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

Myles Haugen
University of North Dakota

Follow this and additional works at: https://commons.und.edu/pt-grad

Part of the Physical Therapy Commons

Recommended Citation
https://commons.und.edu/pt-grad/199

This Scholarly Project is brought to you for free and open access by the Department of Physical Therapy at UND Scholarly Commons. It has been accepted for inclusion in Physical Therapy Scholarly Projects by an authorized administrator of UND Scholarly Commons. For more information, please contact zeineb.yousif@library.und.edu.
AN ELECTROMYOGRAPHIC STUDY
OF THE EFFECTS OF PLYOMETRIC TRAINING SHOES
ON THE LOWER EXTREMITY

by

Myles Edwin Haugen
Bachelor of Science in Physical Therapy
University of North Dakota, 1998

An Independent Study
Submitted to the Graduate Faculty of the
Department of Physical Therapy
School of Medicine
University of North Dakota
in partial fulfillment of the requirements
for the degree of
Master of Physical Therapy

Grand Forks, North Dakota
May
1999
This Independent Study, submitted by Myles Edwin Haugen 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.

(Faculty Preceptor)

(Graduate School Advisor)

(Chairperson, Physical Therapy)
### PERMISSION

<table>
<thead>
<tr>
<th>Title</th>
<th>An Electromyographic Study of the Effects of Plyometric Training Shoes on the Lower Extremity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Department</td>
<td>Physical Therapy</td>
</tr>
<tr>
<td>Degree</td>
<td>Master of Physical Therapy</td>
</tr>
</tbody>
</table>

In presenting this Independent Study Report in partial fulfillment of the requirements for a graduate degree from the University of North Dakota, I agree that the Department of Physical Therapy shall make it freely available for inspection. I further agree that permission for extensive copying for scholarly purposes may be granted by the professor who supervised my work or, in his/her absence, by the Chairperson of the department. It is understood that any copying or publication or other use of this Independent Study Report or part thereof for financial gain shall not be allowed without my written permission. It is also understood that due recognition shall be given to me and the University of North Dakota in any scholarly use which may be made of any material in my Independent Study Report.

**Signature**

**Date** 12-17-98

iii
TABLE OF CONTENTS

List of Figures ........................................................................................................... v
List of Tables ........................................................................................................... vi
Acknowledgements ................................................................................................. vii
Abstract ................................................................................................................... viii
Chapter 1: Introduction .............................................................................................. 1
Chapter 2: Literature Review ................................................................................... 3
Chapter 3: Methods .................................................................................................. 9
Chapter 4: Results .................................................................................................... 22
Chapter 5: Discussion ............................................................................................... 31
Appendices ................................................................................................................ 36
References ................................................................................................................ 55
### LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. SkyFlex® plyometric shoes</td>
<td>11</td>
</tr>
<tr>
<td>2. Electrode placement sites</td>
<td>13</td>
</tr>
<tr>
<td>3. VerTec® vertical height measurement device</td>
<td>19</td>
</tr>
<tr>
<td>4. Average selected lower extremity EMG muscle activity during walking with traditional athletic shoes</td>
<td>23</td>
</tr>
<tr>
<td>5. Average selected lower extremity EMG muscle activity during walking with SkyFlex® plyometric shoes</td>
<td>24</td>
</tr>
<tr>
<td>6. EMG activity during walking with traditional athletic and SkyFlex® plyometric shoes</td>
<td>27</td>
</tr>
<tr>
<td>7. EMG activity during vertical jump with traditional athletic and SkyFlex® plyometric shoes</td>
<td>28</td>
</tr>
<tr>
<td>8. Mean change in vertical jump height of the two training groups</td>
<td>30</td>
</tr>
</tbody>
</table>
# LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Subject Characteristics</td>
<td>9</td>
</tr>
<tr>
<td>2. Surface Electrode Placement</td>
<td>14</td>
</tr>
<tr>
<td>3. Control Group Characteristics</td>
<td>17</td>
</tr>
<tr>
<td>4. Experimental Group Characteristics</td>
<td>17</td>
</tr>
<tr>
<td>5. Average Lower Extremity EMG Activity During Walking with Traditional and SkyFlex® Plyometric Athletic Shoes</td>
<td>25</td>
</tr>
<tr>
<td>6. EMG Activity During Vertical Jump with Traditional and SkyFlex® Plyometric Athletic Shoes</td>
<td>26</td>
</tr>
<tr>
<td>7. Paired Samples t-test: Initial Mean and Final Mean Vertical Jump Heights for SkyFlex® and Traditional groups</td>
<td>29</td>
</tr>
<tr>
<td>8. Analysis of Covariance: Unadjusted and Adjusted Means and Standard Deviations (SD) for SkyFlex® and Traditional Groups</td>
<td>29</td>
</tr>
</tbody>
</table>
ACKNOWLEDGEMENT

