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THE EFFECTS OF ANKLE POSITIONAL STRENGTH
TRAINING ON STRENGTH AND PASSIVE JOINT POSITION
SENSE

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DANA GABRIELLE CORTESE

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THE EFFECTS OF ANKLE POSITIONAL STRENGTH TRAINING ON STRENGTH AND PASSIVE JOINT POSITION SENSE

By

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ABSTRACT

THE EFFECTS OF ANKLE POSITIONAL STRENGTH TRAINING ON STRENGTH AND PASSIVE JOINT POSITION SENSE

By

Dana Gabrielle Cortese

Objective: To compare positional strength training and traditional strength training techniques on the ankle joint, assessing changes in muscular strength and passive joint position sense (PJPS). **Subjects:** Seventeen healthy, physically active college students participated in the study. Subjects were randomly assigned to one of two groups, positional strength training (5 females, 4 males) and traditional strength training (5 females, 3 males). **Measurements:** Pre-test and posttest isokinetic strength and PJPS measures were acquired using an isokinetic dynamometer. Plantar flexion/dorsiflexion and inversion/eversion strength were measured at 30°/s and 180°/s. Plantar flexion PJPS was assessed at three target angles 20°, 30°, and 40°. Inversion PJPS was assessed at three target angles 5°, 10°, and 20°. **Results:** No significant interaction was found between strength training group and time for isokinetic strength. A significant main effect for plantar flexion, inversion, and eversion strength was revealed for all subjects regardless of training group. No significant interaction between strength training group and time was discovered for PJPS. **Conclusions:** Positional strength training did not result in greater improvement in ankle strength and passive joint position sense in comparison to traditional strength training. The positional and traditional training groups exhibited comparable strength gains and passive joint position sense measures.

I would like to dedicate this Master's Thesis to my family and let them know that I have finally found my way home. Thank you for your love and support.
I believe in myself...because you believe in me.

If you wake up with the sunrise, and all your dreams are still as new
And happiness is what you need so bad
The answer lies with you

Led Zeppelin

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In addition, I would also like to thank all of the subjects who volunteered to participate in my research. Thank you for your time and dedication each week to complete the strength training. Your efforts and competitive spirits made my research enjoyable and a success.

To my fellow graduates, I would like to say thank you for your support and assistance; being together has really helped me to endure. Thank you for always lending and ear and being an excellent audience.

I would also like to thank my family and friends for your encouragement and your faith in me. Thank you for your love and unwavering support. I love you!

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INTRODUCTION

Lateral ankle sprains are injuries that plague the athletic population. Eighty-five percent of all ankle injuries occur to the lateral ligaments [1, 2]. Lateral ankle sprains occur through a forceful mechanism of supination. Supination is defined as the combination of inversion, plantar flexion, and adduction of the ankle. The injury most often occurs in jumping and running activities that require a combination of speed and agility, including dynamic movements of forward propulsion and rapid changes of direction [3, 4]. In addition, following initial incidence of a lateral ankle sprain, there is an 80% chance of reoccurrence of injury [5]. As a result, chronic ankle instability or CAI develops [6].

Post injury deficits are evident in both the static and dynamic structures about the ankle complex [3]. Current rehabilitation and prevention programs focus on a variety of components to restore or maintain functional ankle stability (FAS). The three main components involved in joint stability are degree of ligament laxity, muscle strength, and proprioception [2].

One method of rehabilitation that may aid in the restoration of FAS is ankle positional strength training. Ankle positional strength training is a method of strength training in which movement is initiated in the position of supination. Positional strength training places the subject at an angle of 40° of supination. The supination position is intended to help the subject recognize a potentially dangerous position of supination which may lead to a lateral ankle sprain and place the structures of the lateral ankle joint in a stretched position to influence ankle joint mechanoreceptors. Positional strength training requires the subject to move from a position of supination to a neutral position. The subject moves from a position where the lateral ankle structures are in a lengthened or stressed position to a position in which the lateral ankle structures are shorter or unstressed. The potential of positional strength training to influence muscle strength and ankle joint mechanoreceptors may lead to an increase in FAS.

Statement of the Problem

Strength training of the muscles that cross the ankle joint is a method used to develop support about the ankle joint. Some, current strength training protocols do not incorporate the full range of ankle motion [1]. If strength training to develop support of the ankle joint is conducted through a limited range of motion, the ankle joint and its surrounding structures, static and dynamic, may not be placed under sufficient stress to affect desirable changes. Safran et al. [7] recommend that strength training begin in a stress-free position of neutral/dorsiflexion and move to a stressful position of plantar flexion and inversion. The goal of positional strength training is to simulate the position of injury for lateral ankle sprains, placing the ankle in a starting position of supination (i.e., a combination of plantar flexion, inversion, and adduction) to potentially affect desirable strength and neuromuscular changes.

Statement of the Purpose

The purpose of this study is to compare positional strength training and traditional strength training techniques on the ankle joint, assessing changes in muscular strength and passive joint position sense.

Significance

The majority of traditional strength and proprioceptive training has been conducted within the mid-range of normal ankle motion. Positional strength training is performed through an increased range of motion, initiating training in the stressful position of supination. Positional strength training allows insight into the effects of placing a joint under increased stress. In addition, the results may provide information applicable to further rehabilitation or prevention programs for other joints of the body. Ankle strength training of the muscles that cross the ankle joint is warranted because it has demonstrated results of increased strength and joint position sense through training [1, 8, 9]. Deficits in strength and joint position sense may predispose an individual to injury.

Research Hypothesis

It is hypothesized that ankle positional strength training would result in greater improvements in ankle strength and ankle passive joint position sense as compared to traditional strength training.

Delimitations

1) Passive joint position sense testing for plantar flexion and inversion was performed at 4°/s, whereas the majority of ankle motions are many times faster and more dynamic.

2) Isokinetic strength testing for ankle plantar flexion/dorsiflexion and inversion/eversion was conducted at two test velocities, 30°/s and 180°/s, whereas dynamic physical activity occurs in multiple directions and with greater velocity.

Limitations

1) The starting and ending positions for each positional strength training repetition were identical; and, the path from start to end was variable between subjects.

Assumptions

1) Subjects performed strength testing and strength training with maximal effort.

2) The starting position of ankle positional strength training is the most important component of the exercise; placing the greater stress on the ankle joint in supination.

CHAPTER 2

Chapter 2

REVIEW OF LITERATURE

The Ankle Joint

To completely understand the common injury of lateral ankle sprains, comprehension of the ankle complex must be obtained. The ankle joint is comprised of three articulations: talocrural joint, subtalar joint, and distal tibiofibular joint [10]. These three joints work together to provide ankle rearfoot motion [10]. Rearfoot motion can be defined as triplanar motion, occurring in the sagittal, frontal, and transverse planes [10]. Motion that occurs in the sagittal plane is commonly referred to as dorsiflexion and plantar flexion. The motion in the frontal plane is referred to as inversion and eversion. Lastly, the motion that occurs in the transverse plane is referred to as adduction and abduction [10]. However, the motion of the rearfoot does not occur in isolated movement patterns. As stated early, the three joints work together to provide cumulative motions, also known as pronation and supination. Pronation can be defined as dorsiflexion, eversion, and abduction. Supination can be defined as plantar flexion, inversion, and adduction [10].

