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An Electromyographic Study of the Effects of Plyometric Training Shoes on the Lower Extremity

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AN ELECTROMYOGRAPHIC STUDY OF THE EFFECTS OF PLYOMETRIC TRAINING SHOES ON THE LOWER EXTREMITY

by

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This Independent Study, submitted by Brian T. Laumb in partial fulfillment of the requirements for the Degree of Master of Physical Therapy from the University of North Dakota, has been read by the Faculty Preceptor, Advisor, and Chairperson of Physical Therapy under whom the work has been done and is hereby approved.

Thomas Mohr
(Faculty Preceptor)

Thomas Mohr
(Graduate School Advisor)

Thomas Mohr
(Chairperson, Physical Therapy)

PERMISSION

Title	An Electromyographic Study of the Effects of Plyometric Training Shoes on the Lower Extremity
Department	Physical Therapy
Degree	Master of Physical Therapy

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ABSTRACT

Background and Purpose: Plyometric shoes have recently been introduced as an effective training tool to enhance several aspect of an athlete's ability, including vertical jump. The SkyFlex® system utilizes plyomteric training shoes in conjuction with plyometric exercises and drills to achieve maximum athletic performance. There is currently limited research to validate the manufacturer's claims of increasing vertical jump. The purpose of this study is twofold: 1)To describe muscle activity during walking and jumping while wearing traditional athletic shoes and plyometric training shoes. 2)To measure the vertical jump of subjects trained with plyometric training shoes and a control group of subjects trained with traditional athletic shoes.

Subjects/Methods: 1)Ten male subjects participated in lower extremity EMG analysis while walking and jumping with plyometric and traditional athletic shoes. The EMG data was analyzed for each muscle tested. 2)Thirty male subjects participated in a four week plyometric training program, one group training with plyometric and the other with traditional athletic shoes. Their vertical jump height was measured initially and then at the end of each week. A paired samples t-test and ANCOVA was used to analyze the data.

Results: 1)A significant increase in EMG activity was found in the anterior tibialis and the gastrocnemius during walking when wearing SkyFlex® shoes as compared

to traditional shoes. No significant increase was noted during vertical jump. 2)The SkyFlex® training group did not demonstrate a more significant increase in vertical jump height as compared to the traditional athletic shoe group ($p<.05$).

Conclusion: The SkyFlex® plyometric shoe is no more effective in increasing vertical jump height than traditional plyometric training programs.

Chapter One

Introduction

Plyometric shoes have recently been introduced as an effective training tool to enhance several aspect's of an athlete's ability, including vertical jump.[1] The SkyFlex® system utilizes plyometric training shoes in conjunction with plyometric exercises and drills to achieve maximum performance as demonstrated by "linking strength with speed of movement and reflexes to produce power." The company claims that training with their specially designed plyometric shoe can increase an athlete's vertical jump by up to six inches.

Problem Statement: Minimal published research exists documenting the results of training with a plyometric shoe to enhance vertical jump. In addition, no published research currently exists that documents the electromyographic activity of specified muscles during walking and jumping with plyometric training shoes.

The Purpose of this Study: 1) To describe muscle activity during walking and jumping while wearing traditional athletic shoes and plyometric training shoes. 2) To measure the vertical jump of subjects trained with plyometric training shoes and a control group of subjects trained with traditional athletic shoes.

Significance of Study: The results of this study will assist in determining the effectiveness of plyometric training shoes on enhancing lower extremity EMG activity and vertical jump. This will aid coaches and athletes in selecting the appropriate training tool and technique to enhance vertical jump in a maximal, yet safe manner.

Research Questions: 1) Will training with plyometric shoes significantly increase vertical jump height more than training with traditional athletic shoes? 2) Does the amount of EMG activity change while wearing the plyometric training shoe during walking and jumping as compared to wearing traditional athletic shoes? 3) Are there any risks associated with training with plyometric shoes?

Hypothesis: (Null Hypothesis) There is no significant difference in achieved vertical jump height between subjects trained with plyometric shoes and those trained with traditional athletic shoes. There is no significant difference in electromyographic activity during walking and jumping with plyometric shoes and traditional athletic shoes.

CHAPTER 2

LITERATURE REVIEW

"Plyometrics, when used in a dynamic training program have been shown to bridge an elusive gap between shear strength and explosive power, both of which are sought after by many of today's highly trained athlete's."[2] This statement, made over two decades ago is still undergoing study as there is conflicting evidence by researchers who suggest otherwise. Plyometric exercises were first introduced in Russia by Verhoshanski in 1966, where they were extensively developed and later introduced into Western countries around the mid 1970's.[3] Exercises often included in plyometric training regimens are box depth jumps for the lower extremity and drop push-up's and medicine ball technique's for the upper extremity.[3]

The plyometric basis for these exercises is the myotatic stretch reflex. This reflex is key for allowing a given muscle to reach it's maximum strength in the least amount of time possible.[4] Within a muscle there are two types of fibers, extrafusal and intrafusal. Extrafusal fibers contain contractile, relaxation, and elongation properties. These properties are controlled by the brain which sends nerve impulses leading to chemical reactions and finally muscle activation or relaxation. Intrafusal fibers (also known as muscle spindles) lie parallel to the extrafusal fibers and are the main stretch receptors of a muscle. Stretching of the intrafusal fibers, initiates the reflex, which results in an active contraction of the muscle.[4]

In order for a muscle to utilize this reflex, it must perform a rapid eccentric contraction, followed immediately by an explosive concentric contraction. If this cycle doesn't occur fast enough, heat may be given off as potential energy, thus decreasing the force of contraction.[5] Grieve et al[6] states, "The faster a muscle is allowed to shorten, the less tension it can exert. The faster a muscle is forced to lengthen the greater tension it exerts." This means that a quick rate of stretch will allow for maximum tension generation in the muscle.[6,7]

Researcher's studying the effects of plyometric exercise have published numerous conflicting articles about their effectiveness. Brown et al[8] studied vertical jump in high school basketball players and found that plyometric training did significantly improve the vertical jump. Significant improvement was also found by Steben and Steben[9] who trained subjects with plyometric exercises while measuring high jump and triple jump distances. Scoles[10] used an 8 week training program incorporating twice weekly depth jumping exercises and found no significant difference in vertical jump or long jump. Blatter and Noble[11] compared isokinetic and plyometric training and found no significant difference between them in increasing vertical jump height.

In an article by Wilson et al[12] eccentric and concentric force production was reported using plyometric exercise and weight training groups. Forty-one subjects were assigned to an 8 week training program as a control, plyometric, or weight training group member. Values were compared pre and post test to determine significant difference. In the lower extremity weight-training group, subjects showed a significant difference in one repetition squat maximum and vertical jump improvement. The plyometric training group showed a significant improvement in vertical jump as well as eccentric rate of force production. There was, however, no significant difference between the two training groups when the vertical jump was compared.

These conflicting results have sparked interest in research development for plyometric training with special shoes constructed to enhance athletic performance. These shoes were designed to create a rapid intermittent stretching of the gastrocnemius/soleus muscles while plyometric exercises are performed. The SkyFlex® and Strength® Shoe companies have each developed shoes, with claims of increasing vertical jump and sprinting speed when used simultaneously with plyometric exercises.[1,13]

Cook et al[3] studied college age male track and field athletes who trained with Strength® shoes for 8 weeks, 3 times per week. No significant statistical difference was found between the group who wore the plyometric training shoes and the control group when calf circumference, strength, flexibility, and vertical jump were measured. Flarity et al[13] also studied the effects of the Strength® shoe using 20 male college basketball, baseball, and track and field athletes. Subjects were randomly divided into two groups and exercised 3 times per week for 9 weeks using a progressively intensified training regimen. The results showed significant improvement in relative anaerobic power, relative aerobic capacity, vertical jump, and 40-yard dash times for the Strength® Shoe treatment group. These two conflicting studies are part of a limited research base of the plyometric training shoe. More research will need to be done to provide accurate knowledge pertaining to these shoes in order to validate there use.

In a study done by Bangerter,[14] contributive components of vertical jump were measured. This study had five groups, four experimental and one control. Group 1 exercised plantar flexors only. Group 2 exercised knee extensors only while in a seated position. Group 3 exercised hip extensors while being strapped face down on a table. Group 4 did all of the exercises performed by the previous three groups. Group 5, the control group did no exercise. Groups 1-4 exercised 3 times per week for 8 weeks lifting their 1 repetition maximum 8-12 times. Results showed that vertical jump increases in groups 2,3, and 4 were significantly greater than groups 1 and 5. There was no significant difference in vertical jump values between groups 1 and 5. Groups 2, 3, and 4 also showed no significant difference between themselves. Conclusions from this study were that training either knee extensors, hip extensors or the combination of the two contribute significantly to vertical jump, while plantar flexors contribute very little, if at all according to Bargerter. He goes on further to reason that the plantar flexors act only as positioners and resistors to forces elicited on them by other muscle groups.

A list of origin and insertions for the four muscles in review is shown in Table 1. Electromyographic (EMG) activity of specific muscles during human gait has been studied by many researchers. The normative data from these studies is used by researchers to determine recruitment patterns of specific muscles during individual gait cycles. The patterns during individual gait cycles are then compared quantitatively and/or qualitatively. Perry[15] has described normal activation patterns of muscles using EMG, which will be utilized as a guideline in this study (Figure 1).

Table 1. Origins, Insertions, and Actions of Selected Lower Extremity Muscles

MUSCLE	ORIGIN	INSERTION	ACTION
Vastus Lateralis	Linea aspera, greater trochanter	Tibial tuberosity	Knee extension
Anterior Tibialis	Upper 1/2 of the lateral tibia	Plantar surface of the 1st metatarsal and cuneiform	Dorsiflexion, Inversion
Peroneus Longus	Upper 2/3 of the lateral fibula	Dorsal surface of the 1st metatarsal and cuneiform	Plantarflexion, Eversion
Gastrocnemius	Femoral Condyles	Calcaneal tuberosity	Plantarflexion, Knee flexion

Tibialis Anterior: This muscle shows most of it's EMG activity between initial contact and loading response. By mid stance it is mostly silent until pre-swing when the ankle is dorsiflexing, it is active throughout the swing phase as it holds the foot in a dorsiflexed position and remains active into initial contact.

Gastrocnemius: This muscle is normally active at loading response with increasing activity observed through midstance and a peak amplitude displayed at terminal stance as the ankle prepares to actively plantarflex. No activity is noted just prior to pre-swing through terminal swing or initial contact.

Vastus Lateralis: This muscle in normally active at initial contact and peaks at loading response. Activity ceases during midstance and remains silent until terminal swing phase when the knee is extending, activity then continues on through initial contact.

Peroneus Longus: This muscle normally is active during midstance with activity peaking at terminal stance and tapers off as the ankle becomes more mobile just prior to pre-swing.

Review of the literature revealed no published research EMG data of the lower extremity on any of the available plyometric training shoes. As these shoes are becoming more widely used, research must be conducted to validate there use and test safety consideration associated with the intense plyometric training regimens that go along with the shoes.

