigue of the muscle.[23]

The SEBT is sensitive to musculoskeletal impairments, such as CAI. Previous literature examined the effects of a 6-week core strengthening program, including bridges with leg lifts, lower trunk rotations, static abs on a stability ball, planks, bicycles, bridges with marching, trunk rotation with weights, bilateral straight leg raise, long arm crunches, and full vertical crunches, on SEBT. It was discovered that in the anteromedial direction, the experimental group's maximum distance significantly increased at posttest (89%) when compared to pretest (84.9%). In the medial direction, the experimental groups max distance at the posttest was 91%, significantly increasing from the pretest's max distance of 85.1%. In the posteromedial direction, it was observed that the experimental group's max distance was 92.5% at the posttest, while their pretest max distance was 85.5%. The recruiting of the abdominal muscles allowed for the lower extremity to have a stable base of support to help control postural stability.[9]

Ahmadi et.al[1] evaluated children with lower cardiovascular endurance, muscular strength and endurance, and balance, as well as decreased gross motor control. Subjects within the experimental group participated in an eight-week core strengthening program of abdominal crunches on a stability ball, back extension on a stability ball, hip raises on a stability ball and Russian twists. Overall, this core stability training had an improvement on the dynamic balance of mentally challenged children. Posttest scores showed a significant increase in reaching distance in all directions for the experimental group.[1]

Dastmanesh et.al[5] found that after 8 weeks of core training, subjects had an increased mean reaching distance when compared to the pretest. This suggested that while both groups improved, subjects with CAI had a lower postural control. Utilizing a core stability training program allowed for better activation of the core muscles, which in turn allowed for an increase in the feedforward mechanism (anticipatory impulses to prepare the body for movement) and improving neuromuscular control of the lower extremities.[5] Gage et.al[6] also found a correlation between core stability and postural control in college aged athletes. Following an 8-week training program, it was found that abdominal thickness increased in the healthy and CAI groups when compared to the control. Increased thickness or morphological changes are a sign of increased strength.[6] There was an increase in abdominal muscle, vastus medialis and peroneus longus activation during postural control in subjects with CAI, indicating and increase in neuromuscular efficiency was also observed.[6]

1.4 Statement of Purpose

Most sports are performed on a multiplane surface, with athletes adjusting their position in milliseconds in order to maintain their balance and perform efficiently. Athletes with CAI have been shown to have difficulty with landing and balancing, causing further injury. Very few studies have focused on core stability training and its beneficial effects on postural stability in athletes with chronic ankle instability.

1.5 Aims and Hypotheses

This study aims to understand the roles core stability plays in the balance of individuals who experience certain deficits.

Specific Aim 1: To assess the landing-stabilization times of recreationally active individuals with chronic ankle instability following a 6-week core stability program.

Hypothesis 1: It is hypothesized that individuals who complete the core program will have a decrease in landing times.

Specific Aim 2: To assess the reach distance of recreationally active individuals with chronic ankle instability by completing the Star Excursion Balance Test.

Hypothesis 2: It is hypothesized that those who complete the 6-week core program will have a higher reach distance when compared to those who do not.

Chapter 2

Manuscript

2.1 Abstract

Ankle injuries are one of the most common injuries in the athletic population because of the anatomy of the ankle in conjunction with dynamic activity. During injury, mechanoreceptors are damaged, effecting neuromuscular control. Lack of neuromuscular control puts patients at risk for re-injury. Chronic ankle instability (CAI) has been defined as a condition associated with recurrent sprains and persistent symptoms, including feelings of "giving way," loss of function and limited movement and continuous ankle pain. [11,12,14,17] Patients with CAI are commonly shown to have functional deficits in postural control, such as overcompensating on the uninvolved limb or unable to maintain proper balance.[7,8] Previous studies have shown the effects of a core program on the reach distance using a 3-point grid or using subjects with previous knee injuries. Other studies have shown deficits in landing using a drop landing test. Most sports are played on a dynamic plane, meaning the athlete is moving among multiple planes at once. A drop landing test assesses the dynamic balance of patients and can determine if they suffer from a deficit. Many do not focus on landing following a core stability program in conjunction with a balance test in patients with a history of ankle injuries. The aims of this study was to assess the landing-stabilization times and reach distance of recreationally active individuals with chronic ankle instability following a 6-week core stability program compared to those who do not complete the program. The outcomes matched with previous studies of improvement in reach distance, with a higher improvement in the experimental group, meaning that incorporating a core program

resulted in an improv. The outcomes also followed previous research suggesting that subjects with chronic ankle instability show an increased stabilization time. Subjects in the experimental group showed a decrease in their stabilization time. The information gathered in this thesis could benefit patients with a history of ankle injuries by decreasing their risk of re-injury when incorporating a core program into their rehabilitation.

2.2 Participants

Twenty-one subjects (16 female; 5 male; age=21.6± 3.23 years; mass=76.78 kg;) who suffer from chronic ankle instability were recruited for this study. Chronic ankle instability was defined as recurrent sprains and persistent symptoms, including feelings of "giving way," loss of function and limited movement and continuous ankle pain.[11,12,14,17] Inclusion criteria included subjects who were recreationally active, free from any head and lower extremity injuries other than ankle injuries in the past 6 months, a history of at least 1 ankle sprain that caused swelling, pain, and a temporary loss of function, a history of episodes of "giving way" in the past 6 months, and <90% on the Foot and Ankle Disability Index (FADI) and <75% on the FADI-Sport (Figures 1 and 2). Exclusion from this study included a history of lower extremity or head injury in the past six months, bilateral chronic ankle instability, previous lower extremity surgery and/or ankle fracture, and balance disorders, neuropathy, diabetes or any other condition known to affect postural stability. Prior to entering the study, subjects were asked to read and sign an institutionally approved consent form approved by Rowan University Institutional Review Board.