Talocrural Joint

It is important to examine each joint and its contribution to the ankle complex. The talocrural joint is often considered to be "the ankle joint" [11]. The talocrural joint primarily allows the motions of dorsiflexion and plantar flexion within the sagittal plane. During motion of the talocrural joint, accessory motion of the subtalar and tibiofibular joints are also observed about the oblique axis of the joint [10]. For example, in 30° of plantar flexion, 28° of motion occur in the sagittal plane (plantar flexion), 1° of transverse plane motion (adduction), and 4° of frontal plane motion occur (inversion) [10]. The triplanar motion demonstrated about the talocrural joint provides fluid motion and increased joint stability throughout motion [10].

In addition to the stability provided through osseous configuration, the ligaments that surround the talocrural joint also play an important role in maintaining joint stability [10, 12]. Three ligaments laterally support the talocrural joint: anterior talofibular ligament (ATFL), calcaneofibular ligament (CFL), and posterior talofibular ligament (PTFL) [10, 12]. The ATFL is an intra-capsular structure that is an average of 7.2 mm wide and 24.8 mm long [10]. As the ankle joint complex moves from a position of dorsiflexion to plantar flexion, the ATFL becomes taut [12]. The primary role of the ATFL is to prevent excessive anterior displacement of the talus from the talocrural joint and inversion and internal rotation of the talus on the tibia [10]. The ATFL is the most frequently injured ligament of the lateral complex [10]. The CFL is extra-articular and runs from the posterior inferior aspect of the lateral malleolus to the lateral aspect of the calcaneus [10]. Due to the position and angle of attachment of the CFL, it is most taut in the position of dorsiflexion [10]. The role of CFL is to prevent excessive supination that takes place at the talocrural and subtalar joints, aiding to restrict inversion and internal rotation of the rearfoot [10]. Lastly, the PTFL runs from the posterior lateral malleolus to the posterior lateral aspect of the talus [10]. The PTFL is taut only in extreme angles of dorsiflexion, and, because of this, it is the least injured lateral ligament of the ankle [12]. The primary role of the PTFL is to prevent both inversion and internal rotation of the talocrural joint [10].

Subtalar Joint

The subtalar joint allows for motion of pronation and supination. This joint is formed by the articulation between the talus and the calcaneus. The subtalar joint can be further divided into an anterior and a posterior joint separated by the sinus tarsi and canalis tarsi [10]. The anterior joint lies farther medial and has a higher center of rotation than the posterior joint. As a result, rotation about the oblique axis is altered [10]. Rotation about the subtalar oblique axis results in a 42° upward tilt and a 23° medial tilt, as compared to the perpendicular axis of the foot [10].

The support of the subtalar joint is provided by three groups of lateral ligaments: deep ligaments (cervical and interosseous), retinacula, and peripheral ligaments [10]. First, the deep ligaments cross through the canalis tarsi and are often referred to as the "crutiate ligaments" of the subtalar joint [10]. The cervical ligament primarily resists supination, while the interosseous ligament is taut throughout the motions of pronation and supination. Second, the inferior exterior retinacula (IER) supports the lateral aspect of the subtalar joint. Third, the peripheral ligaments of the subtalar joint are the CFL, lateral talocalcaneal ligament (LTCL), and fibulotalocalcaneal ligament (FTCL) [10]. The CFL, as previously stated, aids in restricting inversion and internal rotation of the calcaneus. The other two ligaments, LTCL and FTCL, both aid in preventing excessive supination [10].

Distal Tibiofibular Joint

The distal tibiofibular joint is a syndesmosis joint that is stabilized by the interosseous membrane and the anterior and posterior inferior tibiofibular ligaments [10]. The syndemosis joint is necessary to provide the structure of the talocrural joint, providing stability between the tibia and the fibula [10].

Mechanism of Injury

Lateral ankle sprains occur in a variety of athletic venues, especially soccer, basketball, and volleyball [4]. Ankle injuries most often result during forward propulsion, jumping, and/or cutting activities [4]. The mechanism of injury can be more specifically described as a sudden traumatic supination. As a consequence of traumatic supination, structures of the ankle complex are compromised and injury results.

Chronic Ankle Instability

Chronic ankle instability (CAI) occurs when an individual sustains recurrent ankle injuries. There are two main theories related to the cause of CAI, mechanical instability (MI) and functional instability (FI) [10]. Mechanical instability can be defined as ligament laxity or ligament elongation or rupture [14]. In addition to changes in ligament integrity, joint arthokinematics may be compromised and degenerative joint changes may occur [10]. FI as defined by Freeman is simply a "feeling of giving way" [14]. Further explanation was offered by Hertel et al. [10] who stated that FI was a result of impaired proprioception and sensation, impaired neuromuscular firing patterns, impaired postural control, and strength deficits. In the following section, the components of MI and FI will be examined in detail.

Mechanical Instability

One indicator MI is the extent of ligament damage that has occurred about the ankle complex [10]. The ligaments about the ankle joint serve three major functions: provide proprioceptive information for proper joint function, prevent excessive joint motion, and act as a guide to direct motion [12]. In addition, the ankle ligaments provide neurologic feedback that directly mediates reflex muscle stabilization about the joint [15].

In the presence of ligament laxity, ligament function is compromised and the ankle is predisposed to further injury [10].

Joint arthrokinematics may become compromised following a lateral ankle sprain [10]. As demonstrated by Bernier et al. [14], unstable ankles exhibited increased degrees of inversion just before heel strike during normal walking. In addition, Hertel [10] discovered instances of hypomobility in the talocrural joint which leads to a diminished range of dorsiflexion. As a result, the ankle will be able to invert and internally rotate more easily [10]. In subsequent research, altered arthrokinematics were also discovered in the posterior glide of the talus [10]. Both findings support the alteration of proper arthrokinamatics. Dorsiflexion requires an anterior roll of the talus accompanied by a posterior glide of the talus.

Functional Instability

The four major components that encompass FI are deficits in proprioception and sensation, diminished strength, impaired neuromuscular firing, and poor postural control.

Proprioception

The concept of proprioception can be defined as awareness of posture, movement, and changes in equilibrium, as well as, the knowledge of position, weight, and resistance to objects in relation to the body [16]. Proprioception encompasses the sensation of joint movement (kinesthesia) and joint position sense (JPS) [15]. Proprioceptive input is provided to the central nervous system (CNS) by mechanoreceptors found in the skin, muscles, joints, ligaments, and tendons. In addition, visual and vestibular centers also contribute afferent information to the CNS regarding body position and balance [15].

Mechanoreceptors

Muscle mechanoreceptors include muscle spindle afferent neurons that are able to detect muscle length and provide a unidirectional signal of joint movement [17]. Excitation of muscle afferents, through muscle vibration, results in sensations of joint movement and position [17]. Muscle spindles function to measure muscle stretch over a large range of muscle fiber length [15]. In addition, there are mechanoreceptors specific to muscle tendons, known as golgi tendon organs (GTO) [15]. The GTO serves as a protective mechanism recruited when muscle contraction forcefully pulls on the tendon [15].