I would like to sincerely thank my mom and dad for their love and support throughout my college career. Without them, none of this would be possible. To my brothers and sisters, whom I love and respect, thanks for pushing me to follow my dreams. I would also like to thank my preceptor, Tom Mohr, for all his hard work, guidance, and knowledge with this paper and throughout these past three years. Thank you to Renee Mabey, for all her help with statistics and formulating results. Thanks to my partners: Heather Philips, Sue Buckley, and Brian Laumb, who have made this study worthwhile, fun, and manageable. I would also like to thank the whole PT faculty who have given a lot of time, knowledge, and dedication to shaping me into a physical therapist. Last but not least, to my roommates at the Brown House, thanks for making these last years of college an experience never to be forgotten.
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 plyometric training shoes in conjunction 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 1

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. 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

A large part of American’s interest is directed to athletics. There has been an increasing number of athletic participants during this past decade, whether professional, amateur, or “weekend warrior”. As these numbers increase, the level of performance also rises. Today, athletes must train harder, and smarter, to be competitive. New systems of training have been developed to increase the productivity of an athlete’s training. Plyometric training is one of these methods which has helped athletes reach these new levels.2

Strength, speed, and power are essentials strived for by competitive athletes. Plyometrics was designed to bridge the gap between strength and power required to produce explosive movements necessary in sports.3 The basis of this system of training is the dynamic overload of an eccentrically activated muscle immediately prior to a concentric contraction of the same muscle to produce a more powerful contraction.2,3 A study by Berger4 revealed that this type of dynamic overload training produced better results than static overload training. By forcibly stretching an activated muscle the myotatic stretch reflex is evoked, and mechanical energy is stored in the elastic elements of the muscle.5,6 The potential energy from both of these mechanisms is utilized only if the time between the eccentric phase and the concentric phase is brief. This will elicit a high force production over a short time period, in otherwords a more powerful movement.7 It is speculated that with an adequate training period, a chronic
neuromuscular adaptation should occur within the specific muscles worked and causing a carryover of the explosive movement.\textsuperscript{8} Plymetrics is strictly an anaerobic activity which utilizes the creatine phosphate energy system.\textsuperscript{2} This allows the muscle to store maximal energy in the muscle before a single explosive act is performed.\textsuperscript{2,8}

The muscle spindle is the primary receptor for detection of elongation in the musculotendinous unit.\textsuperscript{9} It responds to both the magnitude and the rate of change in the length of the muscle fibers. The muscle spindle consists of intrafusal fibers, nuclear bag and chain fibers, and secondary receptors, the gamma motor system. As the intrafusal fibers are stretched, impulses are conducted to the spinal cord and then return to the same muscle to stimulate a contraction. This is the myotatic stretch reflex which is produced so the muscles are not actively overstretched. The gamma motor system sets the threshold of response of the intrafusals. When the gamma motors are active, they put the intrafusals on stretch lowering the threshold for the spindle. If gamma motor activity is low, more of a stretch is needed for activation. The golgi tendon organ also responds to excessive tension by either powerful contractions or stretching of the muscle.\textsuperscript{10} It acts as inhibitory response to muscle tension, decreasing the muscle activity.

The muscle spindle is put on stretch during the eccentric phase of plyometrics during initial contact. The dynamic response of muscle spindle is elicited by the quickness of the length change in the intrafusal fibers.\textsuperscript{8} This in turn will increase the motor unit discharge and the number of motor units activated, which leads to an increased intensity of work. Plyometric drills invoke the myotatic reflex by using jumping drills, causing muscle overload following stretch. The intrafusal fibers are
activated and cause the muscles involved to contract powerfully to prevent overstretching.\textsuperscript{9}

The storage of potential energy in the elastic components of a musculotendinous unit plays a large role in plyometric training.\textsuperscript{6,9-14} As a contracted muscle is forcibly stretched, mechanical energy is absorbed by the muscle. This potential energy is released during the following concentric phase if the amortization phase is brief, the time between the eccentric and concentric phases. Bosco et al.\textsuperscript{14} suggests that this is due to the forcibly stretching of myosin heads against their natural tendency of rotation to a position of higher potential energy. This causes a muscle to act like a spring being compressed, during the eccentric phase, and recoiling, in the concentric phase. Cavagna et al.\textsuperscript{12} determined that a muscle will have a greater force production immediately after being stretched in a contracted state then when a muscle shortens after an isometric contraction, or from a relaxed state. He estimates that a muscle is 27.8 percent more efficient when prestretched. Bosco et al.\textsuperscript{13} also acknowledged the improvement of muscular performance due to elastic recoil of the muscle. The subjects in this study had orthopedic casts so only their ankle joint could move in their lower extremity. The study revealed that 72 percent of muscle energy after prestretch was due to the elastic energy recoil, the rest being due to the myotatic stretch reflex.\textsuperscript{13}