	No difficulty at all	Slight difficulty	Moderate difficulty	Extreme difficulty	Unable to do
1. Standing					
2. Walking on even ground					
3. Walking on even ground without shoes					
4. Walking up hills					
5. Walking down hills					
6. Going up stairs					
7. Going down stairs					
8. Walking on uneven ground					
9. Stepping up and down curves					
10. Squatting					
11. Sleeping					
12. Coming up to your toes					
13. Walking initially					
14. Walking 5 minutes or less					
15. Walking approximately 10 minutes					
16. Walking 15 minutes or greater					
17. Home responsibilities					
18. Activities of daily living					
19. Personal care					
20. Light to moderate work (standing, walking)					
21. Heavy work (push/pulling, climbing, carrying)					
22. Recreational activities					

	NO PAIN	MILD	MODERATE	SEVERE	UNBEARABLE
23. General level of pain					
24. Pain at rest					
25. Pain during your normal activity					
26. Pain first thing in the morning					

Figure 1. Foot and Ankle Disability Index (FADI)

	No difficulty at all	Slight difficulty	Moderate difficulty	Extreme difficulty	Unable to do
1. Running					
2. Jumping					
3. Landing					
4. Squatting and stopping quickly					
5. Cutting, lateral movements					
6. Low-impact activities					
7. Ability to perform activity with your normal technique					
8. Ability to participate in your desired sport as long as you would like					

Figure 2. Foot and Ankle Disability Index (FADI)-Sport

2.3 Instruments

AMTI force plates measured time it took for a subject to maintain their balance following a drop landing, measuring at 1000Hz. Data acquisition and analysis was performed on custom software made by LabView routines (National Instruments Corp., Austin, Texas, USA). Using four pieces of tape, an 8-point star was laid out on a flat, stable surface for the Star Excursion Balance Test.

2.4 Pre-Testing

Pilot testing was done prior to the start of the study to determine reliability of the tests. All tests were performed in the biomechanics lab of James Hall at Rowan University. Subjects were asked to report for a pre and posttest taking place 7 weeks apart from each other. Upon arrival, subjects were asked to remove their shoes and any items in their pockets. They were asked to stand in the middle of the force plate in order to be weighed.

2.4.1 Drop landing test. Familiarization trials were performed prior to testing in order for the subjects to understand what was being asked. They were allowed to perform the familiarization trial as many times as it took to fully understand what was being asked. Subjects were asked to stand on a two-foot box without shoes. Subjects took a step out and dropped from the box and landed on their uninvolved leg on to the AMTI force plates. Subjects held their balance for approximately 6 seconds. Three trial were performed on their uninvolved legs. Subjects were given a 30 second break in between each trial. Subjects then switched legs and performed the same test three more times on their involved leg (Figure 3).

Figure 3. Single Leg Drop Landing

2.4.2 Star excursion balance test. Following the landing test, subjects were asked to complete the star excursion balance test (Figure 4). Subjects stood in the middle of an 8-point grid on their uninvolved leg. Subjects then reached out in each direction using their foot (anterior, posterior, medial, lateral, anteromedial, anterolateral, posteromedial, and posterolasteral). Subjects were instructed to keep all pressure on their stabilized leg in the middle of the grid and reach out as far as they could in the direction asked by the examiner. Subjects were allowed to slightly bend their knee in order to reach maximum distance. Subjects held that position while the examiner measured from the distal 1st phalanx of the stabilized foot to the distal 1st phalanx of the reaching limb. Once all 8 directions were reached, subjects switched legs and performed the same task on their involved leg. Three trials for each leg were performed. subjects received a break as they were alternating legs in between each trial. Measurements were taken by the same examiner for each subject. Trials were discarded and repeated if the subjects were visually observed placing excessive weight on their reaching limb, removed stance foot from starting position, lost balance, or abducted hips greater than 30 degrees. Subjects were then randomly assigned to the experimental group or the control group.