Joint mechanoreceptors include both large, rapidly conducting axons, and small diameter afferents, with slow conducting axons [17]. The rapidly conducting afferents are also known as Group 2 afferents, of which there are two main groups - the Ruffini afferents and the Paciniform afferents [17]. The Ruffinin afferents are found mainly in the "flexion" side of the joint, the side of the joint that is stretched when the joint is extended [17]. Ruffini afferents are considered limit detectors, excited only during extreme extension rotations [17]. The Paciniform afferents are stimulated by pressure or compression and are activated by tensile loading of the surrounding joint capsule [17]. The slow conducting afferents are also known as the Group 3 and 4 afferents. These afferents appear to be related to pain rather than proprioception [17].

Joint Position Sense

JPS has been found to decrease following a trauma to the lateral ankle complex. Recent research has found a decrease in sensory input from joint receptors, leading to abnormal body positioning [15]. In addition, a 6-week strength training intervention conducted by Docherty et al. [1] revealed increased dorsiflexion and eversion strength and improved inversion and plantar flexion JPS. Results of the study indicated that deficits were present in both strength and JPS and that both components could be positively affected through strength training [1].

Strength

Conceptually, muscle strength is essential to maintain functional ankle stability. As discussed previously, the mechanism of injury for a lateral ankle sprain places the ankle joint in a compromised position of supination. The strength of the lateral ankle musculature, specifically the peroneus longus and brevus, allow the ankle to resist the supination movement, specifically guarding against inversion [10]. Tropp [18] supported this concept through experimentation on ankle eversion strength. The findings demonstrated a significant difference in muscle peak torque production for pronation between ankles with and without functional instability. The results indicating strength deficits are directly related to functional instability of the ankle [18]. Recent research disputes these findings by demonstrating no eversion strength deficits in the functionally unstable ankle [19-21].

Similarly, the strength of the dorsiflexors may play an important role in resisting the compromising position of plantar flexion. In ankles with a greater degree of plantar flexion and a smaller degree of dorsiflexion to plantar flexion ratio endured a higher incidence of lateral ankle sprains [11]. Furthermore, the anterior drawer test, utilized to determine ATFL laxity, demonstrated increased excursion with increasing degrees of plantar flexion [4]. The results of this study revealed increasing plantar flexion relates to decreasing joint stability. In addition, the results implicate that increasing angles of plantar flexion lead to decreasing joint stability.

Neuromuscular Control

Motor control of an extremity is dependent upon afferent sensory and proprioceptive mechanoreceptors, as well as, efferent reflexive and voluntary muscle responses [22]. Muscle response aids in neuromuscular control and is also a component of dynamic muscular support. Muscle latency can be defined as the time from onset of an inversion moment to the first motor response [4]. Current research has examined muscle latency, specifically of the peroneal musculature. The peroneus longus has been shown to react significantly later in unstable than in stable ankles [4]. Vaes et al. [13], conducted a study investigating muscle response to sudden ankle supination in unstable versus stable ankles. The results of the experiment revealed muscular response occurring at 40 degrees of supination in unstable ankles and at 32 degrees of supination in stable ankles [13]. Moreover, the latency of the peroneus longus and brevis musculature was found to increase with increasing angles of plantar flexion [13].

Postural Control

Postural control is the ability to maintain balance of the entire body during locomotion or perturbation [23]. Postural control is influenced by three components: visual input, vestibular input, and somatosensory input [6]. Balance can be achieved through two strategies, the ankle strategy and the hip strategy [6]. The ankle strategy is used in response to small, slow horizontal perturbations and the forces used to move the body's center of mass occur at the ankle [6]. The hip strategy is used in response to larger, faster perturbations and the forces used to move the center of mass occur at the hip [6]. Normal balance strategy consists of a combination of the ankle and hip strategies [6]. In the absence of normal postural control strategies, a fall or lateral ankle sprain may occur [23].

Rehabilitation

The main goal of a rehabilitation program is to restore function. In the beginning stages of rehabilitation of a lateral ankle sprain, the two main objectives are to regain range of motion and strength [7]. Strength training should begin in a position of relatively low stress and neutral dorsiflexion, and progress to a position of increased stress with inversion and plantar flexion [7]. Safran et al. [7]stated, "It is critical to train the athlete in this position as it is the position of injury.". The majority of strength training protocols that are implemented following lateral ankle sprains involve rubber tubing exercises executed within the mid range of available motion [8, 24]. In addition, free weight exercises of the ankle and calf raises are also used to promote ankle strength gains.

Once range of motion and strength begin to increase, proprioceptive training can be initiated [7]. Ankle disc training, BAPs board, is a common method of proprioceptive rehabilitation. The BAPs board can be utilized in a seated non-weight bearing position and then progressed from partial to full weight bearing [24]. The BAPs board, when performed in the weight bearing position, aids in re-establishing neuromuscular control [25].

Ultimately, in the progression to functional activity, exercise programs should move from open kinetic chain (OKC) exercises to closed kinetic chain exercises (CKC). In the CKC exercises, activity is conducted under the stress of body weight, which proves to be more closely related to functional demands placed on the ankle joint [21].

Benefits of Strength Training

If strengths deficits are not present in functionally unstable ankles, then, why implement strength training protocols in rehabilitation programs? This is a pertinent question that remains to be answered. What are the benefits gained by strength training musculature that crosses the ankle joint? In a study conducted by Docherty et al [1], it was determined that strength training can alter motor recruitment, resulting in selective activation of antagonist muscles, and their motor units, and antagonist coactivation. Furthermore, recent findings suggest that strength training can play a dual role of increasing both strength and joint position sense [1]. In addition, Blackburn et al. [8] demonstrated that proprioception and muscular strength contribute to balance and joint stability in similar manners. The results of their intervention demonstrated that enhancement of proprioception and strength are equally effective in promoting joint stability and the reciprocal maintenance of balance [8].

CHAPTER 3

Chapter 3

METHODS

Subjects

Seventeen healthy and physically active college students (10 females, 7 males, mean age = 24.2 years, mean height = 170.03 cm, mean weight = 72.5 kg) volunteered to participate as subjects. All subjects signed a consent form approved by Michigan State University Institutional Review Board. Subjects were excluded form participation if they had suffered a recent head injury, presented with vestibular deficits, or suffered a lower limb injury within the last year.

Instrumentation

An isokinetic dynamometer (Biodex Inc., Shirley, NY) was utilized to measure strength in the directions of ankle plantar flexion/dorsiflexion and ankle inversion/eversion. The isokinetic dynamometer was also used to evaluate passive joint position sense (PJPS) for the motions of ankle plantar flexion and ankle inversion.

Defined Variables

Peak Torque – Maximum torque production during one set of isokinetic strength testing, measured in Newtons (N).

Average Peak Torque – Calculated average of individual peak torques produced during the three sets of ten repetitions

isokinetic strength testing, measured in Newtons (N).