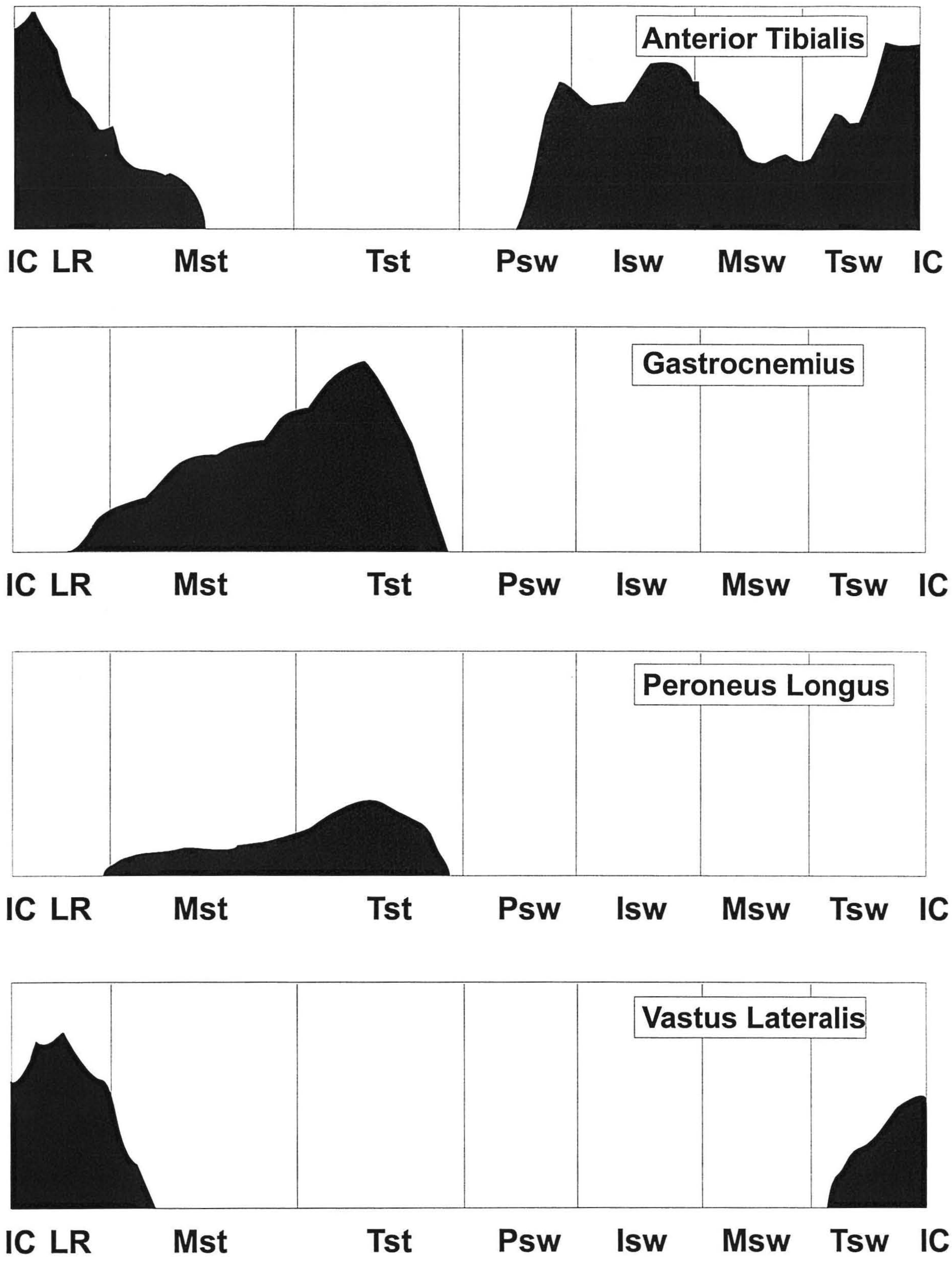


Figure 1. Average selected lower extremity muscle EMG activity during normal gait.

CHAPTER 3

METHODS

Part One: Electromyographic Analysis of the Effects of Plyometric Shoes on the Lower Extremity

Subjects

Ten healthy male subjects volunteered for this study. The subjects were between the ages of 21 and 25 (Table 2). All subjects completed a prescreening questionnaire (appendix) and lower extremity strength test prior to participation in the study. The questionnaire identified previous injuries or complications that would put them at risk or interfere with the results of the study. One subject reported chronic ankle instability and one subject reported a congenital tibial torsion gait, which eliminated them from participation in the study. The subjects were informed of the purpose of this study and their rights as human subjects. All subjects signed a consent form approved by the Institutional Review Board at the University of North Dakota and the Red River Valley Sports Institute (appendix).

Table 2. Subject Characteristics (n=10)

	AVERAGE	RANGE	STANDARD DEVIATION
Age (years)	23	21-25	1.41
Height (inches)	71	69-75.5	2.21
Weight (pounds)	165	137-188	18.06

Instrumentation

Shoes

SkyFlex® plyometric training shoes (Skyflex, PO Box 18387, Indianapolis, IN 46209) are modified low-cut shoes with a 2-1/2-inch extended Airlon Flexfit® sock liner and a one-inch thick platform that measures 7-1/4 x 6-1/2 inches. The platform is attached to the sole of the shoe therefore preventing the heel from striking the ground during training activities.[1] It was designed to increase the amount of stretch on the Achilles tendon before the heel touches the ground, thus enhancing the stretch reflex allowing muscles to reach maximal strength in the shortest amount of time possible.[3] This theoretically enhances the training of the gastrocnemius/soleus complex by increasing the amount of time the muscles are active. The extended sock liner was formulated to add support to the foot, warm the foot and Achilles muscles during activity, and make the heel of the foot fit more snugly into the shoe, all of which are claimed to decrease the chance of injury.

Electromyography

The electromyographic information was collected by a Noraxon Telemyo8 telemetry unit (Noraxon USA, 1340 North Scottsdale Rd., Scottsdale, AZ, 85254) which collected electromyographic data from the EMG electrodes (Multi Bio-Sensory, El Paso, TX, 79913), electrogoniometer (Penny & Giles Inc., 2716 Ocean Park Blvd., Santa Monica, CA), and foot switch (Noraxon USA, 13430 North Scottsdale Rd., Scottsdale, AZ 85254). The EMG signals were transmitted to a Noraxon Telemyo8 receiver and then digitized by a PCM-DAS16S/16-Analog to a digital interface board (Computer Boards, Inc., 16 Commerce Blvd., Middleboro, MA 02346) installed in a Noraxon

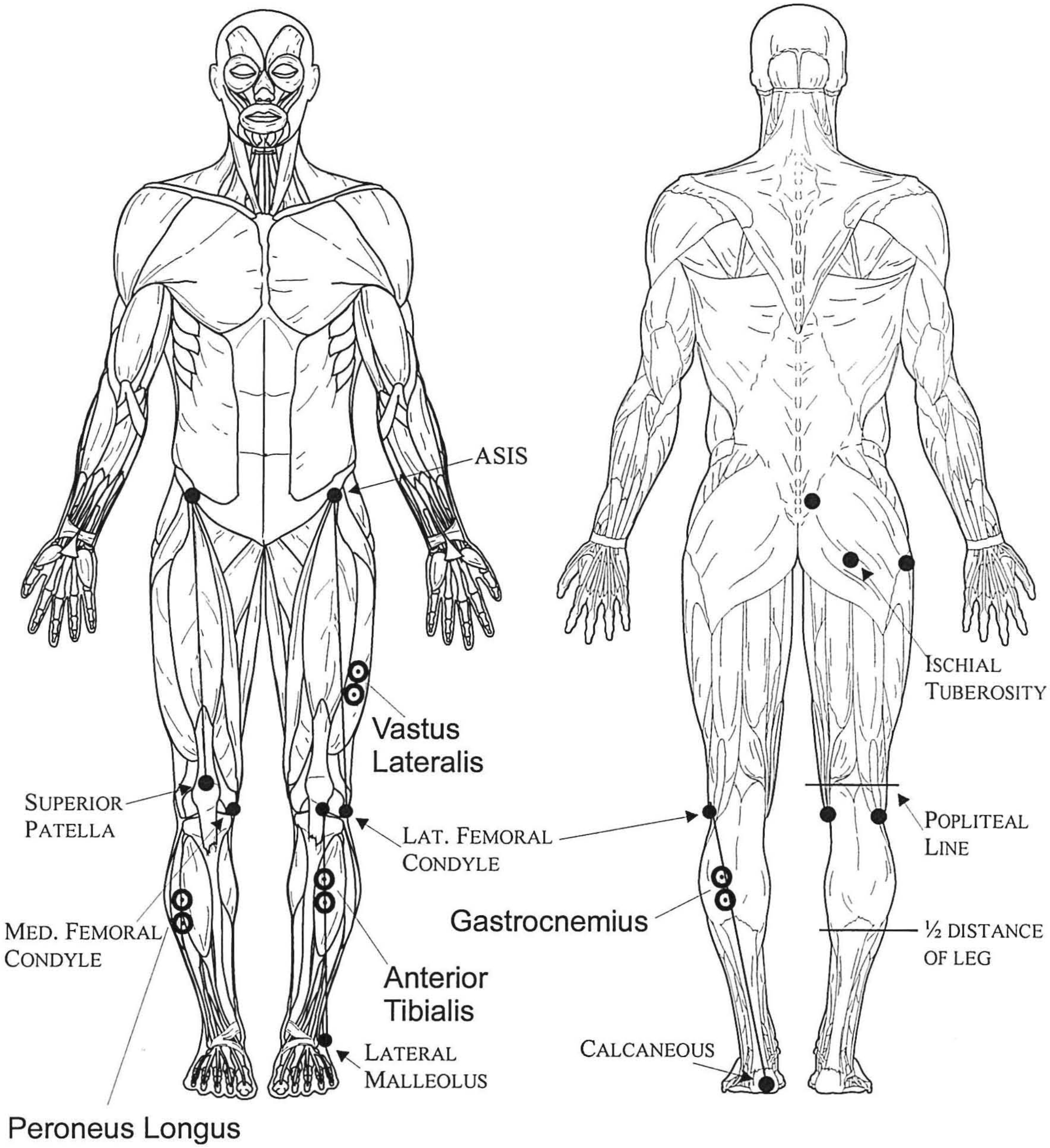
Figure 2. SkyFlex® plyometric shoes

Pentium 133 computer. The digitized information was then analyzed using the Noraxon Myoresearch 97 data collection software that accompanies the Telemyo8 EMG system. Because velocity of muscle contraction is a factor in the EMG activity produced by a muscle, an electric metronome was used to standardize the speed of the tested activity.

Procedure

Before participation in the tested activities, the subjects were required to perform five standing barbell squats at 75 percent of their body weight. This was done to minimize risk of injury by ensuring that each subject had adequate lower extremity muscle strength to complete the tested activities. All subjects were instructed in the proper squat technique as described by Augustsson et al.[16] Each subject placed the barbell on his shoulders, then flexed at the hips and knees until his thighs were parallel to the floor, and finally pushed back to a vertical position.

Pre-gelled, self-adhesive electrodes were placed on the subject's skin over the designated area of muscle activity of the vastus lateralis, anterior tibialis, peroneous longus, and gastrocnemius. These points were located using the appropriate distance between bony landmarks (Figure 3). To reduce skin impedance, hair over the area of electrode placement was shaved and the skin was cleaned with rubbing alcohol prior to application of the electrodes. The electrodes were placed two centimeters apart on the skin over the designated muscle points parallel to the muscle fibers. Placing the electrodes parallel to the muscle fibers allows for conduction in a fixed set of muscle fibers, thus decreasing the chance of recording erroneous conduction velocity.[17]



Vastus Lateralis -along a line ¼ the distance from the lateral knee joint line to the ASIS and over the belly of the vastus lateralis
Anterior Tibialis - over the muscle belly 1/3 the distance from the inferior patellar pole to the lateral malleolus
Peroneus Longus - ¼ the distance from the fibular head to the lateral malleolus
Gastrocnemius - over the muscle belly 1/3 the distance of the leg (fibular head to calcaneous)

Figure 3. Electrode placement sites

Table 3. Surface Electrode Placement

MUSCLE	MEASUREMENTS FOR ELECTRODE PLACEMENT
Vastus Lateralis	Along a line1/4 the distance from the lateral knee joint line to the ASIS and over the muscle belly
Anterior Tibialis	Along a line 1/3 the distance form the inferior patellar pole to the lateral malleolus and over the muscle belly
Peroneus Longus	Along a line 1/4 the distance from the fibular head to the lateral malleolus
Gastrocnemius	Along a line 1/3 the distance from the fibular head to the calcaneus and over the muscle belly

A Penny and Giles M180 electrogoniometer was placed over the lateral aspect of the right knee to obtain knee joint range of motion during each activity performed. The electrogoniometer was centered over the joint axis with the proximal end aligned with the long axis of the femur and the distal end aligned with the long axis of the fibula. The device was secured to the skin with double-sided adhesive tape to avoid movement during data collection.

A footswitch was placed inside the shoe on the plantar surface of the first metatarsal head of the right foot to determine the stance phase of each gait cycle. The footswitch was secured to the foot with athletic tape to ensure contact throughout the activity.