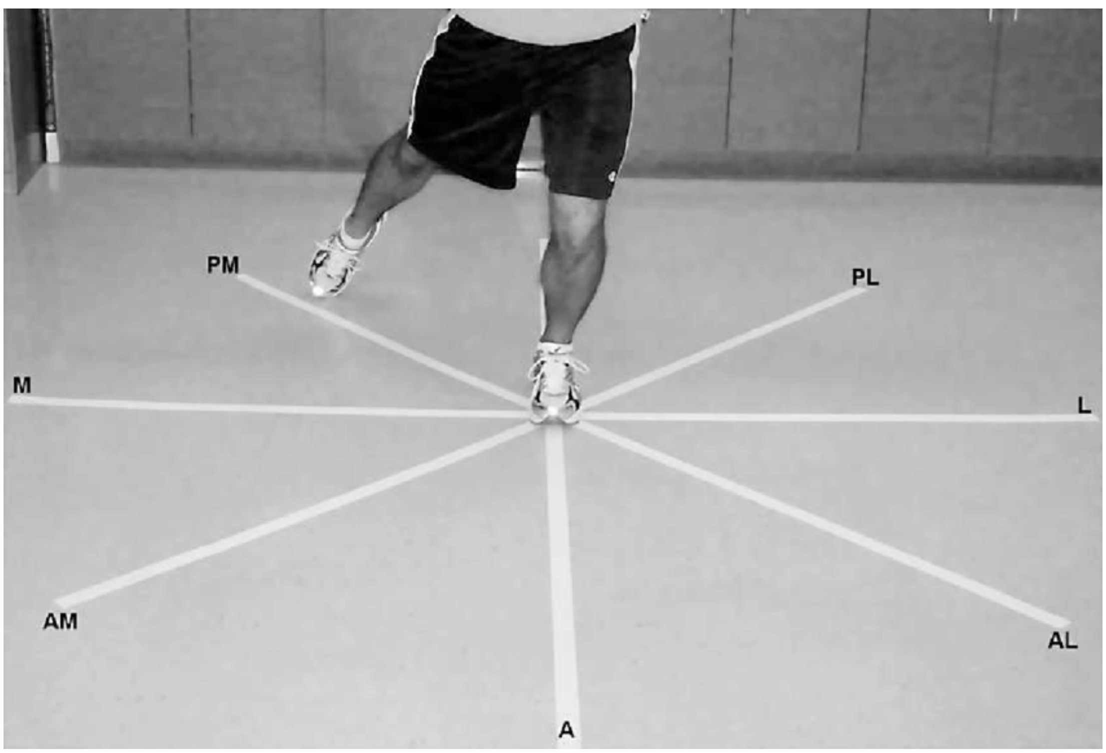

Figure 4. Star Excursion Balance Test

2.4.3 Experimental group. Subjects assigned to the experimental group were asked to complete a 6-week core strengthening program 30-45 minutes 2 times a week under the supervision of the examiner or athletic training student (Table 1). Each week, subjects were given a list of core exercises and asked to fill out an excel sheet with the days they performed the core program in order to assure all subjects were completing all programs. Subjects were taught pelvic neutral prior to the start of week 1 exercises and were asked to maintain that position throughout each exercise. Weeks 1 and 2 consisted of beginner level exercises. These exercises were performed in order to learn pelvic stabilization as well as beginning to activate the core muscles. Exercises included dead bugs, bird/dogs, clam shells, and fire hydrants. All exercises activated the entire lumbo-pelvic-hip complex. Weeks 3 and 4 progressed to moderate level of exercises. Harder exercises were added to the regimen, including Russian twists, hip bridging, and stability ball exercises. Therabands, weights, and increased reps were also added to increase difficulty. Weeks 5 and 6 consisted of advanced level exercises, including stability ball pike ups, V-ups, and side planks with rotation. In order to make sure subjects were staying on schedule, they were asked to report the days they completed their exercises in an excel sheet monitored by the examiner. Subjects were asked to avoid any extra activity that would cause injury and avoid any further core specific training.

Table 1

Core Stability Program

Week	Exercises/Reps
1	• Dead Bugs 3x10 • Bird/Dogs 3x10 • Clam Shells 3x10 • Crunches on a stability ball 3x10 • Fire Hydrants with Theraband 3x10 • Crunches 3x10 • Double Leg Hip Bridges 3x10
2	• Monster Walks—4 lengths of the hall • Planks 4x30 seconds • Double leg hip bridge 3x10 • Russian Twists 3x15 • Crunches 3x12 • Supermans on a Stability Ball 3x10 • Bird/Dog Elbow to Knee 3x10
3	• Russian Twists 3x25 • Plank with Arms on Stability Ball 4x30 seconds • North, South, East, West on Stability Ball 3x4 rotations • Single leg hip bridge 3x10 • Supine leg extension 3x10 • Bird/Dogs elbow to knee 3x15 • Russian Twists 3x25
4	• Planks with feet on stability ball 4x30 seconds • Mountain climbers 3x30-45 seconds • North, South, East, West on Stability Ball 3x5 rotations • Double Leg Hip Bridges on Stability Ball 3x10 • Suitcases 3x10 • Supine leg extension 3x15 • Crunch with a twist 3x15
5	• Single leg hip bridge on stability ball 3x10 • Suitcases 3x10 • Burpees 4x30 seconds • Sit-ups 3x15 • Mountain climbers 3x60 seconds • V-Ups with medicine ball 3x10 • Plank walk-outs 3x30 seconds
6	• Weighted windshield wipers 3x10 • Dumbbell sit-ups 3x10 • Stability ball pike ups 3x10 • Burpees 4x1 minute • V-Ups with medicine ball 3x15 • Scissor kicks with ankle weight 3x15 • Side plank with rotation 5x30 seconds • Plank on medicine ball 5x30 seconds

2.4.4 Control group. The control group was asked to maintain the same level of activity they performed prior to the start of the experiment.

2.5 Post-Testing

20 subjects returned 7 weeks following the pre-test. One subject was unable to return for post testing after sustaining an injury that made her unable to perform any of the post testing. The results from the injured subject's pre-test were not used in the data analysis.