The combination of the myotatic reflex and the elastic recoil is termed the stretch-shortening cycle (SSC). Humphries et al.\textsuperscript{7} and Bosco et al.\textsuperscript{15} determined that the neuromuscular system has a limited time to react (50-75 msec) to forces applied to the muscle during the SSC. Bosco et al.\textsuperscript{15} has also shown that an anticipatory muscular contraction occurs 100 msec before initial contact, causing the intrafusal fibers to be
activated and overcome the neuromuscular delay. This lead to other studies by Bosco and Viitasalo\textsuperscript{9} and Bosco et al.\textsuperscript{13} which concluded that the SSC was a combination of elastic recoil and the myotatic reflex. Kyrolainen and Gollhofer\textsuperscript{16} stated that if the preprogramming of the musculotendinous unit did not happen before ground contact, no recoil of the elastic energy can be expected. The high EMG activity at the end of the eccentric phase enhances the stiffness of the muscle and increases the amount of energy stored.\textsuperscript{9,13,16} Preprogramming of the musculotendinous unit is also dependent on the muscle structure, density of synaptic connections between motor neurons and spindle afferents, the amplitude of monosynaptic EPSP’s, and the amount of EMG potentiation during stretching of a muscle (slow versus fast twitch fibers).\textsuperscript{9} High stretch speeds, short amortization phase, and small angular displacement enhances the efficiency of these combined mechanisms.\textsuperscript{11,12}

Plyometric training emphasizes the fast explosive movements which may carryover to athletic performance, but it also may provide motivational and practical advantages.\textsuperscript{21} It may lead to greater enthusiasm of the trainer and it is a simple spot free exercise. Due to the high impact forces, it increases the chance of injury related to landing.\textsuperscript{7,21,22}

Previous studies by Cook et al.\textsuperscript{17} reported no significant difference in vertical jump or 40 yard sprint times when comparing groups training with plyometric shoes or with traditional tennis shoes. They associated an increase in anterior tibial pain with subjects training with the plyometric shoes. Flarity et al.\textsuperscript{8} showed conflicting results stating a significant difference was found in vertical jump and sprinting times after training with a plyometric shoe. They also revealed that the plyometric training shoe
increased the anaerobic power and anaerobic capacity of subjects. They speculate that this increase in anaerobic power has the potential for increasing athletic performance skill with long term use of the plyometric shoe. This shows controversy in the limited amount of literature on this type of training system.

Our study compares the EMG activity of walking with standard tennis shoes and the SkyFlex® shoes. Normal gait is the basic sequence of limb motion that serve to progress the body along a desired path while maintaining weight bearing stability, conserving energy, and absorbing the shock of floor impact. Although there is some variation from person to person due to individualistic gait patterns and body structure, the lower extremity muscles show a cyclic pattern of activity during the gait cycle.

The anterior tibialis becomes active in pre-swing to move the foot from plantarflexion at toe-off to a neutral position for the swing phase. By the end of pre-swing, the anterior tibialis activity peaks and continues to eccentrically hold the foot in neutral. Before the initial swing, the anterior tibialis activity decreases until terminal swing phase is reached, and it begins to increase again. Activity peaks slightly after initial contact and decreases throughout loading response as it eccentrically controls ankle plantarflexion. Anterior tibialis activity stops at mid-stance.

The gastrocnemius becomes active during loading response by eccentrically controlling the tibia rotating over the fixed foot. The activity continues to increase through mid-stance and peaks in terminal stance when the gastrocnemius concentrically contracts to begin push off. The gastrocnemius activity decreases rapidly and is inactive by the end of terminal swing.
The peroneous longus activity is similar to the gastrocnemius. It begins an eccentric contraction in mid-stance to help control tibia translation over the fixed foot. Activity continues to rise until it peaks in mid-terminal swing where the peroneus longus concentrically contracts to aid in push off. It also augments intertarsal stability on the lateral aspect of the foot. The peroneous longus activity declines and becomes inactive at the end of terminal swing.