EV 30°/s – Average eversion peak torque (N) at 30°/s

INV 30°/s – Average inversion peak torque (N) at 30°/s

EV 180°/s – Average eversion peak torque (N) at 180°/s

INV 180°/s – Average inversion peak torque (N) at 180°/s

PF 30°/s – Average plantar flexion peak torque (N) at 30°/s

DF 30°/s – Average dorsiflexion peak torque (N) at 30°/s

PF 180°/s – Average plantar flexion peak torque (N) at 180°/s

DF 180°/s - Average dorsiflexion peak torque (N) at 180°/s

Degrees of Relative Error – Used as a measure of joint position sense, calculated as angle from the designated target angle, measured in degrees.

Materials

A leg/ankle exerciser (Elgin Exercise Equipment Corp., Lombard, IL) was used for ankle positional strength training and ankle traditional strength training (Appendix A). Athletic tape was used to designate the exercise starting and stopping positions. Plate weights were utilized for the strength training progression.

Protocol

A 4-week strength training intervention program was conducted. Subjects were randomly assigned to one of two strength training groups, positional and traditional training. The positional training group consisted of 9 subjects (5 females, 4 males). The traditional training group consisted of 8 subjects (5 females, 3 males).

The subjects read and signed the consent form prior to participation (Appendix B). During the initial training session, an instructional lesson was implemented; the tutorial included instructions regarding proper foot positioning and fastening and exercise range of motion (initial ankle positioning and final ankle positioning) (Appendix C). In addition, prior to participation each subject performed a pre-test to develop a baseline strength and PJPS measure.

All strength training was conducted for the dominant ankle of each subject. Leg dominance was determined by which leg the subjects prefer to kick a ball. Each subject began the exercise seated on an adjustable treatment table with the knee at 90° of flexion and the foot secured to the footplate. The subject's bare foot was secured to the plate to avoid accessory motion. The foot was positioned posterior on the footplate with the calcaneous in the heel cup. Then it was secured with two straps, one across the metatarsal heads and one across the tarsal metatarsal joints (Appendix D).

Once in the proper position, the subject commenced strength training. The subject was instructed to move from the designated starting position to the end position, completing four sets of six repetitions. A one-minute rest period was provided between each set.

Positional Strength Training

Ankle positional strength training was conducted in a position of supination (plantar flexion, inversion, and adduction). Ankle strength training began with the subject positioned in 40° of supination. The subject was then instructed to move the ankle from supination out to a neutral positioning (Appendix E). The resistance was provided with plate weights positioned on the front weight plate of the leg/ankle exerciser. The subject performed four sets of six repetitions, three sessions per week.

Traditional Strength Training

Ankle traditional strengthening was conducted through the motions of plantar flexion/dorsiflexion. Strengthening began with the foot in plantar flexion and move to a position of dorsiflexion (Appendix E). The resistance was provided with plate weights positioned on the front weight plate of the leg/ankle exerciser. The subject performed four sets of six repetitions, three sessions per week.

Weight Training Progression

Weight training was conducted based on 1 RM measures. One RM was determined through multiple-RM testing. Multiple-RM testing was utilized because the strength training involved one joint and did not include large muscle areas, minimizing the possible effects of fatigue [26]. Multiple-RM testing was determined based on 10 RM. Each subject conducted sets of 10 repetitions, increasing the weight after each set. Subjects were given a 30 second rest period in between each set. Weight increase commenced when the subject was no longer able to obtain the full 10 repetitions. The last weight at which the subject was able to complete the full set was determined to be the 10 RM. Once the 10 RM was established, a conversion chart developed by the National Strength and Conditioning Association was utilized to determine the 1RM [26]. Strength training began at 85% of 1RM. Weight progression was based on the 2-for-2 rule; 2 additional repetitions performed during 2 consecutive training sessions [26]. Weight increase was conducted in increments of 2.5 lbs.

Isokinetic Strength Testing

Strength testing was conducted on the isokinetic dynamometer. The subject's dominant ankle was used for the strength assessment. Inversion/eversion and plantar flexion/dorsiflexion movement patterns were assessed for peak torque and average peak torque production (Appendix F). Isokinetic tests were performed at 30° and 180° per second. Three trials, each consisting of 10 repetitions, were conducted at both test velocities. The subjects were given 10 seconds rest in between trials and one minute rest was provided between the two test velocities. Subjects were encouraged to demonstrate their maximum strength throughout all trials and repetitions.

Passive Joint Position Sense

Plantar flexion testing began with the subject's ankle in a neutral position, with the shank of the lower extremity perpendicular to the metatarsals. Three target angles were used to test joint position sense, 20°, 30°, and 40° of plantar flexion. Inversion testing was conducted with the subject's ankle in a neutral position, no inversion/eversion of the ankle joint. Three target angles were used to test joint position sense, 5°, 10°, and 20° of inversion. For each target angle, the subjects were passively moved towards the target angle at 2° per second. The subject was held at the target position for 10 seconds and then returned to starting position. The subject remained in the neutral position for 10 seconds and then passive motion was initiated at 4° per second. Subjects were instructed to hit a stop button when they perceived the target angle. Each subject was tested three times for joint position sense for each target angle. The testing order for target angles was randomized for each subject. During the trials, the subject was blindfolded to eliminate visual input and the air conditioner was turned on to cause an audible distraction. In addition, instructions emphasized that the subjects should feel the target position and avoid timing the motion or counting throughout the passive motion (Appendix G).

Statistical Analysis

All statistical analyses were performed with SPSS 10.0 (SPSS Inc., Chicago, IL) statistical software package. The independent variable was strength training group, positional strength training or traditional strength training. The dependent variables were isokinetic strength and PJPS. A two way repeated measures ANOVA was used to determine interaction between training group and time for isokinetic strength and PJPS.

CHAPTER 4

Chapter 4

RESULTS

Passive Joint Position Sense Results

The results of the two way repeated measures ANOVA revealed no significant interaction between time and training group for inversion passive joint position sense at 5 degrees, (Positional PRE = 2.9259, POST = 3.4815; Traditional PRE = 2.7917, POST = 2.7083; $P = .494$) 10 degrees, (Positional PRE = 1.4815, POST = 3.2593; Traditional PRE = 1.5000, POST = 1.5000; $P = .237$) or 20 degrees, (Positional PRE = 2.8519, POST = 2.8889; Traditional PRE = 1.7500, POST = 1.1250; $P = .638$) (Figure 1). The descriptive information is depicted in Table 1. Furthermore, the results of the two way repeated measures ANOVA demonstrated no significant main effect for inversion passive joint position sense between pre-test and post-test.

The results of the two way repeated measures analysis of variance revealed no significant interaction between time and training group for plantar flexion passive joint position sense at 20 degrees (Positional PRE = -2.0370, POST = .8148; Traditional PRE = -1.9167, POST = -2.1250; $P = .062$), 30 degrees (Positional PRE = -3.5556, POST = -1.4074; Traditional PRE = -4.3750, POST = -3.7083; $P = .540$), or 40 degrees of plantar flexion (Positional PRE = .4444, POST = 2.8889; Traditional PRE = -.5833, POST = -.5833; $P = .216$) (Figure 2). However, the PJPS testing approaches significance at the 20 degrees of plantar flexion at the $P = .05$. The descriptive information is depicted in Table 2. In addition, the results of the two way repeated measures ANOVA found no significant main effect for plantar flexion passive joint position sense between pre-test and posttest measures.