Each subject stood in the middle of the force plate to be weighed. then they dropped from a 2-foot box on to their uninjured leg and held their balance for approximately 6 seconds. This test was completed three times, with a 30 second break in between each trial. Subjects then performed the same drop landing task on their injured leg. Following the drop landing test, subjects completed the SEBT, beginning with their uninjured leg. Three trials were completed, with subjects alternating between uninjured and injured leg. Reach distance was measured by the same examiner each time. Total means and standard deviations were calculated by the examiner comparing pre- and post test results between the control and experimental group (Table 2).

Table 2

Total Means

Control	Drop Landing (seconds)		SEBT (cm)	
	Uninvolved	Involved	Uninvolved	Involved
Pre	1.16±0.39	1.37±0.78	70.77±14.42	68.17±15.12
Post	1.34±0.39	1.55±0.41	76.04±16.72	73.98±17.36
Experimental	Drop Landing		SEBT	
	Uninvolved	Involved	Uninvolved	Involved
Pre	1.59±0.5	1.58±0.49	69.32±12.99	68.11±12.86
Post	1.23±0.58	1.14±0.48	83.48±14.71	85.61±13.5

2.6 Data Analysis

Stabilization time was calculated as the difference between initial landing time and timepoint of stabilization. Initial landing time was determined when vertical ground reaction force data was within 5% of body weight. AccuPower defines stabilization as maintaining within 5% body weight for 200ms. When the data was between 95% of body and actual body weight for 200ms (.2 seconds), stabilization was attained. To determine the length of time needed to attain stabilization, the difference of stabilization and initial landing time was taken.

2.7 Statistical Analysis

A one-way ANCOVA was conducted with a power of 0.05 to compare the effectiveness of a core stability program while controlling for individual pre-test scores. An ANCOVA was run to control baseline scores for each participant while reducing variance between each group (control v. intervention). Since both tests were reliable, the one-way ANCOVA allowed to better distinguish significant changes between groups during posttest.

2.8 Results

It was hypothesized that the experimental group would show an increase in reach distance for the SEBT and a decrease in stabilization time for the Drop Landing Test. While both groups proved the hypothesis, the experimental group showed a larger improvement.

2.8.1 Stabilization test. Following the 6-week core program, the experimental group had a decrease in stabilization time when compared to the control group. On the uninjured leg, the experimental group showed a landing time of 1.23±0.58 seconds on their uninjured leg compared to the 1.59±0.5 seconds they showed during the pretest (Figure 6). The control group exhibited an average landing time of 1.34±0.39 seconds posttest while they initially had a 1.16±0.39 second landing time on their uninjured leg (Figure 5). For the injured leg, the experimental group had a 1.14±0.48 seconds posttest stabilization time while they had a 1.58±0.49 second stabilization initially (Figure 6). The control group had a 1.55±0.41 seconds compared to their 1.37±0.78 seconds during the pre-test (Figure 5).