The vastus lateralis becomes active at the beginning of terminal swing by concentrically extending the knee in preparation for initial contact. At initial contact the vastus lateralis begins to eccentrically control knee flexion. Its activity peaks at the end of loading response, and begins to decline until it is inactive before the completion of mid-stance.
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 1). 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 1. Subject Characteristics (n=10)

<table>
<thead>
<tr>
<th></th>
<th>AVERAGE</th>
<th>RANGE</th>
<th>STANDARD DEVIATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>23</td>
<td>21-25</td>
<td>1.41</td>
</tr>
<tr>
<td>Height (inches)</td>
<td>71</td>
<td>69-75.5</td>
<td>2.21</td>
</tr>
<tr>
<td>Weight (pounds)</td>
<td>165</td>
<td>137-188</td>
<td>18.06</td>
</tr>
</tbody>
</table>
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 (Figure 1). The platform is attached to the sole of the shoe therefore preventing the heel from striking the ground during training activities.\textsuperscript{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.\textsuperscript{17} 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 1. 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.\textsuperscript{21} 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 2 and Table 2). 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.\textsuperscript{22}
**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 2.** Electrode placement sites
Table 2. Surface Electrode Placement

<table>
<thead>
<tr>
<th>MUSCLE</th>
<th>MEASUREMENTS FOR ELECTRODE PLACEMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vastus Lateralis</td>
<td>Along a line 1/4 the distance from the lateral knee joint line to the ASIS and over the muscle belly</td>
</tr>
<tr>
<td>Anterior Tibialis</td>
<td>Along a line 1/3 the distance from the inferior patellar pole to the lateral malleolus and over the muscle belly</td>
</tr>
<tr>
<td>Peroneus Longus</td>
<td>Along a line 1/4 the distance from the fibular head to the lateral malleolus</td>
</tr>
<tr>
<td>Gastrocnemius</td>
<td>Along a line 1/3 the distance from the fibular head to the calcaneus and over the muscle belly</td>
</tr>
</tbody>
</table>

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 (Tables 3 and 4). 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 3. Control Group Characteristics (n=14)

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Range</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>22.92</td>
<td>21-27</td>
<td>1.59</td>
</tr>
<tr>
<td>Height (inches)</td>
<td>68.07</td>
<td>65-77</td>
<td>13.34</td>
</tr>
<tr>
<td>Weight (pounds)</td>
<td>176.21</td>
<td>140-215</td>
<td>23.95</td>
</tr>
</tbody>
</table>

Table 4. Experimental Group Characteristics (n=15)

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Range</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>22.66</td>
<td>21-27</td>
<td>1.67</td>
</tr>
<tr>
<td>Height (inches)</td>
<td>70.46</td>
<td>68-76</td>
<td>2.38</td>
</tr>
<tr>
<td>Weight (pounds)</td>
<td>168.73</td>
<td>137-220</td>
<td>22.13</td>
</tr>
</tbody>
</table>

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 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 3). 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 $45^\circ$ to either the right or left. 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. Each subject placed the
Figure 3. 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 pictorial 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 4 and 5 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 traditional shoes and the 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.
Figure 4. Averaged selected lower extremity EMG muscle activity during walking with traditional athletic shoes
Figure 5. Averaged selected lower extremity EMG muscle activity during walking with SkyFlex® plyometric shoes
Quantitative

Walking

Table 5 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, vastus lateralis, peroneus longus, anterior tibialis, and gastrocnemius while wearing the SkyFlex® plyometric training shoes was 120.8%, 143.0%, 186.5%, and 143.0%, respectively (Figure 6). 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 5. Average Lower Extremity EMG Activity During Walking with Traditional and SkyFlex® Plyometric Athletic Shoes

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Mean Traditional Athletic Shoe</th>
<th>Mean SkyFlex® Plyometric Shoe</th>
<th>Change %</th>
<th>t (two-tail)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vastus Lateralis</td>
<td>16.264 μV</td>
<td>19.386 μV</td>
<td>120.8</td>
<td>0.142</td>
</tr>
<tr>
<td>Peroneus Longus</td>
<td>30.935 μV</td>
<td>40.096 μV</td>
<td>143.0</td>
<td>0.206</td>
</tr>
<tr>
<td>Anterior Tibialis</td>
<td>29.608 μV</td>
<td>51.361 μV</td>
<td>186.5</td>
<td>0.004*</td>
</tr>
<tr>
<td>Gastrocnemius</td>
<td>23.110 μV</td>
<td>31.815 μV</td>
<td>143.0</td>
<td>0.030*</td>
</tr>
</tbody>
</table>

*significant at the .05 level

Vertical Jump

Table 6 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
EMG activity 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 7).

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

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Mean Traditional Athletic Shoe</th>
<th>Mean SkyFlex® Plyometric Shoe</th>
<th>Change %</th>
<th>t (two-tail)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vastus Lateralis</td>
<td>176.397 μV</td>
<td>167.514 μV</td>
<td>101.2</td>
<td>0.580</td>
</tr>
<tr>
<td>Peroneus Longus</td>
<td>97.143 μV</td>
<td>102.406 μV</td>
<td>105.2</td>
<td>0.500</td>
</tr>
<tr>
<td>Anterior Tibialis</td>
<td>47.666 μV</td>
<td>64.586 μV</td>
<td>131.2</td>
<td>0.058</td>
</tr>
<tr>
<td>Gastrocnemius</td>
<td>100.150 μV</td>
<td>110.221 μV</td>
<td>113.8</td>
<td>0.199</td>
</tr>
</tbody>
</table>

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 7 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
Figure 6. EMG activity during walking with traditional athletic and SkyFlex plyometric shoes.
Figure 7. EMG activity during vertical jump with traditional athletic and SkyFlex plyometric shoes
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).