Each subject's baseline activity of the Vastus Lateralis, Anterior Tibialis, Peroneus Longus, and Gastrocnemius was obtained by having each subject perform forward walking for 30 feet in traditional athletic shoes at a rate of 40 beats per minute and performing one standing vertical jump in traditional athletic shoes. Each subject was allowed practice trials until they were comfortable with the appropriate cadence, and then one trial was recorded. The baseline data was used to normalize EMG data collected during walking with plyometric shoes and performing a vertical jump with plyometric tennis shoes.

For the test procedure the subject received an individual explanation and demonstration of each activity. Each subject performed two activities with traditional athletic shoes and two with the plyometric training shoes. The first activity required the subject to walk 30 feet forward at a rate of 40 beats per minute. The second activity required each subject to perform a standing vertical jump reaching up with one arm. The subject was allowed to squat prior to jumping and use his upper extremities freely, but was allowed no steps to initiate the jump. The subject was allowed up to three practice trials for each activity in order to ensure familiarity with the task.

Once testing was completed the electrodes, electrogoniometer, footswitch, and waist belt were removed, and the skin was cleansed with alcohol. Each subject was interviewed briefly following testing to determine if any injury or pain was elicited during the preceding activities. This concluded the subject's involvement in the study.

Data Analysis

The EMG data was analyzed using the Myosoft software to make comparisons between walking with traditional athletic shoes to walking while wearing SkyFlex® plyometric shoes. Vertical jump while wearing traditional athletic shoes versus vertical jump while wearing SkyFlex® plyometric shoes was also compared. EMG activity of the vastus lateralis, anterior tibialis, peroneus longus, and the gastrocnemius in walking and jumping with traditional athletic shoes was compared to walking and jumping in SkyFlex® plyometric training shoes. The EMG data of walking was quantified using two quality consecutive gait cycles of each subject (heel contact to heel contact). The EMG data of jumping was also quantified using two consecutive vertical jumps (stance to landing). Microsoft Excel was used to perform a student t-test of the means of EMG activity of each muscle group during a complete gait cycle. An alpha level of significance of .05 was chosen ($p<.05$).

Part Two: The Effectiveness of the Plyometric Training Shoe on Increasing Vertical Jump

Subjects

Thirty healthy male subjects between the ages of 20 and 27 volunteered to participate in this study. Prior to participation in the study all subjects were required to pass a lower extremity strength test and complete a pre-participation screening questionnaire (appendix). Subjects were required to be between the ages of 18 and 28. All subjects unable to meet the requirements of pre-participation screening (strength test, age, or medical history) were excluded from the study. The subjects were informed of the purpose of the study and their rights as human subjects. All subjects included in the study signed an informed consent (appendix). In addition each subject's age, height, and weight were recorded. The study was approved by the institutional review board at the University of North Dakota and the Red River Valley Sports Institute (appendix). Twenty seven subjects completed the study and were used for data collection and analysis. One subject participating in the experimental group was excluded from the study secondary to pre-existing ankle instability. Another subject was unable to complete the study due to the onset of achilles pain following the first week of training. And the final subject did not report for the final vertical jump measurement thus discluding him from data analysis.

Table 4. Control Group Characteristics (n=14)

	Mean	Range	Standard Deviation
Age (years)	22.92	21-27	1.59
Height (inches)	68.07	65-77	13.34
Weight (pounds)	176.21	140-215	23.95

Table 5. Experimental Group Characteristics (n=15)

	Mean	Range	Standard Deviation
Age (years)	22.66	21-27	1.67
Height (inches)	70.46	68-76	2.38
Weight (pounds)	168.73	137-220	22.13

Instrumentation

"The SkyFlex® System is a plyometric training program which utilizes jump training to increase leaping ability, speed, quickness, and explosive power. It is a series of drills and exercises aimed at linking strength with speed of movement and reflexes to produce power(skyflex training manual)." SkyFlex® plyometric training shoes (figure 3) are modified low-cut shoes with a 2-1/2 inch extendend Airlon Flexfit® sock liner and a 1 cm thick platform that measures 7-1/4x6-1/2 inches. The platform is attached to the sole of the shoe, therefore preventing the heel from striking the ground during training activities. The shoe was designed to increase the amount of stretch the achilles tendon receives before the heel touches the ground, thus speeding up the stretch reflex allowing muscles to reach maximal strength in the shortest amount of time possible. This theoretically increases the amount of work done by the gastrocnemius/soleus complex thus enhancing training. The extended Airlon Flexfit® sock liner was formulated to increase proprioception thus reducing the risk of injury at the ankle. It also warms the ankle and adds security to the foot in the shoe.

The vertical jump height was measured by using a device called the VerTec(Sports Imports, Inc., Columbus, OH). The portable VerTec is a unit that has an adjustable upright pole that allows measurement of varying degrees of vertical jumps. At the top of the pole is 2 feet of horizontal plastic strips in half-inch increments (Figure 4). Vertical jump is measured by the highest plastic strip the subject is able to displace. A baseline measurement involved having the subject first walk under the VerTec with his elbow, wrist, and hand in an extended position and the shoulder in neutral elevation/depression. To initiate the vertical jump, each subject first stood parallel to the VerTec's plastic strips and then turned 45^0 to either the right or left.[18] Subjects were instructed not to take any steps while jumping. The jump began with the subject squatting down and then explosively propelling himself vertically reaching with the dominant arm. Subjects were allowed to jump 3-5 times with the highest vertical jump recorded. The baseline measurement and each vertical jump were compared and the difference between the two taken to determine the change in vertical jump height.

Procedure

Before participating in the plyometric training regimen, the subjects were required to perform five standing barbell squats at 75 percent of their weight. This was done to minimize risk of injury by ensuring that the subjects had adequate lower extremity muscle strength to perform the necessary training activities. All subjects were instructed in the proper squat technique as described by Augustsson et al.[16] Each subject placed the

Figure 4. VerTec® vertical height measurement device

barbell on his shoulders, then flexed at the hips and knees until his thighs were parallel to the floor, and finally pushed back to a vertical position.

Subjects were randomly assigned to either the control (n=14) or the experimental (n=15) groups. The control group participated in a preset training regimen while wearing athletic shoes. The experimental group participated in the same preset training regimen while wearing SkyFlex® plyometric shoes. The preset training regimen used was the one described in the SkyFlex® intermediate protocol (appendix). An initial vertical jump height was taken prior to initiating training and a vertical jump height was measured at the end of each week of training. Prior to measuring vertical jump, each subject performed five minutes of a warm-up activity on either a stationary bike, stair stepper, or by running.

An investigator was present only for the initial plyometric training session to demonstrate each activity and to insure proper technique of each exercise. Subjects were given pictoral and written instructions to assist them in the completion of each workout (appendix). Subjects were instructed to perform the SkyFlex® training protocol 3 times per week for 4 weeks with a vertical jump measurement at the end of each week.

Data Analysis

Results of the final vertical jump heights were analyzed using the computer program SPSS 7.5 (Statistical Package for the Social Sciences Inc., Chicago, Illinois 60611). After data entry was complete, a paired sample t-test was used to compare the initial and final jump heights within each group. Analysis of covariance (ANCOVA) was used to compare the final jump heights between each group. This allowed for the initial jump heights as well as the final jump heights to be taken into account between groups in the final results. The independent variable tested in this part of the study was the protocol type of shoe while wearing either traditional athletic shoes or the SkyFlex® shoes. The dependent variable tested was the final jump height. An alpha level of significance of .05 was chosen ($p<.05$).

CHAPTER 4

RESULTS

Part One: Electromyographic analysis of the effects of plyometric shoes on the lower extremity

Qualitative

Walking

Figures 5 and 6 show the raw averaged EMG activity during each phase of the gait cycle of the vastus lateralis, anterior tibialis, peroneus longus, and gastrocnemius while wearing SkyFlex® shoes. The vastus lateralis demonstrated activity at both the beginning of the stance phase and the end of the swing phase with its peak activity occurring at terminal swing. The anterior tibialis was active at the beginning of the stance phase and then decreased in activity from loading response to preswing, at which time the EMG activity began to gradually rise until its peak amplitude during midswing which was followed by a gradual decrease in activity. The peroneus longus was active from initial contact to midstance, and then demonstrated a rapid decrease in activity to relatively no activity during the end of the stance phase and throughout the swing phase. The EMG activity in the gastrocnemius rose rapidly from initial contact to loading response, at which time it remained active until it demonstrated a rapid decline in activity from midstance to terminal swing.

Quantitative

Walking

Table 6 shows the average EMG activity of walking with SkyFlex® plyometric training shoes as a percentage of walking with traditional athletic shoes in the four chosen muscle groups. As compared to traditional shoes the average EMG activity during walking of the anterior tibialis, gastrocnemius, vastus lateralis, and peroneus longus while wearing the SkyFlex® plyometric training shoes was 186.5%, 143.0%, 120.8%, and 120.8%, respectively (Figure 7). There was a significant increase in the average EMG activity in both the gastrocnemius and anterior tibialis muscles during walking with the SkyFlex® shoes as compared to traditional athletic shoes ($p<.05$). No significant difference was found in average EMG activity of the peroneus longus and the gastrocnemius muscles between the two shoe groups during walking.

Table 6. Average Lower Extremity EMG Activity During Walking with Traditional and SkyFlex® Plyometric Athletic Shoes

Muscle	**Mean** Traditional Athletic Shoe	**Mean** SkyFlex® Plyometric Shoe	**Change** %	**t** (two-tail)
Vastus Lateralis	16.264 µv	19.386 µv	120.8	0.142
Peroneus Longus	30.935 µv	40.096 µv	143.0	0.206
Anterior Tibialis	29.608 µv	51.361 µv	186.5	0.004*
Gastrocnemius	23.110 µv	31.815 µv	143.0	0.030*

*significant at the .05 level

Vertical Jump

Table 7 shows the percent of average EMG activity in the four muscle groups of vertical jumping with SkyFlex® plyometric training shoes as a percentage of vertical jumping with traditional athletic shoes. As compared to a traditional shoe, the average

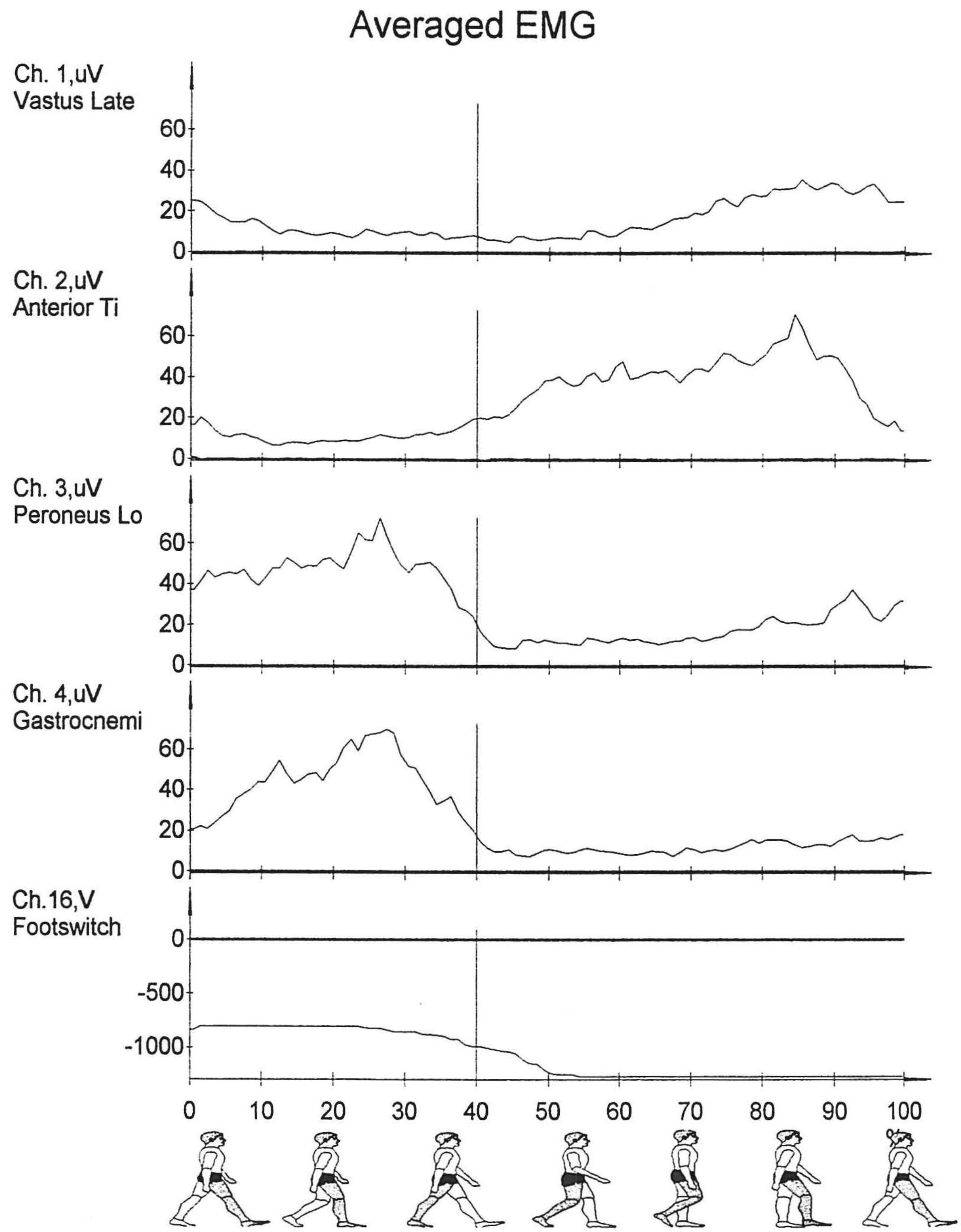


Figure 5. Averaged selected lower extremity EMG muscle activity during walking with traditional athletic shoes