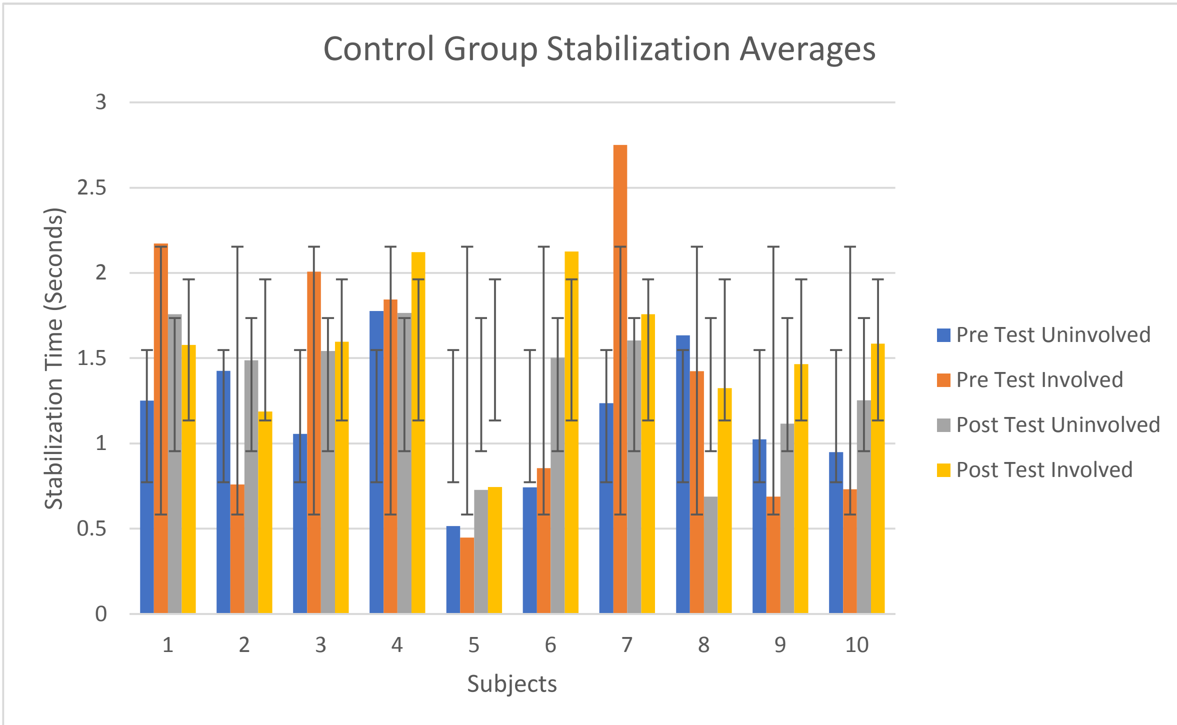

Figure 5. Control Group Stabilization Mean and Standard Deviation

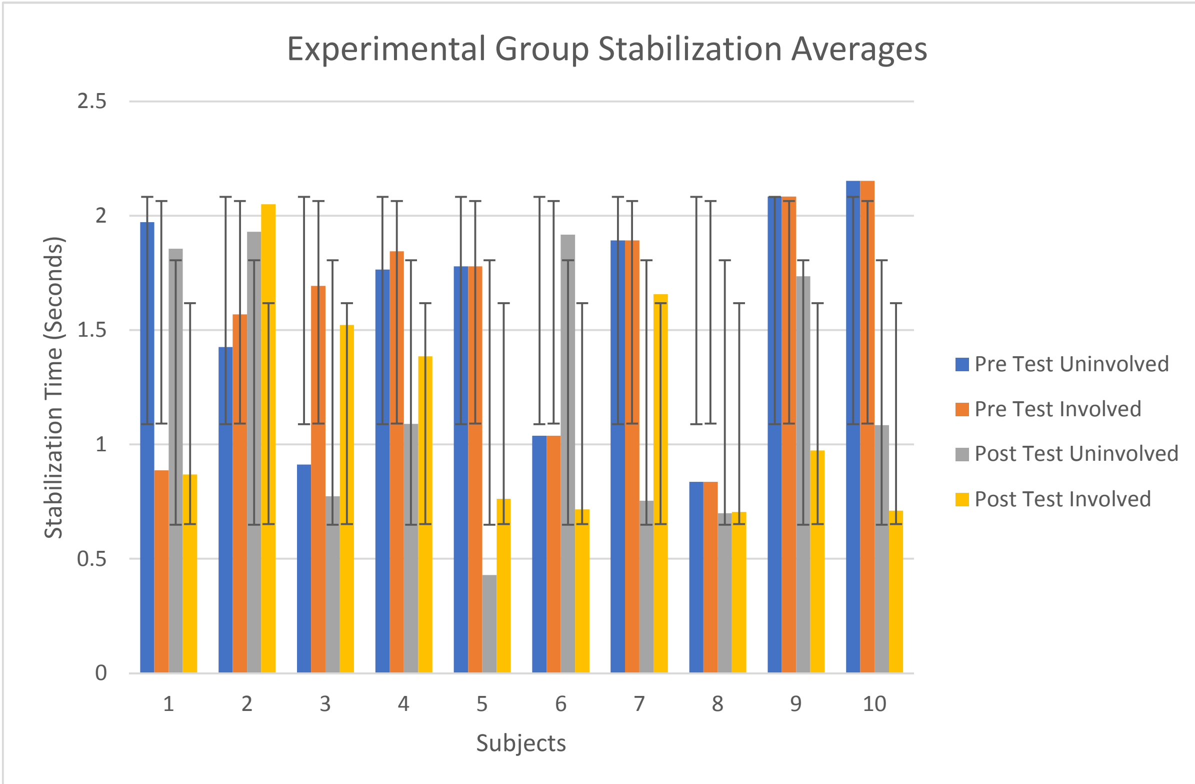

Figure 6. Experimental Group Stabilization Mean and Standard Deviation

There was a significant difference from pretest to posttest between the control group and the experimental group (F=5.629, p=0.0006) in the Drop Landing Stabilization Test (Table 3).

Table 3

Drop Landing Significance

F-Value	**5.629**
Significance	**0.0006**

2.8.2 Star excursion balance test. While both groups improved in the Star Excursion Balance Test, the experimental group was shown to have a larger increase in reach distance compared to the control group. As a whole, the experimental group went from 69.32±12.99 cm pre-test 83.48±14.71 cm posttest on their uninjured leg (Figure 8). The control group's posttest results were 70.77±14.42 cm on their uninjured leg compared to their 76.04±16.72 cm pre-test (Figure 7). For their injured leg, the experimental group's average reach distance in all directions was 85.61±13.5 cm posttest compared to their pretest reach distance of 68.11±12.86 cm (Figure 8). The control group went from 68.17±15.12 cm pre-test to 73.98±17.35cm post-test (Figure 7). The experimental group increased their reach distance by 17.5cm on their injured leg while the control group only increased by 5.82cm. It was found the largest improvement was in the directions of lateral, anteromedial, anterolateral and posterolateral.