<table>
<thead>
<tr>
<th>Group</th>
<th>Initial Mean</th>
<th>SD</th>
<th>Final Mean</th>
<th>SD</th>
<th>Mean Diff.</th>
<th>SD</th>
<th>t</th>
</tr>
</thead>
<tbody>
<tr>
<td>SkyFlex®</td>
<td>26.46</td>
<td>3.92</td>
<td>27.04</td>
<td>3.89</td>
<td>0.57</td>
<td>0.87</td>
<td>2.45*</td>
</tr>
<tr>
<td>Traditional</td>
<td>27.42</td>
<td>3.52</td>
<td>28.04</td>
<td>3.35</td>
<td>0.62</td>
<td>1.26</td>
<td>1.76</td>
</tr>
</tbody>
</table>

*significant at the .05 level

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

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>SS</th>
<th>MS</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Covariate (initial jump height)</td>
<td>1</td>
<td>303.99</td>
<td>303.99</td>
<td>265.54</td>
<td>0.000</td>
</tr>
<tr>
<td>Group (shoes)</td>
<td>1</td>
<td>0.07</td>
<td>0.07</td>
<td>0.067</td>
<td>0.798</td>
</tr>
<tr>
<td>Error</td>
<td>24</td>
<td>27.47</td>
<td>1.14</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>Total (corrected)</td>
<td>26</td>
<td>338.24</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
</tbody>
</table>
Figure 8. Mean change in vertical jump height of the two training groups
CHAPTER 5
Discussion

Manufacturers have claimed that using the SkyFlex® training system will improve an athlete’s vertical jump performance up to six inches, and they also stated that within a four week training period, a noticeable improvement will be seen.1 My study did show a significant increase in vertical jump height from initial jump to final jump within the SkyFlex® trained group, but when compared to the traditional shoe group, there was no advantage of training with the plyometric shoes. The results are similar with the study done by Cook et al.17 where no significant increase of vertical jump height was found in athletes who trained with a similar type of plyometric training shoe. Another study by Flarity et al.8 has conflicting results stating that training with plyometric shoes did significantly increase vertical jump height of athletes. The differences in results could be due to subject numbers, exercise protocols, subject variability, or the length of training period.

This study also incorporated EMG analysis to determine if there was an increase in muscle activity when using the SkyFlex® plyometric shoe during normal gait and vertical jump. The results revealed a significant increase of EMG activity in the anterior tibialis and the gastrocnemius muscles while wearing the SkyFlex® shoe as compared to traditional shoes during normal gait. No significant difference was found in EMG activity of vertical jump while wearing either shoe.
Gait

The increase in activity of the anterior tibialis may be caused by the increase of concentric action needed to clear the large platform of the shoe during the swing phase of normal gait. Another reason for the higher EMG activity could be that the platform gives the anterior part of the shoe additional weight, increasing the muscle activity needed to dorsiflex the ankle and hold it during swing phase. The anterior platform causes the ankle to have increased dorsiflexion at foot flat which increases the amount of plantarflexion needed to reach toe off. This would cause a higher amount of activity from the gastrocnemius muscle the stance period increasing the EMG activity as compared to normal shoes.

Vertical Jump

The increased stretch to the plantarflexors may also cause the golgi tendon organ to fire due to the increased tension. This would cause an inhibition of the stretch reflex, and limiting the EMG muscle activity during vertical jump. The increase in angular displacement at the ankle may cause a longer stretch time, which may also limit the efficiency of the stretch reflex. Another suspected cause for non-significant difference in EMG activity within the gastrocnemius muscle during the vertical jump is due to the fact that it is a two joint muscle. When performing the vertical jump both the ankles and knees are bent decreasing the ability to stretch the gastrocnemius muscle thereby limiting its force production in the vertical jump. Bangerter et al performed a study concluding that the hip extensors, knee extensors, or a combination of the two contribute to vertical jump while the plantarflexors have little contribution.
The effectiveness of plyometric training over other training methods has been controversial. Brown et al.\textsuperscript{5} found that plyometrics increased vertical jump heights in high school basketball players. Steben and Steben\textsuperscript{25} showed significant improvements in high jump and triple jump performance following plyometric training in high school athletes. Miller\textsuperscript{26} and Bosco and Komi\textsuperscript{15} also showed improvements in vertical jump with plyometrics. Clutch et al.\textsuperscript{27} found improvements with depth jumps with college volleyball players, but not a significant difference over a regular jumping routine. Blattner and Noble\textsuperscript{28} compared isokinetic and plyometric training and concluded that both showed improvement, but neither one was more effective. Scoles\textsuperscript{29} study of college age subjects found that depth jumps did not improve vertical jump or long jump performances. Finally, Kramer et al.\textsuperscript{30} found no advantages with plyometric training versus standard training protocols in improving rowing ergometer, weight lifting, vertical jump, or isokinetic performance. These conflicting findings may be due to differences in training periods, individual abilities of subjects, or the closeness of match between the plyometric drill and the exercise tested.

