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

Heather Phillips
University of North Dakota

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

by

Heather Phillips
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 Heather M. Phillips 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

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

Department Physical Therapy

Degree Master of Physical Therapy

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Date 12/14/96
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I would like to thank Dr. Tom Mohr, my graduate advisor, for his dedication to research and his assistance and support in completing this independent study. I would like to give a special thanks to Sue Buckley, Myles Haugen, and Brian Laumb, my research partners, for their commitment and dedication to the research process that allowed for the completion of this study. I also want to extend a special thanks to the faculty and staff of the University of North Dakota Physical Therapy Department for their commitment to excellence which they have shown through their abounding knowledge, continual support, and dedication to the field of Physical Therapy. Finally, I would like to thank my family for their unconditional love and support and for the opportunity to pursue my goals and dreams.
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 conjuction with plyometric exercises and drills to achieve maximum athletic performance. There is currently limited research to validate the manufacturer’s claims of increasing vertical jump. The purpose of this study is twofold: 1) To describe muscle activity during walking and jumping while wearing traditional athletic shoes and plyometric training shoes. 2) To measure the vertical jump of subjects trained with plyometric training shoes and a control group of subjects trained with traditional athletic shoes. 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) 1) There is no significant difference in electromyographic activity during walking and jumping with plyometric shoes and traditional athletic shoes. 2) There is no significant difference in achieved vertical jump height between subjects trained with plyometric shoes and those trained with traditional athletic shoes.
“Staying ahead of the game” is the motto of many of today’s athletes. With the increasing interest in athletics and the rapid advancements being made in training techniques, competition among athletes to obtain elite status has become increasingly difficult. Today, sporting event records are being broken faster than they can be recorded. Athletes are demonstrating phenomenal speed, strength, and power worldwide in all sporting events. Many people ask: What can this sudden explosion in skill be attributed to? O’Shea believes the answer to this question lies not in a physiological evolution within the body, but rather in the improvements that have been made in training techniques and methods that are able to elicit a greater portion of the body’s ultimate potential.

Athletes, as well as coaches, have searched and continue to search endlessly for techniques that will maximize an athlete’s potential and ultimately prepare the athlete for elite competition. Currently, several methods of training are being advocated to assist athletes in increasing vertical jump. One such method is the use of plyometric training shoes. This method has the athlete perform a structured program of plyometric exercises and drills while wearing a specially designed tennis shoe with a one-inch thick rubber platform on the sole of the forefoot. The aim of the combination of plyometric exercises and the plyometric shoe is to increase speed, quickness, and explosive power by
enhancing the body’s stretch reflex and increasing the amount of work done by the gastrocnemius/soleus complex.

Plyometrics, as defined by Chu\(^4\), are closed kinetic chain exercises that utilize the force of gravity to store energy within the muscular framework of the body by eliciting a stretch (myotatic) reflex in the targeted muscle. Plyometric exercises/drills involving the lower extremity are performed in a variety of ways, but they all consist of elevation of the body followed by return to the supporting surface with subsequent projection of the body vertically, horizontally, or a combination of the two.\(^4\) These plyometric exercises facilitate the quick eccentric stretch of a muscle which elicits a stretch reflex by stimulating the muscle spindle’s proprioceptive nerve impulses to travel to the spinal cord and return, producing a powerful concentric contraction to prevent overstretching.

Plyometrics are based on the contention that a concentric contraction is much stronger (greater amount of positive work) if it immediately follows an eccentric contraction.\(^5,6\)

Within the stretch reflex cycle there is an amortization phase, the point at which negative work (eccentric contraction) is converted into positive work (concentric contraction), otherwise identified as the time the individual is in contact with the ground.\(^3,7\) During this conversion potential energy is lost as heat, thus decreasing the length of the amortization phase which results in the production of more positive energy. This in turn results in a greater concentric force.\(^6,7\) It has been noted that this support time or amortization phase can be decreased through learning and skill training, and is therefore one of the aims of plyometric training.\(^7\)

Chu\(^7\) noted that plyometric training enhances the athlete’s performance by changing the strength of the response of the contraction, not the speed. It is also
recognized that when the stretch reflex is elicited, the rate of stretch is more important than the magnitude of the stretch.\textsuperscript{6,7} For this reason, plyometrics aim to increase the speed at which the muscle initially lengthens during the eccentric stretch. Maximum tension develops when an active muscle is stretched quickly; therefore the faster it is forced to lengthen the more efficiently and powerfully it is able to contract.\textsuperscript{5,6,8} Cavagna et al\textsuperscript{5}, in addition to these theories, hypothesized that an increase in length of the stretch causes a slight increase in force and ultimately in positive work. Because of their platform design plyometric shoes allow for an increased magnitude of stretch of the gastrocnemius/soleus thus utilizing Cavagna’s principle as one basis for their design.\textsuperscript{3}