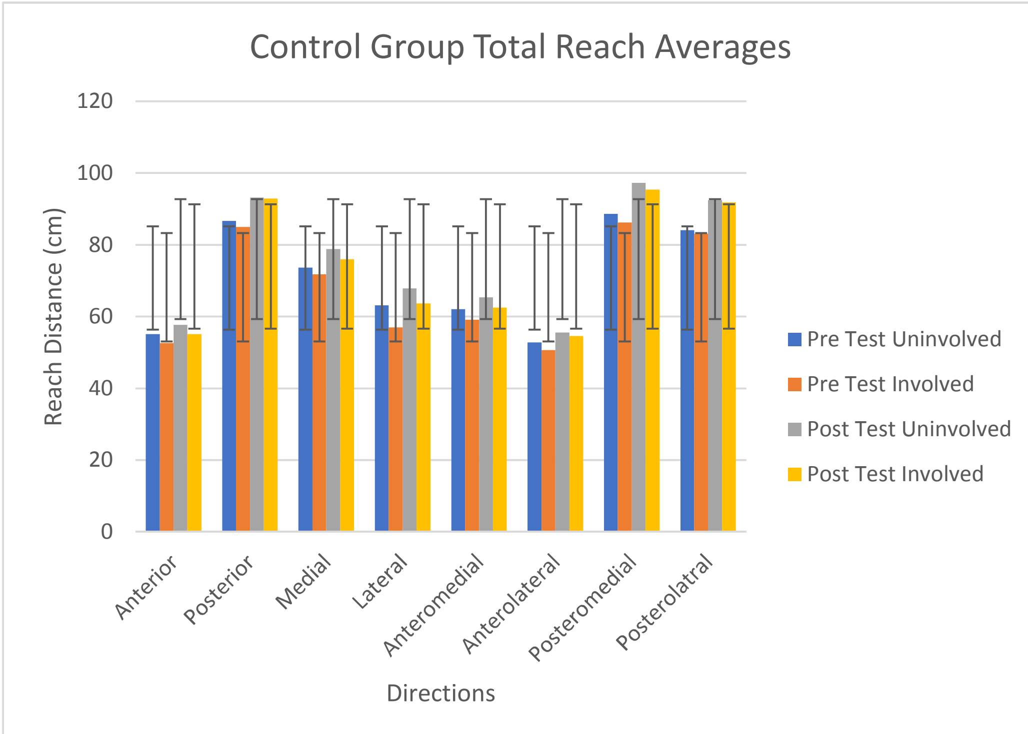

Figure 7. Control Group Total Reach Mean and Standard Deviation

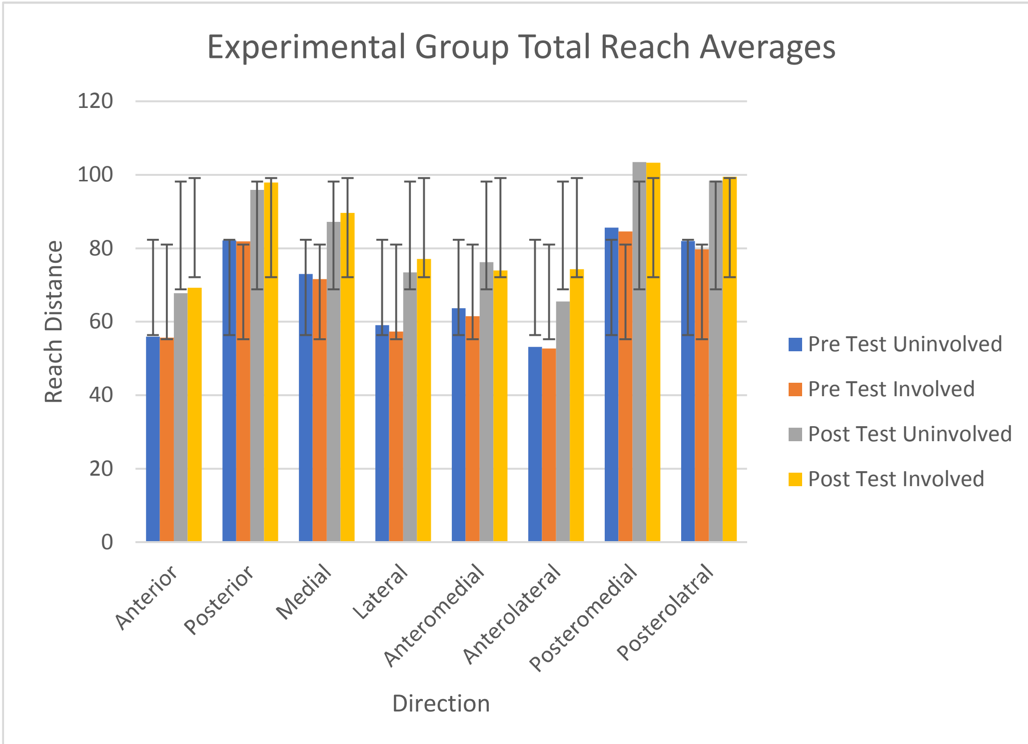

Figure 8. Experimental Group Total Reach Mean and Standard Deviation

There was a significant difference in the SEBT in the anterior (F=10.558, p=.005), medial (F=14.579, p=.001), and the lateral directions (F=14.385, p=.001). There was also a significance in the anteromedial (F=5.554, p=.031), anterolateral (F=5.890, p=.027), posteromedial (F=4.731, p=.044), and the posterolateral directions (F=13.476, p=.002). The only direction that did not show a significance was the posterior direction (F=2.495, p=.133) (Table 4).

Table 4

SEBT Significance

Directions	F-Value	Significance
Anterior	**10.558**	**.005**
Posterior	**2.495**	**.133**
Medial	**14.579**	**.001**
Lateral	**14.385**	**.001**
Anteromedial	**5.544**	**.031**
Anterolateral	**5.890**	**.027**
Posteromedial	**4.731**	**.044**
Posterolateral	**13.476**	**.002**

2.9 Discussions

The purpose of this study was to determine if a 6-week core program would have an impact on the landing stabilization, as well as the reach distance, in patients with chronic ankle instability. Our results found that subjects who completed the 6-week core program had a decrease in stabilization time while the control group had an increase in stabilization time. It was shown that there was a significance in pre and post data when comparing the control and experimental group. It was also found that while all subjects had an improvement in reach distance, the experimental group had a larger increase compared to the control group. There was significance between the control and experimental group in all directions but posteriorly.