This study did not show an advantage of training with SkyFlex\textsuperscript{®} shoes over traditional shoes. Plyometric shoes were produced on the theory that the anterior platform would enhance the efficiency of the calf muscle through the stretch reflex.\textsuperscript{1} Studies by Bosco et al.\textsuperscript{11} and Steben\textsuperscript{25} have shown that the SSC is more efficient with high stretch speeds, short amortization phase, and small angular movements. The platform will cause an increase in the stretch magnitude, but efficiency of the SSC is related to the rate of stretch, not the magnitude of the stretch.\textsuperscript{11,12} The increased length of stretch also will cause the time of stretch to be higher and the angular displacement to increase,
causing decreased efficiency of the stretch reflex. The golgi tendon organ may also be caused to fire due to the increased tension in the muscle. This would cause an inhibition of the stretch reflex, also decreasing muscle activity.

**Limitations**

The small number of subjects within each part of this study was a limiting factor when analyzing the results. An outlier within the small group would cause a large standard deviation in the results. Other factors that could have a big influence on the results are subject variabilities. That is, a well-conditioned subject might be closer to their maximal vertical jump height and therefore not show much improvement over the training period. Also the percentage of fast or slow twitch muscle fiber types of subjects may have played a role. A larger number of fast twitch fibers will recruit more motor units and produce a more powerful movement and a higher vertical jump height.

The length of this study may need to be increased as most plyometric studies train subjects for an 8 week period or longer. Research suggests that neuromuscular adaptation should occur within the specific muscles worked and in time, enhance the stretch reflex efficiency. The four week training period may not have been of sufficient time for these adaptations to occur.

Another limitation is of subject compliance to the training protocols. The subjects were observed during their first workout and whenever questions about the performance of an exercise arose. Therefore it was up to the subjects to perform the workouts on their own. The number of workouts between recorded jumps was set, but the scheduling of workouts between was left up to the subjects. This may have lead to consecutive training days, or training on the day before recorded jump heights were taken which may
have influenced the results. Also the intensity of training may have been less among different subjects.

**Future Research**

Increasing the subject numbers of future studies would increase the power of the results and also decrease the deviation due to outliers within a group. The workouts should be scheduled and observed by a member of the study coordinators. EMG analysis of the hip extensors and knee extensors would be valuable in determining the amount of activity produced in these muscles compared to the gastrocnemius. The amount of soleus activity during vertical jump would also be of interest to see if the plyometric shoe causes enhanced activity of this muscle. Performing motion analysis to determine the biomechanics of the subjects during vertical jump may also influence the ideas of how the plyometric shoe works and muscles activated.

**Conclusion**

This study did not show any advantages of training with the plyometric shoe to enhance vertical jump heights. It did show an increase in activity of the gastrocnemius during walking, but did not show significant differences during vertical jump. The high dynamic forces due to the impact at initial contact is associated with an increased chance of lower extremity injuries. The hypothesis or ideas of how the platform may effect the biomechanics and muscular efficacy of the lower extremity needs to be researched more to determine the validity of this type of training.
APPENDIX
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
PROPOSED SCHOOL/COLLEGE: Medicine & Health Sciences DEPARTMENT: Physical Therapy
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) ___ USE OF DRUG ___ COOPERATING INSTITUTION

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

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

___ PRISONERS ___ ABORTUSES ___ 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 utilizing SkyFlex® plyometric training shoes.
The project will be completed at the University of North Dakota Department of Physical Therapy in Grand Forks, ND.