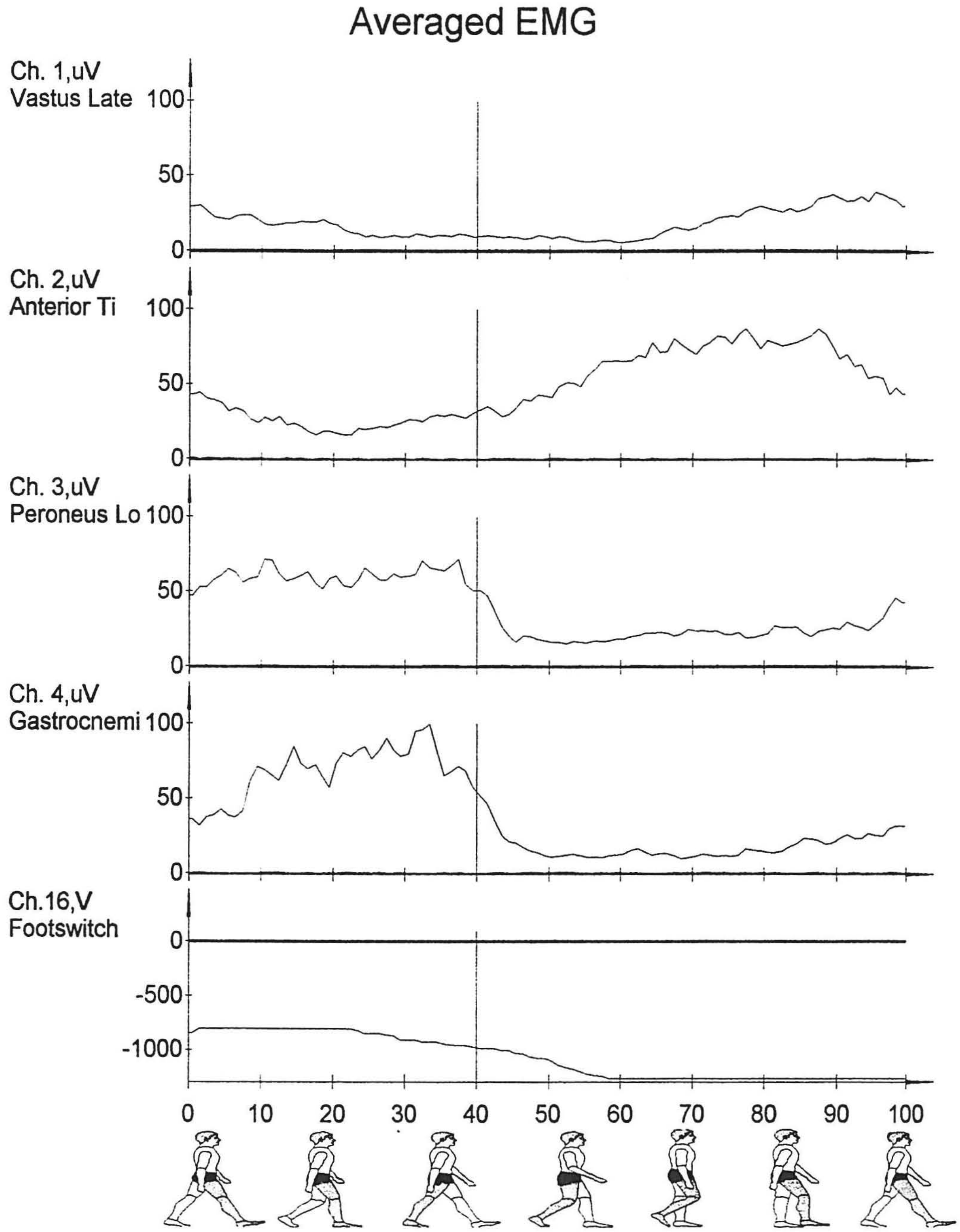


Figure 6. Averaged selected lower extremity EMG muscle activity during walking with SkyFlex plyometric shoes

EMG activity during jumping of the vastus lateralis, peroneus longus, anterior tibialis, and gastrocnemius while wearing the SkyFlex® plyometric training shoe was 101.2%, 105.2%, 131.2%, and 113.8%, respectively (Figure 8).

No significant difference in EMG activity of the vastus lateralis, peroneus longus anterior tibialis, or the gastrocnemius was found between the subjects wearing plyometric training shoes and those wearing traditional athletic shoes during a vertical jump ($p<.05$). The greatest amount of percent change, although not significant, was found in the anterior tibialis muscle, and was 131.2% of the anterior tibialis activity when performing a vertical jump with traditional athletic shoes.

Table 7. EMG Activity During Vertical Jump with Traditional and SkyFlex® Plyometric Athletic Shoes

Muscle	**Mean** Traditional Athletic Shoe	**Mean** SkyFlex® Plyometric Shoe	**Change** %	**t** (two-tail)
Vastus Lateralis	176.397 μv	167.514 μv	101.2	0.580
Peroneus Longus	97.143 μv	102.406 μv	105.2	0.500
Anterior Tibialis	47.666 μv	64.586 μv	131.2	0.058
Gastrocnemius	100.150 μv	110.221 μv	113.8	0.199

Part Two: The effectiveness of the plyometric training shoe on increasing vertical jump

The SkyFlex® training group demonstrated a significant increase in vertical jump height over the four week training period ($p<.05$), whereas the traditional group demonstrated no significant increase ($p>.05$) as reported in a paired sample t-test. Table 8 contains the initial and final mean vertical jump heights of the two groups. Although there was a significant increase within the SkyFlex® training group, upon analysis of the ANCOVA test, the SkyFlex® training group did not demonstrate an increase in vertical jump height that was significantly higher than the traditional training (Figure 9). Table 9 contains the initial means and adjusted means for the two groups. Additional statistical tests verified that all assumptions of ANCOVA were met. The power for the effect of the shoes on jump height was .057.

Table 8. Paired Samples t-test: Initial Mean and Final Mean Vertical Jump Heights (inches) for SkyFlex® (N=14) and Traditional Groups (N=13).

Group	Initial Mean	SD	Final Mean	SD	Mean Diff.	SD	t
SkyFlex®	26.46	3.92	27.04	3.89	0.57	0.87	2.45*
Traditional	27.42	3.52	28.04	3.35	0.62	1.26	1.76

*significant at the .05 level

Table 9. Analysis of Covariance of Adjusted Final Jump Heights Comparing Individuals Wearing the SkyFlex® or Traditional Shoes.

Source	df	SS	MS	F	p
Covariate (initial jump height)	1	303.99	303.99	265.54	0.000
Group (shoes)	1	0.07	0.07	0.067	0.798
Error	24	27.47	1.14	...	
Total (corrected)	26	338.24	...	...	

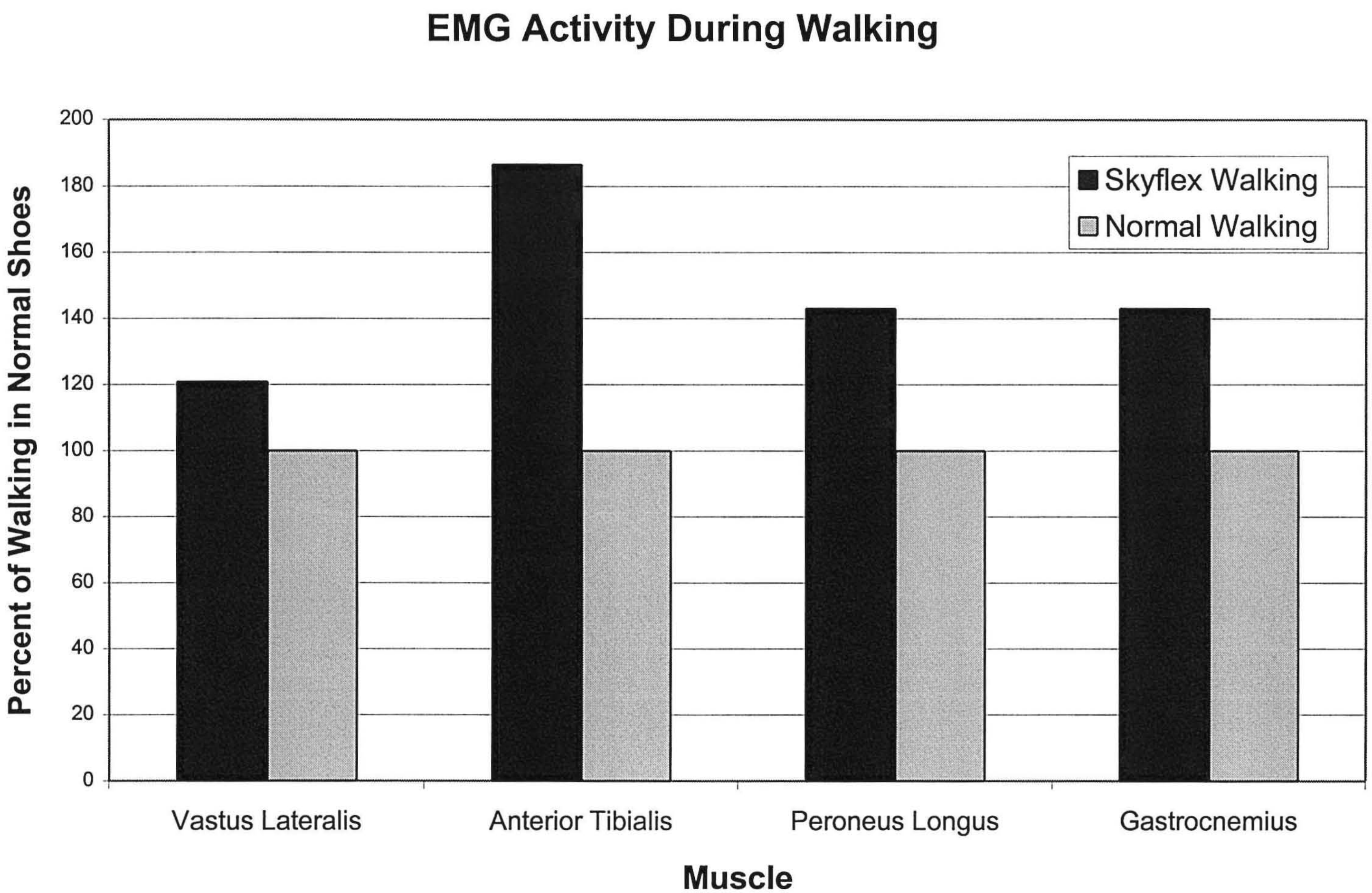


Figure 7. EMG activity during walking with traditional athletic and SkyFlex plyometric shoes