The primary reason plyometric exercises are utilized to achieve a training benefit is their ability to elicit the stretch reflex, thus increasing the power of a muscle contraction which in theory increases an athlete’s speed, quickness, and power.\textsuperscript{3} This, however, may not be the only reason an athlete’s performance is affected. Additional possible training benefits of plyometrics include increased muscle loading (overload principle), improved proprioception in the involved muscle (specificity principle), and an increase in the load tolerance of the musculotendinous unit; all of which contribute to improved lower extremity function. Whether it be strictly the benefits of the stretch reflex or the additional stated benefits, plyometrics have been shown in various studies to be effective in increasing vertical and horizontal jump.\textsuperscript{8,9,10,11} They have also been deemed beneficial in the training of sprinters, jumpers, basketball players, and volleyball players.\textsuperscript{4} Plyometrics have also been effective in maximizing the coordination of neuromuscular skills, muscular strength, and improved coordination of arms and legs.\textsuperscript{10}
The plyometric shoe has evolved from the desire to enhance the currently noted benefits of plyometrics in the lower extremities. The plyometric shoe as described above is a specially designed tennis shoe with a platform disc at the forefoot which shifts the body weight anteriorly, thus preventing the heel from striking the ground during plyometric exercise and requiring the gastrocnemius/soleus complex to be more active than with traditional shoes.\(^3\) It is hypothesized that, secondary to the anterior weight shift, the athlete who trains in plyometric shoes is conditioned to take off on the forefoot only, thus achieving a more consistent maximal acceleration and vertical height.\(^{12}\) The theory backing the design also contends that shifting the body weight anteriorly will enhance the stretch reflex by increasing the speed and magnitude of lengthening and the production of tension during the eccentric phase, resulting in a more powerful contraction of the gastrocnemius/soleus.\(^{13}\)

Currently there are several different makes and models of the plyometric shoe. Each one utilizes the same basic plyometric theory for structure and design; however, each shoe also has its own unique characteristics that potentiate additional benefits. This study involves the analysis and utilization of the SkyFlex\(^\text{\textregistered}\) plyometric shoe. Little research exists concerning the effectiveness of training with plyometric shoes to increase vertical jump. In addition, all studies that have been conducted have used the Strength\(^\text{\textregistered}\) plyometric shoe. No research currently has been published concerning the SkyFlex\(^\text{\textregistered}\) plyometric shoe. Flarity et al\(^{13}\) conducted a study testing the effectiveness of plyometric shoes with 20 male college students, 10 who trained with plyometric shoes and 10 who trained with traditional athletic shoes. Their subjects participated in a manufacturer designed plyometric exercise program 3 times per week for 9 weeks. The results of this
study indicated that the control group and the treatment group both demonstrated a significant increase in their vertical jump with the control group increasing by 7% and the treatment group increasing by 13.3%. Additional items the subjects demonstrated a significant improvement in were anaerobic capacity and power and 40-yard dash time.

Cook et al$^3$ conducted a similar study with 12 male collegiate athletes. These subjects trained with a manufacturer's plyometric exercise program 3 times per week for 8 weeks. Their results showed no significant improvement in flexibility, strength, 40-yard dash time, vertical jump, or calf size. There was also no significant difference between the control and the training groups. Cook’s study noted that 1/3 of the subjects wearing the plyometric shoes complained of anterior tibial pain during the time of training. No one wearing traditional athletic shoes reported any complaints of pain. These researchers reported that the Strength® plyometric shoe offered no training benefit and because of the reports of pain did not recommend it as a safe, effective training tool.

Although research has begun to emerge concerning the efficacy of plyometric shoes as beneficial training tools, more is needed due to the conflicting results. In addition, because safety has become an issue as a result of Cook’s study, other questions arise: how much stress or force is going to be imparted on the involved muscle, tendon, and ligaments, is a disproportionate amount of stress being put on the ankle, hip, or knee; and what level of physical maturity should be reached before beginning training with these shoes.$^{13}$

Manufacturers of plyometric shoes contend that shifting an individual’s body weight anteriorly changes the amount of work done by the lower extremity muscles during activity, specifically the gastrocnemius/soleus complex.$^3$ In order to evaluate any
significant difference, it is essential to first understand the role and action of the muscles in a standardized situation—which in this study is gait with traditional athletic shoes.