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 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 electromyographic (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 training 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 psychological, 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:**

\[Signature\]  
Principal Investigators  
Date  
4/20/98

\[Signature\]  
Project Director or Student Adviser  
Date  
4/20/93

\[Signature\]  
Training or Center Grant Director  
Date

(Revised 3/1996)
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
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 will 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**

<table>
<thead>
<tr>
<th>Subject</th>
<th>μV Traditional Athletic Shoe</th>
<th>μV SkyFlex Plyometric Shoe</th>
<th>Difference (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>11.55</td>
<td>17.01</td>
<td>147.3</td>
</tr>
<tr>
<td>2</td>
<td>19.25</td>
<td>21.81</td>
<td>111.3</td>
</tr>
<tr>
<td>3</td>
<td>10.68</td>
<td>9.51</td>
<td>89.0</td>
</tr>
<tr>
<td>4</td>
<td>28.05</td>
<td>25.71</td>
<td>91.7</td>
</tr>
<tr>
<td>5</td>
<td>19.91</td>
<td>34.84</td>
<td>175.0</td>
</tr>
<tr>
<td>6</td>
<td>6.66</td>
<td>8.60</td>
<td>129.1</td>
</tr>
<tr>
<td>7</td>
<td>22.64</td>
<td>25.02</td>
<td>110.5</td>
</tr>
<tr>
<td>8</td>
<td>11.37</td>
<td>12.59</td>
<td>110.7</td>
</tr>
</tbody>
</table>

Average 120.8%  
Standard Deviation 28.9%

Integrated EMG Activity in Walking  **Anterior Tibialis**

<table>
<thead>
<tr>
<th>Subject</th>
<th>μV Traditional Athletic Shoe</th>
<th>μV SkyFlex Plyometric Shoe</th>
<th>Difference (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>23.67</td>
<td>55.38</td>
<td>234.0</td>
</tr>
<tr>
<td>2</td>
<td>32.17</td>
<td>55.68</td>
<td>173.1</td>
</tr>
<tr>
<td>3</td>
<td>26.80</td>
<td>42.47</td>
<td>158.5</td>
</tr>
<tr>
<td>4</td>
<td>39.25</td>
<td>38.46</td>
<td>98.0</td>
</tr>
<tr>
<td>5</td>
<td>25.42</td>
<td>76.21</td>
<td>299.8</td>
</tr>
<tr>
<td>6</td>
<td>23.18</td>
<td>47.40</td>
<td>204.5</td>
</tr>
<tr>
<td>7</td>
<td>51.35</td>
<td>65.91</td>
<td>128.4</td>
</tr>
<tr>
<td>8</td>
<td>15.02</td>
<td>29.38</td>
<td>195.6</td>
</tr>
</tbody>
</table>

Average 186.5%  
Standard Deviation 62.9%

Integrated EMG Activity in Walking  **Gastrocnemius**

<table>
<thead>
<tr>
<th>Subject</th>
<th>μV Traditional Athletic Shoe</th>
<th>μV SkyFlex Plyometric Shoe</th>
<th>Difference (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>21.59</td>
<td>49.52</td>
<td>229.4</td>
</tr>
<tr>
<td>2</td>
<td>44.64</td>
<td>54.11</td>
<td>121.2</td>
</tr>
<tr>
<td>3</td>
<td>21.75</td>
<td>25.06</td>
<td>115.2</td>
</tr>
<tr>
<td>4</td>
<td>20.06</td>
<td>20.52</td>
<td>102.3</td>
</tr>
<tr>
<td>5</td>
<td>14.24</td>
<td>14.99</td>
<td>105.3</td>
</tr>
<tr>
<td>6</td>
<td>24.30</td>
<td>33.62</td>
<td>138.4</td>
</tr>
<tr>
<td>7</td>
<td>26.10</td>
<td>30.43</td>
<td>116.6</td>
</tr>
<tr>
<td>8</td>
<td>12.20</td>
<td>26.27</td>
<td>215.3</td>
</tr>
</tbody>
</table>

Average 143.0%  
Standard Deviation 50.3%
Individual Trial Data From Subjects (cont’d)

Integrated EMG Activity in Walking Peroneus Longus

<table>
<thead>
<tr>
<th>Subject</th>
<th>μV Traditional Athletic Shoe</th>
<th>μV SkyFlex Plyometric Shoe</th>
<th>Difference (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>30.32</td>
<td>75.51</td>
<td>249.0</td>
</tr>
<tr>
<td>2</td>
<td>57.37</td>
<td>41.26</td>
<td>71.9</td>
</tr>
<tr>
<td>3</td>
<td>22.28</td>
<td>29.45</td>
<td>132.2</td>
</tr>
<tr>
<td>4</td>
<td>30.85</td>
<td>40.01</td>
<td>129.7</td>
</tr>
<tr>
<td>5</td>
<td>19.07</td>
<td>39.84</td>
<td>208.9</td>
</tr>
<tr>
<td>6</td>
<td>40.61</td>
<td>33.14</td>
<td>81.6</td>
</tr>
<tr>
<td>7</td>
<td>20.05</td>
<td>32.99</td>
<td>164.5</td>
</tr>
<tr>
<td>8</td>
<td>26.93</td>
<td>28.57</td>
<td>106.1</td>
</tr>
</tbody>
</table>