Figure 1 **Means (± 1 SD) for Inversion Passive Joint Position Sense Target Angles 5 Degrees, 10 Degrees, 20 Degrees. (n = 17).** (P = .05).

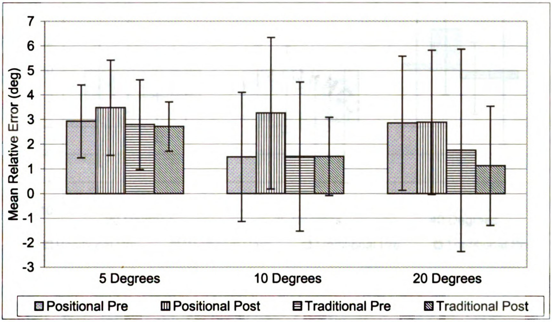

Table 1 **Descriptive Table for the Means of the Interaction of Training Group and Time on Inversion Passive Joint Position Sense**

	Positional		Traditional	
Measure (units)	**Pre (SD)**	**Post (SD)**	**Pre (SD)**	**Post (SD)**
5 Degrees	2.9259° (1.4793)	3.4815° (1.9373)	2.7917° (1.8252)	2.7083° (0.999)
10 Degrees	1.4815° (2.62)	3.2593° (3.0767)	1.5000° (3.0237)	1.5000° (1.5836)
20 Degrees	2.8519° (2.7239)	2.8889° (2.9297)	1.7500° (4.1125)	1.1250° (2.4165)

Figure 2 **Means (± 1 SD) for Plantar Flexion Passive Joint Position Sense Target Angles 20 Degrees, 30 Degrees, 40 Degrees. (n = 17).** (P = .05).

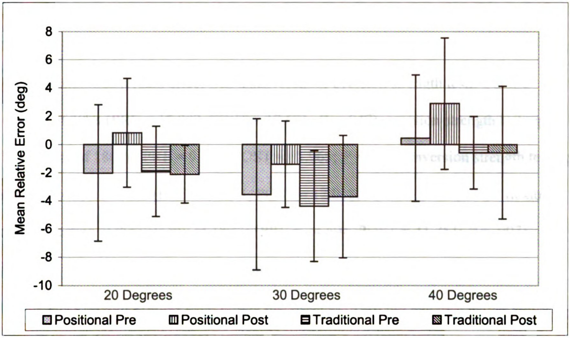

Table 2 **Descriptive Table for the Means of the Interaction of Training Group and Time on Plantar Flexion Passive Joint Position Sense**

Measure (units)	Positional Pre (SD)	Positional Post (SD)	Traditional Pre (SD)	Traditional Post (SD)
20 Degrees	-2.037° (4.8404)	0.8148° (3.8446)	-1.9167° (3.2059)	-2.125° (2.0388)
30 Degrees	-3.5556° (5.3671)	-1.4074° (3.0631)	-4.375° (3.9378)	-3.7083° (4.3441)
40 Degrees	0.4444° (4.4659)	2.8889° (4.6518)	-0.5833° (2.5681)	-0.5833° (4.6997)

Isokinetic Strength Results

The results of the repeated measures ANOVA demonstrated no significant interaction between time and training group for isokinetic strength testing (Figure 3, 4). The descriptive information is shown in Table 3.

A significant main effect was discovered for eversion strength testing at the velocity of 30°/s (PRE = 15.882, POST = 17.671; $P = .047$), eversion strength testing at the velocity of 180°/s (PRE = 9.224, POST = 11.965; $P = .000$), inversion strength testing at the velocity of 180°/s (PRE = 10.041, POST = 12.018; $P = .011$), and plantar flexion strength testing at the velocity of 180°/s (PRE = 24.694, POST = 31.753; $P = .007$) (Figure 5, 6). The descriptive information is shown in Table 4.

The eversion average peak torque increased between pre and post across entire subject population. In addition, inversion average peak torque increased between pre and post testing across entire subject population. Lastly, plantar flexion average peak torque increased between pre-test and post-test across the entire subject population.

Figure 3 **Means ($\pm$ 1 SD) for Eversion/Inversion Isokinetic Peak Torque Variables EV 30°/s, INV 30°/s, EV 180°/s, INV 180°/s. (n = 17).** (P = .05).

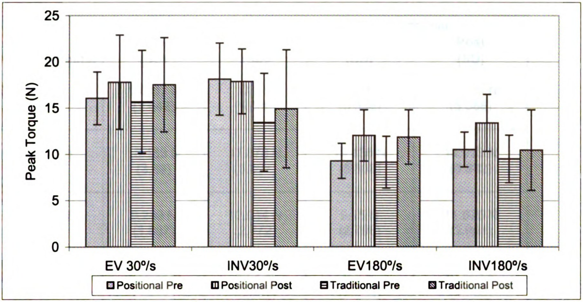

Figure 4 **Means ($\pm$ 1 SD) for Plantar Flexion/Dorsiflexion Isokinetic Peak Torque Variables PF 30°/s, DF 30°/s, PF 180°/s, DF 180°/s. (n = 17).** (P = .05).

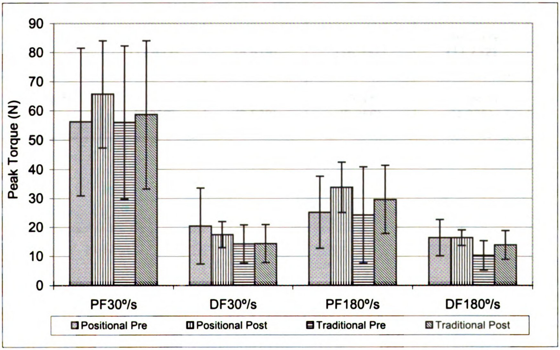

Table 3 **Descriptive Table for the Means of the Training Group and Time for Isokinetic Strength**

Measure (units)	Positional Pre (SD)	Positional Post (SD)	Traditional Pre (SD)	Traditional Post (SD)
EV30°/s (N)	16.067 N (2.842)	17.8 N (5.088)	15.675 N (5.558)	17.525 N (5.088)
INV30°/s (N)	18.133 N (3.89)	17.878 N (3.497)	13.438 N (5.308)	14.913 N (6.382)
EV180°/s (N)	9.289 N (1.897)	12.044 N (2.772)	9.15 N (2.796)	11.875 N (2.941)
INV180°/s (N)	10.522 N (1.877)	13.4 N (3.081)	9.5 N (2.568)	10.463 N (4.358)
PF30°/s (N)	56.233 N (25.278)	65.667 N (18.355)	56.037 N (26.264)	58.65 N (25.381)
DF30°/s (N)	20.411 N (13.099)	17.433 N (4.498)	14.225 N (6.359)	14.35 N (6.524)
PF180°/s (N)	25.133 N (12.411)	33.733 N (8.619)	24.2 N (16.552)	29.525 N (11.732)
DF180°/s (N)	16.389 N (6.239)	16.356 N (2.688)	10.3 N (5.056)	13.888 N (4.935)

Figure 5 **Means (± 1 SD) for the Main Effect Eversion/Inversion Isokinetic Peak Torque Variables EV 30°/s, INV 30°/s, EV 180°/s, INV 180°/s. (n = 17).** (*P<.05).