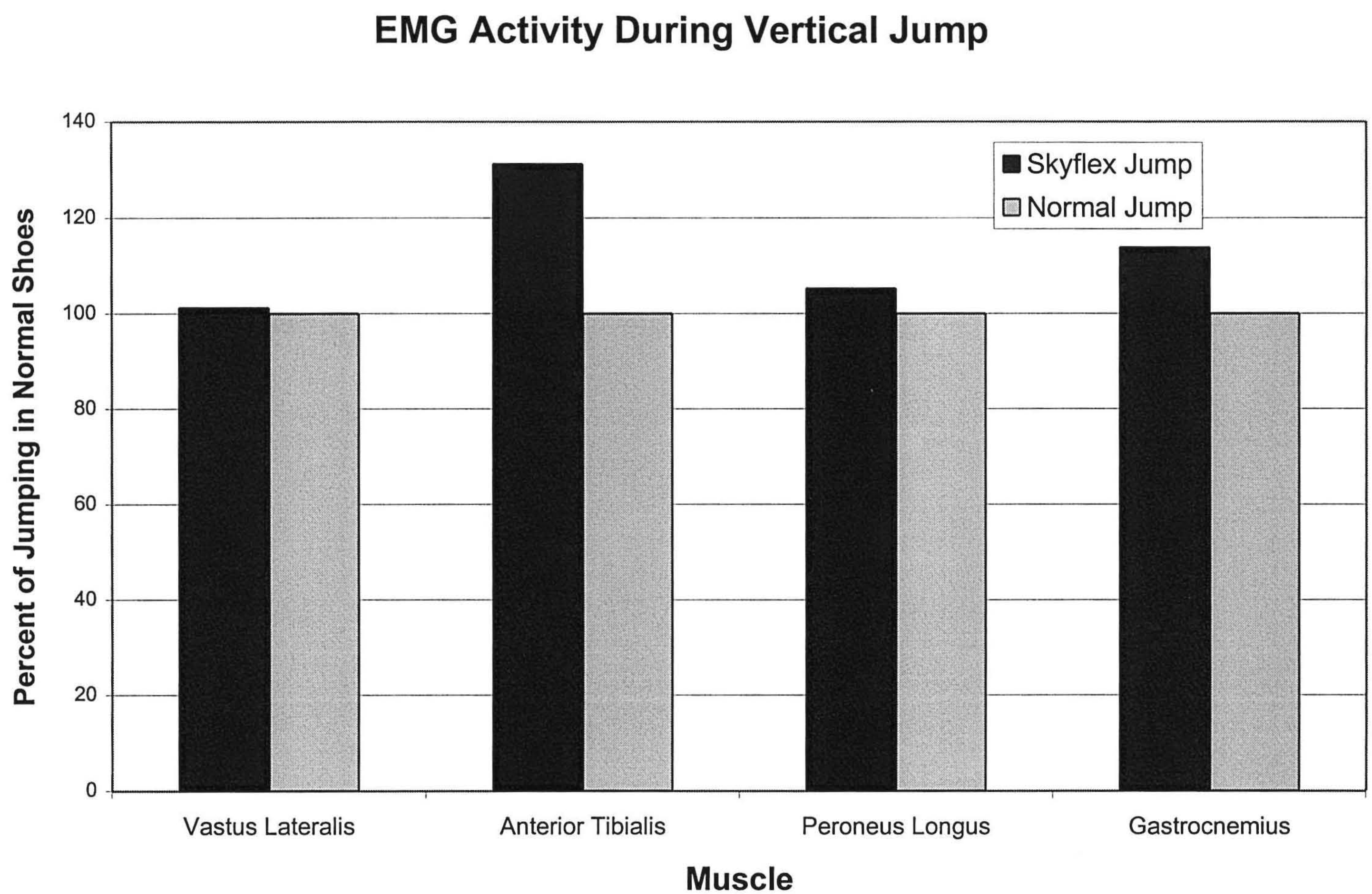


Figure 8. EMG activity during vertical jump with traditional athletic and SkyFlex plyometric shoes

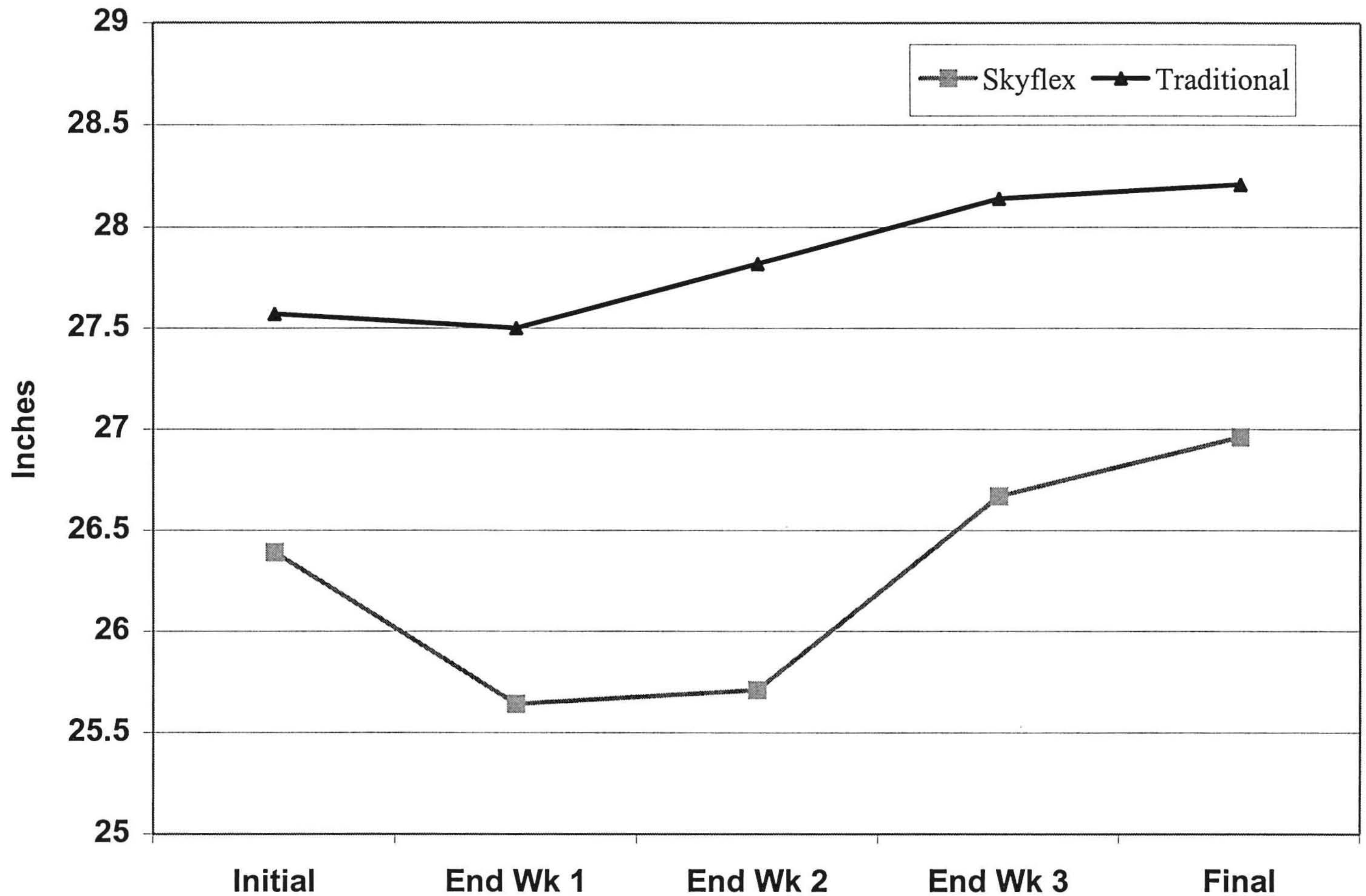


Figure 9. Mean change in vertical jump height of the two training groups

CHAPTER 5

DISCUSSION

The analyzed results of this study were inconsistent with certain claims of the SkyFlex® manufacture, but are similar to other researcher's results. When training with SkyFlex® plyometric shoes, one should expect to see results in 4 weeks according to the SkyFlex® company.[1] Our results indicate that vertical jump was not significantly increased during the four week training protocol. It is interesting to note that there was a significant increase in the vertical jump in the SkyFlex® plyometric shoe group from initial jump to final jump. Figure 9 shows the average vertical jump of the SkyFlex® group and it appeared it was on the rise at four weeks, after a sharp initial drop. One can only speculate the average vertical jump may have continued to rise if training was continued. One published research article also supports our findings. Cook et al[3] studied the Strength® shoe and reported no significant differences in vertical jump height when compared to traditional athletic shoes.

The EMG results showed that wearing either the SkyFlex® plyometric shoes or traditional athletic shoes resulted in similar activity in all four muscles studied (Fig. 5 & 6). The muscle EMG activity showed a significant difference between walking trials with traditional athletic shoes and SkyFlex® plyometric training shoes in two muscles, the anterior tibialis and gastrocnemius. There was, however, no significant difference in EMG activity between the two shoe groups when comparing vertical jump. The gastrocnemius activity increase is consistent with the SkyFlex® company claim's, as they promote the shoes to develop strength in the lower extremity calf musculature.[1] The heel less platform and pillar design reportedly allows this shoe to increase the activity of the gastrocnemius when used in combination with plyometric exercises, thus increasing vertical jump height. A conflicting study by Bangerter[14] identified the main contributive components of vertical jump to be the hip and knee extensors. He found the ankle plantar flexors as acting only in response to other forces as resistors and positioners. This may explain the nonsignificant EMG difference between the groups.

The anterior tibialis, which also showed a significant increase in EMG activity may have been due to the shoe design. The platform is a solid rubber base which is positioned directly under the ball of the foot, therefore adding weight and increasing the moment arm through which the body weight acts.[19] Both of these factors may play a role in increasing the EMG activity as the foot dorsiflexes to clear the floor during swing phase.

Plyometric exercise's have been challenged by investigators whose research does not support claims based on it's principles. Scoles[10] Used box depth jumps, while Blattner and Noble[11] compared isokinetic and plyometric exercise. The results of these studies did not show significant differences when vertical jump was measured. The SkyFlex® company has since come forth with their plyometric shoe to enhance training exercises by initiating a greater stretch reflex.[1] Our study's results do not support this theory of enhancement.

EMG data gathered in our study showed a significant increase in walking while wearing SkyFlex® plyometric training shoes. This increase in activity doesn't accurately reflect the results obtained from vertical jump measurements of subjects who trained with SkyFlex® shoes when compared to traditional athletic shoes. Since the gastrocnemius is a two joint muscle acting at the knee and ankle, I suspect both joints must be in the correct position for the gastrocnemius to receive an optimal stretch. Subjects in our study exercised using more dynamic activities, with the knee remaining in a relatively extended position and the ankle dorsiflexing. In contrast, when they prepared for the standing jump position, the knee was bent and the gastrocnemius was placed on slack. It can therefore be reasoned that the gactrocnemius didn't receive an adequate amount of stretch with the knee bent to facilitate the stretch reflex.

Researchers also speculate that the rate of stretch is more important than the magnitude of stretch when trying to increase the amount of positive work done by a muscle[6,7,20]. This being the case, the SkyFlex® plyometric shoe may increase the magnitude of the stretch because of it's heel less design allowing a more eccentric movement through a greater distance, therefore taking more time. If this is true, the shoe may actually be inhibiting the stretch reflex when subjects were performing their exercises.

Limitations

Although this study was monitored closely by the investigators it isn't without limitations. First, the EMG portion only had 10 subjects, so any slight deviation in a single subject's walking pattern would have a profound impact on the results. Also subjects may have been unfamiliar with walking in the plyometric shoes causing them possible balance problems and abnormal muscle recruitment patterns.

In the SkyFlex® training protocol portion of the study, subjects were relied on to be independent in performing their exercises 3 times/week after an initial supervised training session, bringing up possible compliance issues. Secondly, all subjects did pass the initial strength test, but they each possessed varying levels of fitness and athletic capability which required some subjects to work harder during their workouts. This could possibly have allowed the more 'fit' subject an easier work out which would limit his gains.

Future Research

Investigators wishing to carry out a plyometric shoe study may want to increase the training sessions to 6 or 8 weeks to evaluate the longer term outcomes. Also exercise intensity should be progressed every 2 weeks as the subjects find the workouts get easier.