Core stability should always be incorporated into any rehabilitation program because balance and coordination training are common components of intervention programs for the prevention of acute ankle sprains and CAI.[3] Ankle injuries account for up to forty-five percent of all injuries, with half of them progressing to chronic ankle instability.[7,8] Using the FADI and FADI Sport, Hale et.al[7] found subjects with CAI were sensitive to balance deficits and an increase in dysfunction following a six-week rehabilitation program. It was also discovered that the FADI Sport is more sensitive to deficits in young individuals who regularly participate in sport.[7] Using outcome measures, ankle injuries and performance can be measured subjectively and help to determine whether or not a patient is suffering from CAI. In order to determine if a potential subject had chronic ankle instability, they had to obtain a certain score in the FADI and FADI-Sport to participate in this study.

Using objective measures can help further suggest a patient's ankle instability. Hass et.al[11] and Omsted et.al[18] each discovered there to be relationship between ankle instability and a disruption in the feedforward/feedback mechanism as well as the supraspinal pathways. Decreasing neuromuscular efficiency caused an increase in proximal muscle activation. This activation made up for the loss of neural receptors in the ankle, allowing the patient to have an improved balance.[18] They found that these deficits will have negative consequences in the functional performance of patients with CAI.[18] Our study found that outcomes measures had a high sensitivity in those with chronic ankle instability. All subject who participated had a lower FADI score when compared to those who had a near perfect score.

Strength and range of motion demands are greater in those performing dynamic tasks such as the SEBTs compared with static tasks. Maintaining single-leg stance while performing maximum reach with the opposite leg requires the stance leg to have sufficient ankle, knee, and hip motion.[18] Subjects with CAI reported feelings of apprehension when performing reaches while balancing on their injured limbs. In a balance task during quiet standing, apprehension may be substantially less because a subject's limits of stability are rarely challenged.[18]

Previous research found an increase in balance test scores following six to eight-week core stability training. Gabe et.al[6] found there to be a decrease in muscle activation down the lower kinetic chain following an eight-week core training, indicating an increase in neuromuscular efficiency. This suggests training proximal muscles can help overcome the deficits in the lower extremities, such as instability and balance defects. Incorporating core training into any rehabilitation program can show positive results for athletes.

Our study was successful in suggesting that core training has an improvement of dynamic balance tests. Our subjects who completed the 6-week core program had a much larger improvement in the SEBT when compared to those who did not complete the training. There was also an improvement in landing times. Stabilization times for subjects in the experimental group showed a decrease in stabilization time when compared to the control group. This improvement will help decrease the likelihood of future ankle injury in those with a history of ankle instability.

There are thousands of athletes who experience their first ankle sprain every day. Almost half of those patients will eventually develop chronic ankle instability due to repetitive injury and extensive damage to the neurotransmitters in the ankle. While there are exercises used to help strengthen the muscles surrounding the ankle joint, strengthening the proximal muscles, such as the core, can ensure that the athlete does not experience any further damage. Providing additional core stability exercises to an ankle rehabilitation program can help ensure that athletes do not continue to feel “unstable” and decrease the likelihood of reinjuring the ankle.

Chapter 3

Conclusions

Ankle injuries are one of the most common injuries seen in the athletic population. Our findings suggest that subjects with chronic ankle instability have significant deficits in balance and stability. Even with proper rehabilitation, patients are at risk for re-injury due to damaged mechanoreceptors and weak musculature surrounding the joint. Integrating a core stability program into a normal ankle rehabilitation can have a beneficial impact on dynamic stability. By training the proximal musculature to activate, the lower extremities will be protected from injury. The findings from this study can benefit clinicians in the treatment of their patients with chronic ankle instability and prevent future re-injury. The dynamic performance of athletes will improve and they will safely be allowed to participate in their sport without the risk for injury.

3.1 Limitations

Like many studies, there were limitations. There was difficulty in recruiting subjects. A lot of potential subjects were willing to participate until they were informed of what they would have to do. They felt like a 6-week core program was a lot of work and could not guarantee they would be able to complete it and return on time for post testing. Many potential subjects did not meet all of the inclusion criteria, limiting the amount of subjects in the study. Many subjects recruited were female, with only 4 males participating in the study. Since subjects were randomly assigned to each group, there was not an equal male to female ratio in each of the groups, which could affect the validity of the experiment. Also, subjects were allowed to continue their everyday activities, leading to potential injury. Many subjects participated in club sports at the university and were not able to leave their club. Once injured, subjects had to be dropped from the study. Limiting what subjects can and cannot do can help decrease the risk for possible injury.

The frequency of the core workout was also a limitation. The core program asked subjects to complete two days of workouts each week. Three to four days a week was the intended range of workouts. Due to the availability of the subjects as well as the observers of this study, two days a week was the maximum that people could complete. Since two workouts a week were the maximum, the diversity of workouts for the core program had to be limited to include the most important workouts we wanted the subjects to complete. Adding in one or two more days could show an increase in performance in the experimental group due to the increase in core strength and stability.