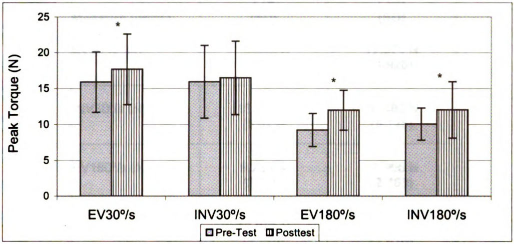

Figure 6 **Means (± 1 SD) for the Main Effect Plantar Flexion/Dorsiflexion Isokinetic Peak Torque variables EV 30°/s, INV 30°/s, EV 180°/s, INV 180°/s. (n = 17).** (*P<.05).

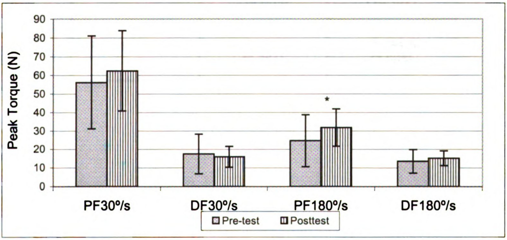

Table 4 **Descriptive Table for the Means of the Main Effect of Time on Strength Variables**

Measure (units)	Pre (SD)	Post (SD)
EV30°/s (N)	15.882 N (4.195)	17.671 N (4.928)
INV30°/s (N)	15.924 N (5.073)	16.482 N (5.125)
EV180°/s (N)	9.224 N (2.286)	11.965 N (2.763)
INV180°/s (N)	10.041 N (2.219)	12.018 N (3.916)
PF30°/s (N)	56.141 N (24.925)	62.365 N (21.525)
DF30°/s (N)	17.500 N (10.706)	15.982 N (5.591)
PF180°/s (N)	24.694 N (14.039)	31.753 N (10.102)
DF180°/s (N)	13.524 N (6.361)	15.194 N (3.985)

CHAPTER 5

Chapter 5

DISCUSSION

The results of this study support the null hypothesis. Positional strength training did not result in greater improvement in ankle strength and passive joint position sense. The positional and traditional training groups exhibited comparable strength gains and passive joint position sense measures.

Passive Joint Position Sense

The study revealed no significant interaction between strength training group and time for passive joint position sense. The positional and the traditional training groups did not differ in degrees of relative error post testing.

In contrast, research conducted by Elis et al. [9] demonstrated an increase in plantar flexion and dorsiflexion PJPS following a six-week rehabilitation program. This program consisted of a combination of 12 different strength and proprioceptive exercises. This disparity in PJPS results may be due to the instrumentation used in testing. This study utilized a custom built device, consisting of a footplate and a Penny & Giles goniometer [9]. The passive movement was controlled manually, allowing for variable speeds during testing. This subject provided a verbal cue to stop passive movement when they felt replication of the testing position, relying on reaction of the practitioner to cease passive movement. In the current study, the isokinetic dynamometer was used for PJPS testing, which provided a more direct measure of PJPS. The speed of passive movement was regulated and a trigger given to the subject stopped passive movement.

A relationship between strength training and joint position sense was also identified by Docherty et al. [1], demonstrating improved inversion and plantar flexion JPS following a six-week ankle strength training protocol. Strength training was conducted with Thera-band tubing in the directions of inversion, eversion, plantar flexion, and dorsiflexion. The results of the current study may differ from those of Docherty et al. [1] because a different component of joint position sense was measured. Docherty et al. [1] examined active joint repositioning as opposed to passive joint repositioning. The mechanoreceptors stimulated during active movement are different from those stimulated during passive joint movement. Active movement stimulates pacinian corpusles, which are considered the pure dynamic mechanoreceptors due to their reaction to joint acceleration and deceleration [27]. Passive movement at a slow angular velocity is thought to stimulate Ruffini endings and GTO mechanoreceptors [15]. Ruffini ending signal static joint position and GTO respond to increase in tension [15].

Joint mechanoreceptors also play a role in joint position sense. Joint mechanoreceptors are responsible for responding to extremes in range of motion [1]. In the current study, the positional strength training protocol positioned subjects in 40° of supination and the passive joint position sense testing was conducted in plantar flexion at a maximum angle of 40° and inversion at a maximum angle of 20°. Thus, even if positional strength training increased stimulation to the joint mechanoreceptors in training, the joint mechanoreceptors were not stimulated during testing. The discrepancy in training stimulation and testing stimulation may be the reason for no increase in passive joint position sense post positional strength training.

Based on the results obtained for passive joint position sense testing and the dynamic nature of positional strength training, perhaps a more functional assessment of joint position sense and proprioception would be warranted. A study conducted by

Blackburn et al. [8] examined the effects of strength, proprioception, and a combination of strength and proprioception training on balance. Strength training consisted of Thera-band, free weights, and calf raises. The results revealed individual strength and proprioception training, as well as combination training, were all equally effective in achieving balance improvement [8]. The improved balance achieved through strength training reveals an increase in overall proprioception. Proprioception can be defined as sensation of joint movement or kinesthesia and joint position sense [15]. In the current study, only one component of proprioception was evaluated. Hence, the efficacy of positional strength training may be better understood by examining overall ankle proprioception.

Proprioception is an important component in neuromuscular control, contributing to muscle reflex through alpha motor neuron activation and stimulation of the cortical pathway [15]. The muscle spindles respond to the alpha motor neurons producing postural tone and may lead to an increased response when a muscle is placed on a stretch, yielding dynamic joint stability [15, 28]. The positional strength training protocol placed the ankle joint in an increased degree of supination, resulting in increased stress to the lateral ankle structures. Therefore, the positional strength training may influence overall joint proprioception.

Isokinetic Strength

The study revealed no significant interaction between strength training group and time for isokinetic strength. A main effect was demonstrated for isokinetic strength in the directions of eversion, inversion, and plantar flexion.

The results of this experiment support the null hypothesis. The positional training group did not prove to have a greater impact on eversion strength, as compared to the traditional training group. The results produced in the positional training group may be due to the order of muscle recruitment. The complex movement pattern of pronation (dorsiflexion, eversion, and abduction) may be difficult for subjects to perform. Subjects recruit the larger, stronger tibialis anterior first and then recruit the smaller peroneal muscles to more easily execute the complex movement [29]. The results of increased eversion strength for the traditional training group may be equated to the action of the peroneals as dorsiflexors. The results imply the motion of dorsiflexion requires adequate peroneal activity.

The findings of increased strength are supported by Docherty et al. [1]. They identified increased eversion strength as a result of a six-week Thera-band strength training program. This result indicates an increase in strength of the peroneal musculature and possible subsequent increase in ankle stability. The peroneal muscles have the ability to alter stiffness of the ankle joint by providing increased muscle stiffness and greater muscle tone [30]. Hence, an increase in peroneal strength altars muscle tone and may lead to an increase in stability of the ankle joint [30]. Based on the effect of positional strength training on the ankle musculature, future research should examine the effects of positional strength training on joint stability.