Clinical Implications

Plyometric shoes used in combination with plyometric exercise are one method of sport training used by many of today's coaches and athletes. This study didn't show the SkyFlex® plyometric training shoe to be a more effective device than plyometric training in traditional athletic shoes. In fact other studies suggest that a similar shoe, specifically the Strength® shoe may be harmful to the lower extremity musculoskeletal system[3]. Coaches who may want to implement such exercise system may want to review literature by Chu[5] and Kulund[21] as they provide more stringent guidelines for plyometric training than the SkyFlex® company.

APPENDIX

_X__EXPEDITED REVIEW REQUESTED UNDER ITEM _3__ (NUMBER[S]) OF HHS REGULATIONS
___EXEMPT REVIEW REQUESTED UNDER ITEM _____ (NUMBER[S]) OF HHS REGULATIONS

UNIVERSITY OF NORTH DAKOTA HUMAN SUBJECTS REVIEW FORM FOR NEW PROJECTS OR PROCEDURAL REVISIONS TO APPROVED PROJECTS INVOLVING HUMAN SUBJECTS

PRINCIPAL INVESTIGATOR: Thomas Mohr, Sue Buckley, Myles Haugen, Brian Laumb, Heather Phillips **TELEPHONE:** 777-2813
DATE: 6/10/97
ADDRESS TO WHICH NOTICE OF APPROVAL SHOULD BE SENT: PO Box 9037, Dept. Of Physical Therapy, UND

SCHOOL/COLLEGE: Medicine & Health Sciences **DEPARTMENT:** Physical Therapy **PROPOSED PROJECT DATES:** 5/1/98-5/1/99 (Month/Day/Year)

PROJECT TITLE: An Electromyographic and Video Motion Analysis Study of the Effects of Plyometric Training Shoes on the Lower Extremity

FUNDING AGENCIES (IF APPLICABLE): None

TYPE OF PROJECT (Check ALL that apply):

_X_ NEW PROJECT ___ CONTINUATION ___ RENEWAL ___ DISSERTATION OR THESIS RESEARCH _X_ STUDENT RESEARCH PROJECT

___ CHANGE IN PROCEDURE FOR A PREVIOUSLY APPROVED PROJECT

DISSERTATION/THESIS ADVISER, OR STUDENT ADVISER: Thomas Mohr, PT, Phd

PROPOSED PROJECT: ____ INVOLVES NEW DRUGS (IND) ____ INVOLVES NON-APPROVED USE OF DRUG _X_ INVOLVES A COOPERATING INSTITUTION

IF ANY OF YOUR SUBJECTS FALL IN ANY OF THE FOLLOWING CLASSIFICATIONS, PLEASE INDICATE THE CLASSIFICATION(S):

___ MINORS (<18 YEARS) ___ PREGNANT WOMEN ___ MENTALLY DISABLED ___ FETUSES ___ MENTALLY RETARDED

___ PRISONERS ___ ABORTUSES _X_ UND STUDENTS (>18 YEARS)

IF YOUR PROJECT INVOLVES ANY HUMAN TISSUE, BODY FLUIDS, PATHOLOGICAL SPECIMENS, DONATED ORGANS, FETAL MATERIAL, OR PLACENTAL MATERIALS, CHECK HERE ________

IF YOUR PROJECT HAS BEEN\WILL BE SUBMITTED TO ANOTHER INSTITUTIONAL REVIEW BOARD(S),PLEASE LIST NAME OF BOARD(S): Red River Sports Medicine, Fargo, ND

Status: _________ Submitted; Date 4/15/98 Approved; Date 4/15/98 Pending____

1. **ABSTRACT:** (LIMIT TO 200 WORDS OR LESS AND INCLUDE JUSTIFICATION OR NECESSITY FOR USING HUMAN SUBJECTS.
There is a continual challenge to develop improved training tools and techniques for athletes. One such technique is the use of plyometric training shoes to enhance vertical jump. Although the shoes are being actively marketed, there is no research that supports their use. Therefore, the purpose of our study is twofold: 1) to compare muscle activity and joint motion during walking and jumping while wearing traditional athletic shoes and specialized plyometric training shoes, and 2) to evaluate the vertical jump of subjects trained with plyometric training shoes and subjects trained with traditional athletic shoes . For the first part of the study, muscle activity (electromyographic or EMG) will be monitored using surface electrodes. In addition, video equipment will be utilized to film the subject. We will analyze the EMG data along with joint movement to quantitatively compare the differences between subjects wearing traditional athletic shoes and those wearing plyometric training shoes. In the second part of the study, we will have two groups of subjects undergo plyometric training with the two types of shoes and then measure their vertical jump at the end of four weeks of training. Normal, trained, healthy subjects will be used in this research project. Human subjects are needed for this EMG research study in order to determine when the selected muscles are active while walking and jumping with traditional athletic shoes and plyometric training shoes. Human subjects will also be needed for the second part of this study to determine the benefits of a training regimen utizlizing SkyFlex® plyometric training shoes.

PLEASE NOTE: Only information pertinent to your request to utilize human subjects in your project or activity should be included on this form. Where appropriate attach sections from your proposal (if seeking outside funding).

2. **PROTOCOL:** (Describe procedures to which humans will be subjected. Use additional pages if necessary.)

Subjects:
For Part One of the study, it is anticipated that we will recruit 10 subjects between the ages of 18 and 28. For Part Two of the study, it is anticipated that we will recruit 30 male subjects between the ages 18 and 28. All of the subjects will participate voluntarily. The subjects will be chosen due to their athletic abilities. This will decrease the potential for injury due to the skill level of these activities. The project will be completed at the University of North Dakota Department of Physical Therapy in Grand Forks, ND.

Methods:
Part One (N = 10)
Prior to the walking and jumping trials, each subject's age, height, and weight will be recorded. During the trial, we will measure electromygraphic (EMG) activity in selected lower extremity muscles. We will measure activity in the following muscles while the subjects are walking and/or jumping: 1)vastus lateralis, 2)anterior tibialis, 3)peroneus longus, 4)gastrocnemius.
To record EMG activity, electrode placement will be determined using a protocol that incorporates measurements between bony landmarks. The skin of the lower extremity of each subject will be prepared by cleansing the skin with alcohol before attachment of the EMG adhesive electrodes. Adhesive surface electrodes will be placed on the subject's skin over the determined location. The EMG signals will be transmitted to a receiver unit and then fed into a computer for display and recording of data. Prior to the experimental trials each subject's EMG activity will be recorded while walking in traditional shoes. This procedure is done to normalize the EMG data (i.e. that collected during walking) for later analysis.

Video analysis will be used to measure range of motion during the activities. Reflective markers will be attached to the skin using double-sided adhesive tape. We anticipate placing markers on the shoulder, elbow, wrist, hip, knee and ankle. The video cameras will film and then track the markers. We also will be taping footswitches to the bottom of the foot to determine when the foot is in contact with the floor. We anticipate that we will be attaching an electrogoniometer (using tape) to the outside of the thigh and leg to measure knee motion. The information from the EMG, footswitches, electrogoniometer and video cameras will be fed into a computer for analysis.

The subject will perform three trials of each of the following activities: walk 30 feet, perform a standing vertical jump, and perform a 12 inch box jump. Each of the activities will be performed wearing traditional athletic shoes, Jump Soles® plyometric shoes, and SkyFlex® plyometric shoes.

Part Two (N = 30)
Prior to initiating the following training program each subject's age, height, weight, and vertical jump will be recorded. The subject's will be randomly divided into 2 groups (15 in each group). The first group of subject's will be a control group and will participate in the preset training regimen while wearing traditional athletic shoes. Their vertical jump will be measured every week for 4 weeks. The second group of subjects will participate in the same preset training program while wearing SkyFlex® plyometric shoes and their vertical jump will also be measured every week for 4 weeks. The subjects will complete the SkyFlex® protocol three times per week for four weeks. Before starting the plyometric training, each subject's lower extremity strength will be tested by having the subject perform 5 repetitions of a squat lift that is equivalent to 75% of their body weight. If they cannot perform the lifts, safely, they will not be included in the study. Following the strength testing, each subject will be given instructions regarding the plyometric training protocol they will follow for the experiment (see Instructions attached to the Consent Form). Each training session will consist of a warm-up, stretching, plyometric exercises, and a cool-down. The warm-up will consist of a 5 minute jog. The subject will then stretch the muscles of both lower extremities. Following this, the subject will perform plyometric exercises as outlined in their protocol. For the definition of specific exercises and the number of repetitions, refer to the protocol attached to the consent form. The session will end with a 5 minute cool-down jog. The subject will perform this set of exercises three (3) times per week for four (4) weeks. The only difference between the two groups will be that one group will perform the training protocol with regular athletic shoes and the other will perform the same training protocol with the plyometric shoes.

Data analysis:
Descriptive statistics describing the subjects' anthropometric profiles will be provided. The mean activity of each monitored muscle will be calculated. The EMG data collected during the experimental trials will be expressed as a percentage of the EMG activity recorded during the walking trial in traditional athletic shoes (i.e. normalized). The video image will be converted to a stickman-like figure, from which we can determine joint angles and limb velocity. The EMG data is synchronized with the video data to determine the level of EMG activity during the various walking and jumping trials. As appropriate, repeated measures ANOVA and t-tests will be used to compare EMG activity during walking, running, and jumping with plyometric tranining shoes and with traditional athletic shoes. Repeated measures ANOVA and t-tests (as appropriate) will be used to test for differences in vertical jumping ability.

3. **BENEFITS:** (Describe the benefits to the individual or society.)

For the first part of the study, the data collected will be analyzed to determine the amount of EMG activity in lower extremity muscles when the subject is wearing plyometric training shoes and traditional athletic shoes while walking and jumping. In the second part of the study, we will try to determine the effectiveness of the plyometric shoes as part of a training regimen. The data should provide information on the effectiveness of training with SkyFlex® plyometric training shoes and this information will provide the basis for developing protocols specifically for training athletes. It will also further the available knowledge base of research in this area.

4. **RISKS:** (Describe the risks to the subject and precautions that will be taken to minimize them. The concept of risk goes beyond physical risk and includes risks to the subject's dignity and self-respect, as well as psycho-logical, emotional or behavioral risk. If data are collected which could prove harmful or embarrassing to the subject if associated with him or her, then describe the methods to be used to insure the confidentiality of data obtained, including plans for final disposition or destruction, debriefing procedures, etc.)

The risks involved in this research project are minimal. The EMG, footswitch, electrogoniometer and video analysis equipment causes no discomfort to the subject, since they are only monitoring devices. Because the video information is converted to stickman-like diagrams, the actual subject's video is not used in data reporting. Therefore, the subject is not recognizable.

The process of physical performance testing does impose a potential risk of injury to the muscle. The testing will occur in a controlled setting , and because only subjects who are physically fit and have passed a lower extremity strength test (as outlined in the training protocol handout) will be included in this study, the risk for injury is minimal. The investigator or participant may stop the experiment at any time if the participant is experiencing discomfort, pain, fatigue, or any other symptoms that may be detrimental to his/her health.

The subjects' names will not be used in any reports of the results of this study. Any information that is obtained in connection with this study and that can be identified with the subject will remain confidential and will be disclosed only with the subject's permission. The data will be identified by a number known only by the investigator.

5. **CONSENT FORM:** A copy of the **CONSENT FORM** to be signed by the subject (if applicable) and/or any statement to be read to the subject should be attached to this form. If no **CONSENT FORM** is to be used, document the procedures to be used to assure that infringement upon the subject's rights will not occur.

Describe where signed consent forms will be kept and for what period of time.

Consent forms will be kept in the Physical Therapy Department at the University of North Dakota for a period of 3 years.

6. For **FULL IRB REVIEW** forward a signed original and thirteen (13) copies of this completed form, and where applicable, thirteen (13) copies of the proposed consent form, questionnaires, etc. and any supporting documentation to:

Office of Research & Program Development
University of North Dakota
Grand Forks, North Dakota 58202-7134

On campus, mail to: Office of Research & Program Development, Box 7134, or drop it off at Room 105 Twamley Hall.

For **EXEMPT** or **EXPEDITED REVIEW** forward a signed original and a copy of the consent form, questionnaires, etc. and any supporting documentation to one of the addresses above.