3.2 Future Work

Our results can show presumption about improvements in core stability training in conjunction with balance. While there was improvement among all of the groups, every subject in this study suffered from chronic ankle instability. We cannot conclude how these results would compare to subjects that do not suffer from chronic ankle instability. This study can benefit healthy subjects by improving their dynamic stability and reduce their risk for first time injury. Future studies can show the outcomes of healthy subjects and progress to outcomes between healthy and injured subjects.

We are also unaware how these results would compare to subjects suffering from knee or hip pathologies. Subjects with ACL reconstruction could benefit from a core stability program to help protect their surgical knee and prevent instability during return to play progression. It is important in the future how this information could improve the performance of all individuals who may suffer from other pathologies.

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Appendix

Core Stability Program Exercise Descriptions

- Learn pelvic neutral
    - Lay on your back
    - Arch your low back as far as you can
    - Tilt forward as far as you can
    - Determine what is the middle of both
    - Maintain pelvic neutral throughout all exercises
- Dead Bugs
    - Start on your back with arms in the air and knees bent in the air
    - Slowly lower opposite arm and leg as close to the floor as possible
    - Focus on keeping other arm and leg in starting position
    - Bring back to starting position and repeat on opposite arm and leg
- Bird Dogs
    - Begin in a quadruped position (On hands and knees)
    - Raise opposite arm and leg out straight
    - Bring back to starting position and repeat on opposite arm and leg
- Clam Shells
    - Place a theraband above knees
    - Lay sidelined with knees bent and heels touching
    - Slowly separate knees while keeping heels touching
    - Hold 3 seconds and return to starting position
- Crunches on stability ball
    - Lay on a stability ball with the ball at the center of your back
    - Hand behind head
    - Slowly crunch up and hold for 3 seconds
    - Return to starting position
- Fire Hydrants
    - Begin in a quadruped position (On hands and knees) with a theraband above your knees
    - Slowly bring one knee out to the side and hold for three seconds
- Crunches
    - Lay on back with knees in the air and hands behind your head
    - Crunch up and hold for 3 seconds
    - Return to starting position and repeat
- Double leg hip bridges
    - Start on back with knees bent
    - Bring your hips up and hold for 3 seconds
    - Lower hips and repeat
- Monster walks
    - Place a theraband above knees
    - Bend knees and keep back straight
    - Side shuffle slowly down the hall

- Planks
    - Start in a push up position and hold for 30 seconds

- Supermans on stability ball
    - Lay face down on a stability ball
    - Roll out so your legs are straight
    - Raise your arms and arch your back
    - Hold for 3 seconds
- Bird/Dog--elbow to knee
    - Go through bird/dog as explained before
    - When returning to starting position, bring your elbows to your knees
- Russian Twists
    - Start in a crunch position as explained before
    - Twist side to side at your core while trying to tap both hands to the floor next to you
- Plank with arms on stability ball
    - Start in a plank position with elbows on a stability ball
    - Hold for 30 seconds
- North, South, East, West on stability ball
    - Start in a plank position with elbows on a stability ball
    - While holding the plank position, move elbows/stability ball up, down, left, and right
        - Hit each direction 1 time=1 rotation
- Single leg hip bridge
    - Start on back with knees bent
    - Raise one leg off of the ground
    - Bring your hips up and hold for 3 seconds
    - Lower hips and repeat
- Supine Leg Extension
    - Start on your back
    - Bend knees with feet in the air
    - Slowly extend one leg out until it is straight
    - Hold for 3 seconds and return to starting position
- Plank with feet on stability ball
    - Start in a plank position with feet on the stability ball
    - Hold for 30 seconds
- Mountain climbers
    - Begin in a push-up position
    - Bring one knee to your chest and return it back to start position
- Double leg bridge on stability ball
    - Start on back with knees bent and feet on a stability ball
    - Bring your hips up and hold for 3 seconds
    - Lower hips and repeat
- Suitcases
    - Start on your back with legs straight
    - While keeping legs straight, crunch up until hands and feet are touching

- Crunch with a twist
    - Start in a crunch position
    - Crunch up, hold and twist slowly
    - Return to starting position and repeat with the opposite side
- Single Leg bridge on stability ball
    - Start on back with knees bent on a stability ball
    - Raise one leg off of the stability ball
    - Bring your hips up and hold for 3 seconds
    - Lower hips and repeat
- Burpees
    - Start standing
    - Squat down, kick your feet out, bring them back to your chest, and jump
        - Do not have to do a push up
- V-ups with medicine ball
    - Lay on your back
    - Hold a medicine ball
    - Bring the medicine ball to your feet
    - Bring medicine ball back to starting position
- Plank Walk outs
    - Start in a plank position
    - Walk your hands to your feet and back to starting position
- Weighted Windshield Wipers
    - Hold dumbbells in the air
    - Lay on your back with legs straight in the air
    - Rotate legs side to side, as close to the floor as possible without touching the floor
- Dumbbell sit ups
    - Hold a 8-10 pound dumbbell while performing a sit up
- Stability Ball Pike Ups
    - Start in a push up position with feet on a stability ball
    - Bring stability ball to your chest
    - Return to starting position
- Scissor Kicks with ankle weight
    - Place ankle weight around your ankles
    - Start on your back with legs out straight
    - Bring legs 6 inches off of the ground and kick quickly for 30 seconds