The positional and traditional training groups both exhibited strength gains. The main effect present reveals that positional strength training is equally effective as traditional strength training. Positional strength training has proven to increase strength and may also have additional influence based on the method of training. Theoretically, the positional strength training method has a greater effect on the lateral ankle due to position of supination. The positional strength training places the lateral capsule, lateral ligaments, and articular tissue under stress. Pacinian corpuscles are present in these tissues and are sensitive to acceleration and deceleration movements [27]. The stimulation of these joint afferents may lead to increased awareness to joint movement, for example, during acceleration of the ankle joint into sudden supination. Increased awareness of joint acceleration may lead to increased muscle reaction to accelerating motion. Future research should consider examining positional strength training and its effect on reaction to a sudden supination movement or muscle latency. Vaes et al. [13] identified a difference in peroneal latency time between stable and unstable ankles. The latency was assessed based on response to sudden 50° of supination. The results verified a longer latency time for unstable ankles and faster acceleration during 50° of supination in the unstable ankles. The unstable ankles demonstrated a decrease in ability to control the speed of the injurious moment.

Clinical Implications

The goal of a rehabilitation program is to obtain functional stability. The purpose of this study was to compare positional and traditional ankle strength training, evaluating changes in ankle strength and PJPS. Results of positional strength training revealed an increase in strength and no significant change in PJPS as measured by degrees of relative error post training.

Positional strength training proves to be very applicable in a rehabilitation program. Positional strength training is time and cost efficient. The leg/ankle exerciser is a low cost training device that only requires plate weights to provide resistance. The simple machine is multi-axial allowing for all ranges of available motion, as well as movement restrictions if necessary post surgery. Normal movement patterns and sport activities are multi-axial. Hence, the multi-axial device permits an athlete to train functionally.

In a rehabilitation program aimed to return an injured athlete to competition, the athlete must be exposed to stress and perturbation that may be experienced during participation. Positional strength training is an introductory strengthening exercise that introduces the ankle to inversion stress experienced during lateral ankle sprains. As the athlete progresses to more functional and sport specific tasks, the same philosophy remains. Ultimately, the positional strength training follows the S.A.I.D principal of rehabilitation Specific Adaptations to Imposed Demands. Exposure to supination allows the ankle complex, including both static and dynamic structures to adapt to increased lateral stress about the ankle joint.

Overall, muscle weakness post lateral ankle sprain is a controversial issue. Research, conducted by Kaminski et al. [19], Lentell et al. [20], and McKnight et al. [21], demonstrates the absence of evertor muscle weakness post lateral ankle sprain or in the presence of functional ankle instability. Nevertheless, practitioners should continue to implement strength training exercises because of the potential strength gains and prospective influence on proprioception.

Considerations for Future Research

The current research attempted to examine two methods of strength training, comparing their effects on strength and passive joint position sense. Suggestions for future research are:

1) assessment of proprioception

2) assessment of muscle latency

APPENDICES

APPENDIX A

MATERIALS

MATERIALS

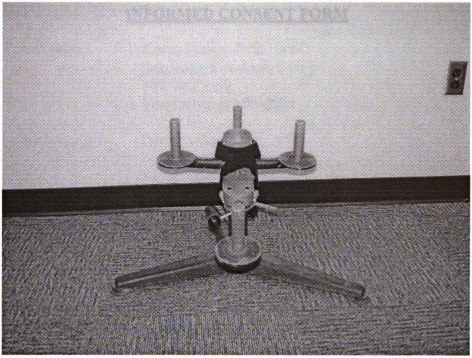

Figure 7 Leg/Ankle Exerciser

APPENDIX B

INFORMED CONSENT FORM

INFORMED CONSENT FORM FOR CLINICAL RESEARCH STUDY
Michigan State University

Title of Project: The Effects of Ankle Positional Strength Training on Strength and Passive Joint Position Sense.

Primary Investigator:	Kavin Tsang, Ph.D., ATC Department of Kinesiology 105 IM Circle East Lansing, MI 48824
Secondary Investigator:	Dana Cortese, B.S., ATC Department of Kinesiology 38 IM Circle East Lansing, MI 48824

This is to certify that I, ____________________, have been given the following information with respect to my participation as a volunteer in a program of investigation under the supervision of Dr. Kavin Tsang.

1. **Purpose of the study:** The purpose of this study is to compare positional strength training and traditional strength training techniques on the ankle; assessing changes in muscular strength and passive joint position sense.

2. **Procedures to be followed:**
   A. If you agree to take part in this research, you will be asked to complete a 4-week strength training program, positional or traditional strength training groups. In addition, pre and posttests will be conducted examining isokinetic strength and passive joint position sense.

   1) Positional Strength Training – Ankle positional training is conducted in a position of supination (plantar flexion, inversion, and adduction). Ankle strength training begins with the subject positioned in 40° of supination. The subject is then instructed to move the ankle from supination out to a neutral positioning. The resistance will be provided with plate weights positioned on the front weight plate of the leg/ankle exerciser. The subject will complete 4 sets of 6 repetitions.

   2) Traditional Strength Training - Ankle strengthening is conducted through the motions of plantar flexion/dorsiflexion. The subject will perform each motion in isolation. Strengthening through the motion of dorsiflexion will begin with the foot in plantar flexion and move to a neutral position. The resistance will be provided with plate weights positioned on the front weight plate of the leg/ankle exerciser. The subject will complete 4 sets of 6 repetitions.

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3) Weight Training Progression – Weight training is conducted based on 1 RM measures. One RM will be determined through multiple-RM testing. The subjects 10 RM will be established and converted to 1 RM using a table constructed by the National Strength and Conditioning Association. Once the 1 RM is determined, strength training will commence at 85% of the subject's 1RM. Weight progression will based on the 2-for-2 rule; 2 additional repetitions performed during 2 consecutive training sessions. Weight increase will be conducted in increments of 2.5 lbs.

4) Isokinetic Strength Testing – Strength testing will be conducted on the isokinetic dynamometer. The subject's dominant ankle will be used for the strength assessment. Plantar flexion/ dorsiflexion and inversion/ eversion movement patterns will be assessed for peak torque and average peak torque production. Isokinetic tests will be performed at 30° and 180° per second. Three trials, each consisting of 10 repetitions, will be conducted at both test velocities. The subjects will be given 10 seconds rest in between trials and one minute rest will be provided between the two test velocities.

5) Passive Joint Position Sense – Plantar flexion testing will begin with the subject's ankle in neutral, with the shank of the lower leg perpendicular to the metatarsals. Three target angles will be tested, 20°, 30°, and 40° of plantar flexion. Inversion testing will be conducted with the subject's ankle in neutral. Three target angles will be tested 5°, 10°, and 20° of inversion. Next, the subjects will be passively moved towards the target angle at 2° per second. The subject is held at the target position for 10 seconds and then returned to starting position. The subject remains in neutral for 10 seconds and then passive motion is initiated at 4° per second. The subject is instructed to hit the stop button when they perceive the target angle. Each angle was tested three times. During the trials, the subject will be blindfolded to eliminate visual input and the air conditioner will be turned on to cause an audible distraction. In addition, instructions emphasize to feel the position and avoid timing the motion or counting throughout the passive motion.