The policies and procedures on Use of Human Subjects of the University of North Dakota apply to all activities involving use of Human Subjects performed by personnel conducting such activities under the auspices of the University. No activities are to be initiated without prior review and approval as prescribed by the University's policies and procedures governing the use of human subjects.

SIGNATURES:

4-20-98

Principal Investigators Date

4/20/98

Project Director or Student Adviser Date

Training or Center Grant Director Date

(Revised 3/1996)

Red River Valley
Sports Medicine Institute

April 15, 1998

Dr. Thomas Mohr, PT
UND School of Medicine
Department of Physical Therapy
501 N. Columbia Road
P.O. Box 9037
Grand Forks, ND 58202-9037

Dear Dr. Mohr,

I have had the opportunity to review the research proposal "Electromyographic and Video Motion Analysis Study of the Effects of Plyometric Training Shoes on the Lower Extremity". As the Medical Director of the Red River Valley Sports Medicine Institute, I approve and fully support this research endeavor. We look forward to working together with you.

Sincerely,

Mark A. Lundeen, MD
Medical Director RRVSMI

Caring for competitive & recreational athletes participating in all sports

US SKIING

2301 25th Street South • Suite C
Fargo, North Dakota 58103
Tel 701-281-2400
Fax 701-237-0922

INFORMATION AND CONSENT FORM
PART ONE STUDY

TITLE: An Electromyographic and Video Motion Analysis Study of the Effects of Plyometric Training Shoes on the Lower Extremity

You are being invited to participate in a study conducted by Sue Buckley, Myles Haugen, Brian Laumb, Heather Phillips and Thomas Mohr from the physical therapy department at the University of North Dakota. The purpose of this study is to measure the muscle activity in your lower extremity while you are walking and jumping wearing plyometric training shoes and then again while wearing traditional athletic shoes. We will also be measuring the motion of your lower extremity joints while you are exercising. Only trained, normal, healthy subjects will be asked to participate in this study.

You will be asked to perform the following activities: 1) walk 30 feet, 2) a standing vertical jump, and 3) a 12 inch box plyometric jump. Each of these activities will be performed first with traditional athletic shoes and then with plyometric training shoes.

The study will take approximately one hour of your time. You will be asked to report to the University of North Dakota Physical Therapy Department, at an assigned time. You will then be asked to change into gym shorts for the experiment. We will first record your age, gender, height and weight. During the experiment, we will be recording the amount of muscle activity and the angles of your joints that is present while you are walking and jumping in the two different pairs of shoes.

Although the process of physical performance testing always involves some degree of risk, the investigator in this study feels that, because of your prior training and a required lower extremity strength test, the risk of injury or discomfort is minimal. In order for us to record the muscle activity, we will be placing electrodes on your lower extremity. Before we apply the electrodes to the skin, we will prepare it with an alcohol swipe and, if needed, a small area of hair will be shaven. The recording electrodes are attached to the surface of the skin with an adhesive material. We will also attach reflective markers at various points on your leg and trunk. These devices only record information from your muscles and joints, they do not stimulate the skin. The amount of exercise you will be asked to perform will be mild to moderate.

Your name will not be used in any reports of the results of this study. Any information that is obtained in connection with this study and that can be identified with you will remain confidential and will be disclosed only with your permission. The data will be identified by a number known only by the investigator. The investigator or participant may stop the experiment at any time if the participant is experiencing discomfort, pain, fatigue, or any other symptoms that may be detrimental to his/her health. Your decision whether or not to participate will not prejudice your future relationship with the Physical Therapy Department or the University of North Dakota. If you decide to participate, you are free to discontinue participation at any time without prejudice.

The investigator involved is available to answer any questions you have concerning this study. In addition, you are encouraged to ask any questions concerning this study that you may have in the future. Questions may be asked by calling Dr. Thomas Mohr at (701) 777-2831. A copy of this consent form is available to all participants in the study.

In the event that this research activity results in a physical injury, medical treatment will be available, including first aid, emergency treatment and follow up care as it is to a member of the general public in similar circumstances. Payment for any such treatment must be provided by you and your third party payer, if any.

ALL OF MY QUESTIONS HAVE BEEN ANSWERED AND I AM ENCOURAGED TO ASK ANY QUESTIONS THAT I MAY HAVE CONCERNING THIS STUDY IN THE FUTURE. MY SIGNATURE INDICATES THAT, HAVING READ THE ABOVE INFORMATION, I HAVE DECIDED TO PARTICIPATE IN THE RESEARCH PROJECT.

I have read all of the above and willingly agree to participate in this study explained to me by Sue Buckley, Myles Haugen, Brian Laumb, Heather Phillips.

____
Participant's Signature Date

____
Witness (not the scientist) Date

INFORMATION AND CONSENT FORM
PART TWO STUDY

TITLE: An Electromyographic and Video Motion Analysis Study of the Effects of Plyometric Training Shoes on the Lower Extremity

You are being invited to participate in a study conducted by Sue Buckley, Myles Haugen, Brian Laumb, Heather Phillips and Thomas Mohr from the physical therapy department at the University of North Dakota. The purpose of this study is to measure the vertical jump of subjects trained with plyometric training shoes and subjects trained with traditional athletic shoes. Only trained, normal, healthy subjects will be asked to participate in this study.

You will be asked to perform a four week, vertical jump SkyFlex® training protocol which includes the following activities: plyo jog, swivel hips, alternating ankle jumps, plyo rope jump, flexors, scissors, skis, three step leaps, lateral hops, two foot bounds, and sprints (please see attached instructions). Each training session will take approximately 20-30 minutes of your time, three times a week. You will be provided with a descriptive copy of all the exercises. In addition, your initial session with consist of instruction in and performance of each exercise with an investigator. Following the first instructive session, you will be exercising at home and at your convenience. A random assignment will determine whether you perform these exercises with plyometric training shoes or traditional athletic shoes.

Your vertical jump will be measured prior to starting the exercise program, at the end of each week of training and at the end of the four week training period. For the testing sessions, you will be asked to report to the University of North Dakota Physical Therapy Department, at an assigned time. The initial training session will take approximately 30 minutes of your time, and the follow-up measurements will take approximately ten minutes.

Although the process of physical performance testing always involves some degree of risk, the investigator in this study feels that, because of your prior training and a required lower extremity strength test, the risk of injury or discomfort is minimal. To further decrease the risk of injury, you will be given warm up exercises, a stretching program, and cool down instructions. The amount of exercise you will be asked to perform will be moderate.

Your name will not be used in any reports of the results of this study. Any information that is obtained in connection with this study and that can be identified with you will remain confidential and will be disclosed only with your permission. The data will be identified by a number known only by the investigator. The investigator or participant may stop the experiment at any time if the participant is experiencing discomfort, pain, fatigue, or any other symptoms that may be detrimental to his/her health. Your decision whether or not to participate will not prejudice your future relationship with the Physical Therapy Department or the University of North Dakota. If you decide to participate, you are free to discontinue participation at any time without prejudice.

The investigator involved is available to answer any questions you have concerning this study. In addition, you are encouraged to ask any questions concerning this study that you may have in the future. Questions may be asked by calling Dr. Thomas Mohr at (701) 777-2831. A copy of this consent form is available to all participants in the study.

In the event that this research activity results in a physical injury, medical treatment will be available, including first aid, emergency treatment and follow up care as it is to a member of the general public in similar circumstances. Payment for any such treatment must be provided by you and your third party payer, if any.

ALL OF MY QUESTIONS HAVE BEEN ANSWERED AND I AM ENCOURAGED TO ASK ANY QUESTIONS THAT I MAY HAVE CONCERNING THIS STUDY IN THE FUTURE. MY SIGNATURE INDICATES THAT, HAVING READ THE ABOVE INFORMATION, I HAVE DECIDED TO PARTICIPATE IN THE RESEARCH PROJECT.

I have read all of the above and willingly agree to participate in this study explained to me by Sue Buckley, Myles Haugen, Brian Laumb, Heather Phillips.

____

Participant's Signature Date

____

Witness (not the scientist) Date

SkyFlex® Plyometric Vertical Jump Intermediate Training Program

All steps to the training program must be completed to decrease the risk for injury and to validate the results of the study.

Entire Program is to be completed 3 times per week for 4 weeks

*Warm-Up and stretching are to be performed in traditional athletic shoes
Warm-Up: Five minute jog

Stretching: In order to gain maximum results from the plyometric jump training as well as to prevent muscle pulls, cramps, and strains, always stretch your muscles before beginning the jumping exercises. Static stretching which smoothly stretches a muscle to a certain position for 6 to 15 seconds is the preferred method of stretching. Keep your stretch slow and smooth and refrain for "bouncing", which could cause snaps or tears. This type of stretch should be performed three times each on your calves, thighs, groin, and lower back. You know you are doing the stretch correctly if you feel tautness in the muscle you are stretching. **SkyFlex®**

Perform stretches 1-6 on the handout.

Plyometric Exercises: Perform the following exercises as outlined below. Refer to the handout for the description of each exercise.

1.Plyo Jog	**4 repetitions/25 yards each**
2.Swivel Hips	2 repetitions/25 yards each
3.Alternating Ankle Jumps	**4 repetitions/30 seconds each**
4.Plyo Rope Jump	3 repetitions/90 seconds each
5.Flexors	**2 repetitions/60 seconds each**
6.Scissors	4 repetitions/30 seconds each
7.Skis	**4 repetitions/30 seconds each**
8.Three Step Leaps	2 repetitions/30 yards each
9.Lateral Hops	**4 repetitions****
10.Two Foot Bound	4 repetitions/30 yards each
11.Sprints	**6 repetitions/40 yards each**

**down and back equals one repetitions

*Cool-Down and Stretching are to be performed in traditional athletic shoes
Cool-Down: 5-minute jog

Stretching: A complete stretch after the workout reduces/and or eliminates muscle soreness. **SkyFlex®**

Perform stretches 1-6 on the handout with the same technique you used in the warm-up.

Preparticipation Questionnaire

Name: ____________________ Age: ________ Date of Birth: ____________

*Please explain **YES** answers below*

1. Have you ever had surgery?.. yes no
2. Have you ever passed out during or after exercise?................................ yes no
3. Do you have trouble breathing or do you cough during or after activity?........ yes no
4. Have you ever had any heart problems?... yes no
5. Have you ever sprained/strained, dislocated, fractured, broken, or had repeated swelling and or pain with exercise, or other injuries of any bones or joints?...... yes no
   Head Neck Chest Shoulder Elbow Wrist Hand
   Back Hip Thigh Knee Shin/Calf Ankle Foot
6. Do you have any other medical problems? (i.e. mononucleosis, diabetes, exercised induced asthma)?.. yes no
7. Have you had any longstanding or congenital orthopedic problems?............. yes no

*Explain **YES** answers

____

____

____

____

I hereby state that, to the best of my knowledge, my answers to the above questions are correct.