Average 143.0%  
Standard Deviation 61.6%

Integrated EMG Activity in Vertical Jump Vastus Lateralis

<table>
<thead>
<tr>
<th>Subject</th>
<th>μV Traditional Athletic Shoe</th>
<th>μV SkyFlex Plyometric Shoe</th>
<th>Difference (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>161.92</td>
<td>146.76</td>
<td>90.6</td>
</tr>
<tr>
<td>2</td>
<td>316.95</td>
<td>223.37</td>
<td>70.5</td>
</tr>
<tr>
<td>4</td>
<td>168.42</td>
<td>172.22</td>
<td>102.3</td>
</tr>
<tr>
<td>5</td>
<td>228.01</td>
<td>226.50</td>
<td>99.3</td>
</tr>
<tr>
<td>7</td>
<td>143.78</td>
<td>141.13</td>
<td>98.2</td>
</tr>
<tr>
<td>8</td>
<td>90.32</td>
<td>122.74</td>
<td>135.9</td>
</tr>
<tr>
<td>9</td>
<td>125.38</td>
<td>139.88</td>
<td>11.6</td>
</tr>
</tbody>
</table>

Average 101.2%  
Standard Deviation 19.9%

Integrated EMG Activity in Vertical Jump Anterior Tibialis

<table>
<thead>
<tr>
<th>Subject</th>
<th>μV Traditional Athletic Shoe</th>
<th>μV SkyFlex Plyometric Shoe</th>
<th>Difference (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>53.37</td>
<td>99.27</td>
<td>186.0</td>
</tr>
<tr>
<td>2</td>
<td>61.63</td>
<td>86.97</td>
<td>141.1</td>
</tr>
<tr>
<td>4</td>
<td>34.16</td>
<td>30.44</td>
<td>89.1</td>
</tr>
<tr>
<td>5</td>
<td>38.36</td>
<td>61.29</td>
<td>159.8</td>
</tr>
<tr>
<td>7</td>
<td>76.74</td>
<td>105.43</td>
<td>137.4</td>
</tr>
<tr>
<td>8</td>
<td>28.77</td>
<td>35.18</td>
<td>122.3</td>
</tr>
<tr>
<td>9</td>
<td>40.63</td>
<td>33.52</td>
<td>82.5</td>
</tr>
</tbody>
</table>

Average 131.2%  
Standard Deviation 36.9%
Individual Trial Data From Subjects (cont’d)

Integrated EMG Activity in Vertical Jump Gastrocnemius

<table>
<thead>
<tr>
<th>Subject</th>
<th>μV Traditional Athletic Shoe</th>
<th>μV SkyFlex Plyometric Shoe</th>
<th>Difference (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>169.93</td>
<td>156.75</td>
<td>92.2</td>
</tr>
<tr>
<td>2</td>
<td>173.91</td>
<td>180.41</td>
<td>103.7</td>
</tr>
<tr>
<td>4</td>
<td>88.32</td>
<td>89.73</td>
<td>101.6</td>
</tr>
<tr>
<td>5</td>
<td>58.50</td>
<td>74.31</td>
<td>127.0</td>
</tr>
<tr>
<td>7</td>
<td>87.70</td>
<td>126.89</td>
<td>144.7</td>
</tr>
<tr>
<td>8</td>
<td>69.79</td>
<td>96.61</td>
<td>138.4</td>
</tr>
<tr>
<td>9</td>
<td>52.90</td>
<td>46.85</td>
<td>88.6</td>
</tr>
</tbody>
</table>

Average 113.8%
Standard Deviation 22.7%

Integrated EMG Activity in Vertical Jump Peroneus Longus

<table>
<thead>
<tr>
<th>Subject</th>
<th>μV Traditional Athletic Shoe</th>
<th>μV SkyFlex Plyometric Shoe</th>
<th>Difference (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>117.46</td>
<td>113.52</td>
<td>96.6</td>
</tr>
<tr>
<td>2</td>
<td>114.65</td>
<td>143.30</td>
<td>125.0</td>
</tr>
<tr>
<td>4</td>
<td>129.43</td>
<td>109.28</td>
<td>84.4</td>
</tr>
<tr>
<td>5</td>
<td>95.68</td>
<td>125.58</td>
<td>131.3</td>
</tr>
<tr>
<td>7</td>
<td>92.54</td>
<td>102.87</td>
<td>111.2</td>
</tr>
<tr>
<td>8</td>
<td>64.20</td>
<td>69.68</td>
<td>108.5</td>
</tr>
<tr>
<td>9</td>
<td>66.04</td>
<td>52.61</td>
<td>79.7</td>
</tr>
</tbody>
</table>

Average 105.2%
Standard Deviation 19.5%
Weekly recorded vertical jump measurements

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

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 front 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 forward 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 being and the knee behind straight. Point your toes directly toward the wall and hold both heels down. Lean into the 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. **Plyometric 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 into 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 clearing 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.
REFERENCES