3. **Discomforts and risks:**

   a. An inherent risk of strength training is enduring muscle damage, specifically a muscle strain. However, positional strength training presents a minimal risk of injury due to the nature of the strengthening protocol. The amount of weight and the speed of training progression will be determined on an individual basis. In addition, explicit strength training instructions will be provided to all the participants.

   b. In the event of an injury, the secondary investigator will provide first aid treatment as well as a referral to EMS. The subject assumes all responsibility and any cost incurred due to participation will be at the expense of the subject.

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4. a. **Benefits to the subject:**
You will gain valuable knowledge regarding proper strength training technique.

b. **Potential benefits to society:**
The results will provide the Athletic Trainer with insight into the effects of ankle positional strength training. In addition, results will demonstrate the importance for continuing research in the area of positional training.

5. **Alternative procedures which could be utilized:**
No alternative to ankle positional strength training currently exists.

6. **Time duration of the procedures and study:**
Your participation in this experiment will include a 4-week training program. Three training sessions will be required each week, each session lasting approximately 10min.

7. **Statement of Confidentiality:**
Your participation in this research is confidential. Your privacy will be protected to the maximum extent allowable by law. Only the person in charge will have access to your identity and to information that can be associated with your identity. To make sure your participation is confidential, only a code number will appear on the data collection sheet. Only the researchers can match your name with your code.

8. **Right to ask questions:**
   A. You may ask any questions about the research procedures, and the secondary investigator will answer these questions. Further questions may be directed to Dr. Kavin Tsang, (517) 353-2010.

   B. If you have any questions or concerns regarding your rights as a study participant, or are dissatisfied at any time with any aspect of this study, you may contact – anonymously, if you wish – Peter Vasilenko, Ph.D., Chair of the University Committee on Research Involving Human Subjects (UCRIHS) by phone: (517) 355-2180, fax: (517) 432-4503, e-mail: ucrihs@msu.edu, or regular mail: 202 Olds Hall, East Lansing, MI 48824.

   C. Your participation is voluntary. You are free to stop participating at any time, or to decline to answer any specific questions without penalty.

I have been given the opportunity to ask any questions I may have and all such questions or inquiries have been answered to my satisfaction.

Subject Signature: ______________________________ Date:____________

APPENDIX C

INSTRUCTIONAL TUTORIAL

INSTRUCTIONAL TUTORIAL

1. Subject Position
    a. Seated upright
    b. Knee at 90 Degrees
    c. Barefoot secured to the footplate
2. Range of Motion
    a. Positional Training
        i. Starting position of supination obtained when tape marks are aligned
        ii. Ending position obtained when foot is parallel to the floor
        iii. Move from starting position to ending position by way of a "J" motion, a combination motion requiring simultaneous movement of the foot up and over (Demonstrate motion to the subject)
        iv. Subject instructed to replicate "J" motion
    b. Traditional Training
        i. Starting position of plantar flexion obtained when tape marks are aligned
        ii. Ending position obtained when foot is parallel to the floor
        iii. Move from starting to ending position by way of dorsiflexion and upward motion (Demonstrate motion to the subject)
        iv. Subject instructed to replicate dorsiflexion

APPENDIX D

STRENGTH TRAINING POSITION

STRENGTH TRAINING POSITION

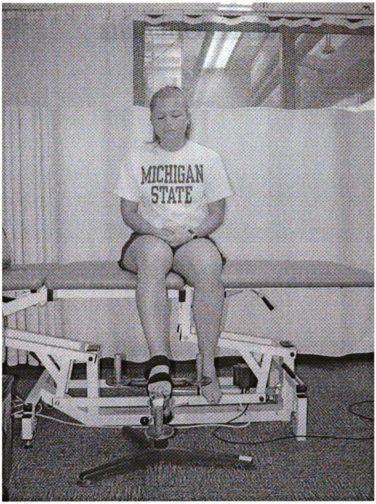


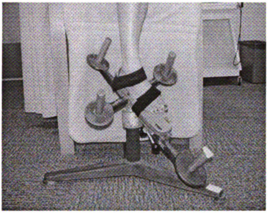
Figure 8 Subject Position

APPENDIX E

STRENGTH TRAINING

STRENGTH TRAINING

Positional Training



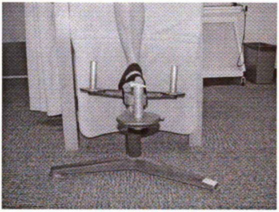
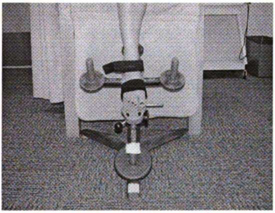


Figure 9 Starting Position **Figure 10** Ending Position

Traditional Training



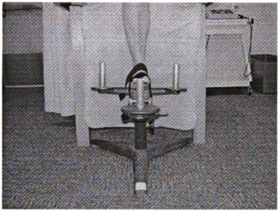


Figure 11 Starting Position **Figure 12** Ending Position

APPENDIX F

ISOKINETIC STRENGTH TESTING

ISOKINETIC STRENGTH TESTING

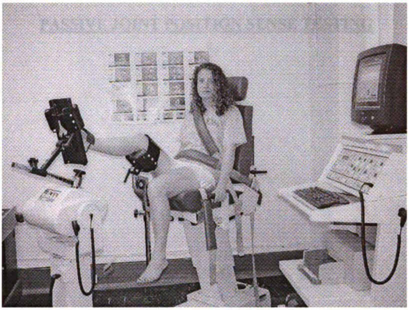


Figure 13 Inversion/Eversion Subject Position

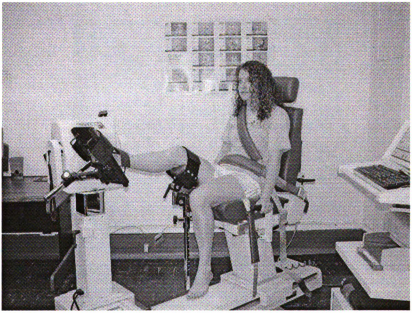


Figure 14 Plantar Flexion/Dorsiflexion Subject Position

APPENDIX G

PASSIVE JOINT POSITION SENSE TESTING

PASSIVE JOINT POSITION SENSE TESTING

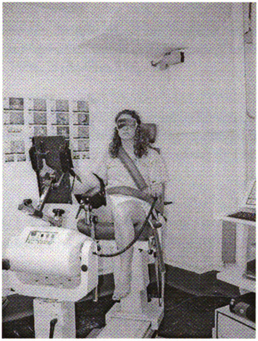


Figure 15 Inversion/Eversion Subject Position

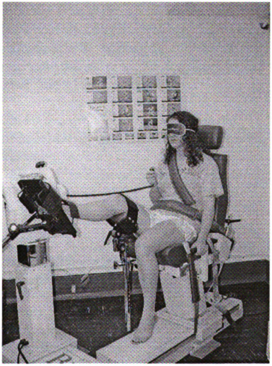


Figure 16 Plantar Flexion/Dorsiflexion Subject Position

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BIBLIOGRAPHY

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