Signature ________________________ Date ________________

Individual Trial Data From Subjects

Integrated EMG Activity in Walking **Vastus Lateralis**

Subject	µv Traditional Athletic Shoe	µv SkyFlex Plyometric Shoe	Difference (%)
1	11.55	17.01	147.3
2	19.25	21.81	111.3
3	10.68	9.51	89.0
4	28.05	25.71	91.7
5	19.91	34.84	175.0
6	6.66	8.60	129.1
7	22.64	25.02	110.5
8	11.37	12.59	110.7
		Average	**120.8%**
		Standard Deviation	**28.9%**

Integrated EMG Activity in Walking **Anterior Tibialis**

Subject	µv Traditional Athletic Shoe	µv SkyFlex Plyometric Shoe	Difference (%)
1	23.67	55.38	234.0
2	32.17	55.68	173.1
3	26.80	42.47	158.5
4	39.25	38.46	98.0
5	25.42	76.21	299.8
6	23.18	47.40	204.5
7	51.35	65.91	128.4
8	15.02	29.38	195.6
		Average	**186.5%**
		Standard Deviation	**62.9%**

Integrated EMG Activity in Walking **Gastrocnemius**

Subject	µv Traditional Athletic Shoe	µv SkyFlex Plyometric Shoe	Difference (%)
1	21.59	49.52	229.4
2	44.64	54.11	121.2
3	21.75	25.06	115.2
4	20.06	20.52	102.3
5	14.24	14.99	105.3
6	24.30	33.62	138.4
7	26.10	30.43	116.6
8	12.20	26.27	215.3
		Average	**143.0%**
		Standard Deviation	**50.3%**

Individual Trial Data From Subjects (cont'd)

Integrated EMG Activity in Walking **Peroneus Longus**

Subject	µv Traditional Athletic Shoe	µv SkyFlex Plyometric Shoe	Difference (%)
1	30.32	75.51	249.0
2	57.37	41.26	71.9
3	22.28	29.45	132.2
4	30.85	40.01	129.7
5	19.07	39.84	208.9
6	40.61	33.14	81.6
7	20.05	32.99	164.5
8	26.93	28.57	106.1

Average 143.0%
Standard Deviation 61.6%

Integrated EMG Activity in Vertical Jump **Vastus Lateralis**

Subject	µv Traditional Athletic Shoe	µv SkyFlex Plyometric Shoe	Difference (%)
1	161.92	146.76	90.6
2	316.95	223.37	70.5
4	168.42	172.22	102.3
5	228.01	226.50	99.3
7	143.78	141.13	98.2
8	90.32	122.74	135.9
9	125.38	139.88	11.6

Average 101.2%
Standard Deviation 19.9%

Integrated EMG Activity in Vertical Jump **Anterior Tibialis**

Subject	µv Traditional Athletic Shoe	µv SkyFlex Plyometric Shoe	Difference (%)
1	53.37	99.27	186.0
2	61.63	86.97	141.1
4	34.16	30.44	89.1
5	38.36	61.29	159.8
7	76.74	105.43	137.4
8	28.77	35.18	122.3
9	40.63	33.52	82.5

Average 131.2%
Standard Deviation 36.9%

Individual Trial Data From Subjects (cont'd)

Integrated EMG Activity in Vertical Jump **Gastrocnemius**

Subject	μv Traditional Athletic Shoe	μv SkyFlex Plyometric Shoe	**Difference (%)**
1	169.93	156.75	92.2
2	173.91	180.41	103.7
4	88.32	89.73	101.6
5	58.50	74.31	127.0
7	87.70	126.89	144.7
8	69.79	96.61	138.4
9	52.90	46.85	88.6

Average 113.8%
Standard Deviation 22.7%

Integrated EMG Activity in Vertical Jump **Peroneus Longus**

Subject	μv Traditional Athletic Shoe	μv SkyFlex Plyometric Shoe	**Difference (%)**
1	117.46	113.52	96.6
2	114.65	143.30	125.0
4	129.43	109.28	84.4
5	95.68	125.58	131.3
7	92.54	102.87	111.2
8	64.20	69.68	108.5
9	66.04	52.61	79.7

Average 105.2%
Standard Deviation 19.5%

Weekly recorded vertical jump measurements

Subject	Initial jump	2^{nd} jump	3^{rd} jump	4^{th} jump	5^{th} jump	Increase
1	30.0	29.5	31.0	31.5	n/a	1.5
2	28.5	28.5	29.0	29.0	30.0	1.5
3	30	28.5	29.5	30.0	31.5	1.5
4	25.0	25.0	25.5	25.5	26.0	1.0
5	24.5	25.0	25.0	25.0	24.5	0.0
6	28.0	27.5	27.0	27.5	27.5	-0.5
7	30.5	30.5	30.5	29.5	30.5	0.0
8	32.0	31.0	32.0	30.5	33.5	1.5
9	22.5	21.5	22.0	22.0	22.0	-0.5
10	30.0	29.0	30.5	28.5	30.5	0.5
11	20.5	22.5	22.5	23.5	24.0	3.5
12	27.0	27.0	26.5	28.5	26.5	-0.5
13	30.5	31.5	31.0	32.0	29.5	-1.0
14	26.5	27.0	27.5	28.5	28.0	1.5
15	**28.0**	**28.5**	**27.5**	**28.5**	**28.0**	**0.0**
16	**24.0**	**23.5**	**24.5**	**24.5**	**25.5**	**1.5**
17	**22.5**	**22.5**	**23.5**	**24.0**	**24.0**	**1.5**
18	**23.5**	**23.5**	**22.0**	**24.5**	**24.0**	**0.5**
19	**31.0**	**30.5**	**31.0**	**31.5**	**31.0**	**0.0**
20	**21.0**	**19.5**	**20.0**	**20.5**	**21.0**	**0.0**
21	**26.5**	**25.0**	**25.0**	**27.0**	**27.0**	**0.5**
22	**29.0**	**27.5**	**28.0**	**29.5**	**28.5**	**-0.5**
23	**30.0**	**29.0**	**27.0**	**28.5**	**29.5**	**-0.5**
24	**27.0**	**27.5**	**26.5**	**29.0**	**29.5**	**2.5**
25	**25.0**	**24.0**	**23.0**	**25.0**	**25.0**	**0.0**
26	**20.0**	**19.0**	**19.0**	**20.0**	**20.5**	**0.5**
27	**31.5**	**31.5**	**32.5**	**32.0**	**33.0**	**1.5**
28	**32.5**	**30.0**	**32.0**	**33.0**	**32.5**	**0.0**
29	**21.0**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**

Jump height is reported in inches
Regular face print indicates traditional athletic shoe subjects (n=14)
Bold face print indicates **SkyFlex® shoe subjects** (n=15)

SkyFlex® Plyometric Vertical Jump Intermediate Training Program

Stretches

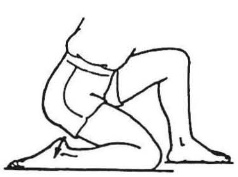
1 To stretch your **thighs**, the "hurdler" stretch can be used. This technique involves first sitting on the floor. Extend out straight forward one leg and tuck the other leg you wish to stretch behind you so that your ankle is against your buttocks and your knee rests on the floor The thigh is then stretched when you lean back gently and lie your back on the floor. Alternatively, you can stand up on one leg and bend the leg you wish to stretch behind you so that your heel is against your buttocks and your knee is pointing down to the floor. Grab the elevated ankle and slowly pull your leg up behind you. To maintain your balance, you may want to hold onto a chair with your free hand.

2 To stretch your **hamstrings**, the "hurdler" stretch can be used again. This time, while in the hurdler position (one leg straight out in fron of you with the other tucked behind), lean your body forward towards your outward leg. When leaning forward, always lean with your chest and chin, and do not bend from the back. You'll feel a sensation in the hamstring muscle on the back side of your outstretched leg. Once the right hamstring is stretched, switch extended legs and stretch the left hamstring.

3 To stretch your **lower back**, lie flat on your back and elevate your legs slightly. Reach with your arms and wrap your hands around the underside of your knees. Pull your legs to your chest.

4 To stretch your **groin**, assume an Indian-style position and attempt to place the bottoms of your feet flat against each other. Lean forwar and press your knees downward. Feel the tension in your groin muscles.

5 To stretch your **calves,** position yourself against a wall or sturdy structure as shown with the knee in front be and the knee behind straight. Point your toes directly toward the wall and hold both heels down. Lean into t wall until you feel a stretch and then hold it. Switch legs and repeat



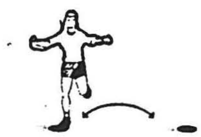
6 To stretch the **muscles in the front of your leg** position yourself as shown in a half-kneeling position. Point the toe of the leg on the ground straight back. Lean back over the leg on the ground until you feel a stretch. Switch legs and repeat.

SkyFlex® Plyometric Vertical Jump Intermediate Training Program

Exercises

1 **Plyometric Jog.** Simply slip on your SkyFlex trainers and jog a distance of twenty five yards. Turn around at the end of your jog, rest briefly, and jog back at a slightly quicker pace. Do as many of these twenty five yard jogs as prescribed. Each time, turn up the speed a little so that, for your last jog, you are going at about a 70% speed level. Concentrate on good running form. Remember, this is just a jog!!

2 **Swivel Hips.** This is a drill covering twenty five yards. Straddle an imaginary line. Begin jogging with your right foot always landing on the left side of the line and your left foot always landing on the right side of the line. Because you will be jogging forwards this crossing over of your legs will cause your hips to swivel. Like the plyometric jog, gradually increase the pace of each successive swivel hip jog until your last jog approaches a 70% speed level.

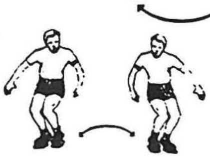


3 **Alternating Ankle Jump.** Mark two spots on the ground at least 3 feet apart. Stand in the middle of these markers and begin hopping from one foot to the other. When you land on your right foot, your right foot should be touching the ground marker to your right. Then, when you land on your left foot, that foot should be touching the marker on your left. This hopping back and forth should continue for the duration of the drill. As your skill level increases, move the markers so that they are wider than 3 feet apart.

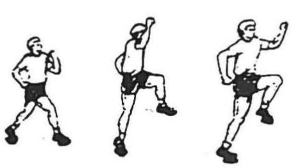
4 **Plyomteric Rope Training.** Very simple. Grab your favorite jump rope, slip on your SkyFlex trainers, and begin jumping rope. Set a pace you're comfortable with and can maintain for the duration of the drill. If you really want to push yourself and enhance the results of this drill, mix in squat jumping sets (usually 30 to 60 seconds) with the normal rope jumping. To do this, assume a squat position while you continue to jump and leap into the air a minimum of ten inches high for each jump. You will feel the increased stress levels in your legs until you switch back over to your normal rope jumping.

5 **Flexors.** Stand with feet no more than shoulder width apart and begin hopping up and down on your toes. Pivot your feet in and out with each jump so that you alternate touching your toes and heels each time you land on the ground. While striving to hop as high as possible, you will be landing toes in, toes out, toes in, toes out, and so on. This drill may feel a little awkward at first, but it is the best way to strengthen your lower leg muscles at different angles.

6 **Scissors.** This is another jumping in place drill. Take off with your right leg forward and left leg back, and land with your left leg forward and right leg back. Then, after spending minimal time on the ground, take off from the left leg forward right leg back position and land in a right leg forward left leg back position. Continue this alternating or "scissors" action as the hops continue. Keep a constant, smooth pace and get into the quickest rhythm you can maintain until the end of the drill.

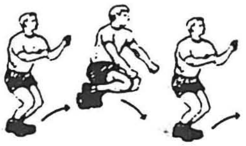


7 **Skis.** With both feet no more than shoulder width apart, jump up and down, taking off from and landing on both feet simultaneously. Begin simulating the motion of a downhill skier attacking a mountain of moguls. While keeping your shoulders square and always facing forward, twist the bottom half of your body (from the waist down) with each jump. First, land twisted to the right, then land twisted to the left. Continue this left-right-left-right skier action until the end of the drill. Concentrate on using your arms for balance and try to land each time with your toes pointing about 45 degrees to the right of left. This motion will, in turn, work your whole body and bolster your overall coordination.



8 **Three Step Leap.** First, stand with one foot slightly ahead of the other. Then take a 3 step take off (left-right-left or right-left-right) and leap upward off the last step. Your take off should be a vertical explosion. As soon as you land after the first jump, step int the next sequence of three steps. Continue this drill for the prescribed distance.

9 **Lateral Hops.** Position on the ground four objects, each two feet apart, that you will be hopping across laterally. Depending on your skill and comfort level, choose anything from 6 inch high blocks to 18 inch high cones to be your "lateral hurdles". Face forward with feet shoulder width apart and have the row of four hurdle items immediately stretched out to the right of you. Jump sideways down the row of lateral hurdles. When jumping, take off from two feet and land on two feet until you clear the last hurdle. After clea ing the last hurdle, land on your outside foot only and propel yourself back the other direction. Now, you'll be jumping laterally to your left. Again, once you clear the last hurdle, land on your outside foot only and switch directions again. Keep facing forward and keep jumping at a constant, steady pace!!



10 Two Foot Bound. While keeping feet no more than shoulder width apart, leap forward as far and as high as possible. By concentrating on jumping up and out, you will be strengthening the muscles needed for both vertical and horizontal explosiveness. Feel free to use your arms to help your body gain as much vertical and horizontal power as possible. Elbows must be brought behind the midline of the body so that the arms can be brought rapidly forward to generate momentum. Continue leaping, or bounding, in this manner for the prescribed distance keeping a smooth and constant pace.

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