Although all of the lower extremity muscles play a role in gait, this study analyzed those most likely to be affected by the proposed training effect of the plyometric shoe: vastus lateralis, anterior tibialis, peroneus longus, and gastrocnemius; secondary to their origin, insertion, and action (Table 1).

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

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

Vastus Lateralis: Muscle activity begins in terminal swing. Muscle intensity increases and peaks at the beginning of the loading response and remains active throughout this phase. At mid stance its activity decreases and ends one-half of the way through this phase (Figure 1).

Anterior Tibialis: Onset of muscle activity begins in pre-swing. The intensity rises rapidly throughout initial swing. At mid swing muscle activity decreases to a minimum, but then increases gradually in terminal swing to position the foot for stance. The muscle remains active at initial contact and then quickly reaches its peak activity. Muscle activity decreases to zero by the end of the loading response (Figure 1).

Gastrocnemius: Muscle activity begins at the end of the loading response with the medial head firing immediately before the lateral head. The intensity slowly rises.
Figure 1. Average selected lower extremity muscle EMG activity during normal gait.
through mid stance and then rapidly increases to its peak one-half of the way through terminal stance. Rapid decline then occurs and activity reaches zero at the onset of pre-swing. Some researchers have also found it common to observe a brief contraction of the gastrocnemius in mid swing, but the reason for this is currently unknown (Figure 1).

**Peroneus Longus:** Onset of activity occurs at the beginning of mid stance. Intensity gradually increases and peaks one-half of the way through terminal stance and then decreases to zero by the end of this phase (Figure 1).

Vertical jump relies on the ability of the body’s various muscle groups to raise its center of gravity. The vertical jump consists of three phases: the first two result in negative mechanical work and the third one elicits positive work. Phase I is described as the process in which the body’s center of gravity is moved slowly downward and forward (eccentric contraction). During Phase II the body’s center of gravity reaches its lowest point; the head, arm, and trunk flex forward; and the thigh and lower leg reverse their direction as the ankle, knee, and hip extensors halt the downward progression of the center of gravity. Phase III results in an upward thrust of the center of gravity (concentric contraction). The foot then rotates forward as the heel leaves the ground. This phase is ended with the legs, thighs, head, arms, and trunk straightening as the respective joints extend fully.

Although researchers tend to agree on the biomechanics of the vertical jump, they continue to disagree on the degree of contribution of the lower extremity, trunk, and upper extremity musculature. Bangerter conducted a study of 112 college men in which the subjects were divided into five groups (4 training and 1 control) with each group training one or a combination of the following groups of muscles: hip extensors, knee...
extensors, or plantarflexors. The results of his study concluded that knee extensors, hip extensors, and the combination of the two contribute the force production in vertical jump, whereas the plantarflexors play a very insignificant role. Rather, he postulated that they act as positioners and resistors to the incurred forces.¹⁷

Luhtanen and Kami¹⁸ conducted a study of 8 male athletes in which they utilized force-platform and film analysis to determine the segmental contribution to forces in vertical jump. Their results revealed the following percentage of total contributions: knee extensors 56%, plantarflexors 22%, trunk extensors 10%, arm swing 10%, and head swing 2%. These results indicate that the plantarflexors do play a significant role in power production during vertical jump.

Robertson and Fleming¹⁹ also found that the work of the plantarflexors provided a significant contribution to the vertical jump. Their study analyzed the vertical jumps of 6 subjects using a force platform, film analysis, and biomechanical software. The analysis resulted in the following percentage of contributions: hip- 40%, knee- 24.2%, and ankle- 35.8%. They concluded that, although the muscles crossing the knee contributed significantly, it was the muscles crossing the hip and ankle that contributed to a majority of the work. In addition to EMG analysis of gait, EMG analysis of vertical jump was compared with the two different training shoes to determine relative contributions to the event. The components of a vertical jump are incorporated into numerous sports specific skills and therefore an athlete’s performance will generally benefit from enhancement of this basic technique.
CHAPTER 3

METHODS

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

Subjects

Ten healthy male subjects volunteered for this study. The subjects were between the ages of 21 and 25 (Table 2). All subjects completed a prescreening questionnaire (appendix B) 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 A).

<table>
<thead>
<tr>
<th>Table 2. Subject Characteristics (n=10)</th>
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<tr>
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<tr>
<td>Age (years)</td>
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<tr>
<td>Height (inches)</td>
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<tr>
<td>Weight (pounds)</td>
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</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. The platform is attached to the sole of the shoe therefore preventing the heel from striking the ground during training activities. 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. 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 Telemetry8 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 Telemetry8 receiver and then digitized by a PCM-DAS16S/16-Analog to a digital interface board (Computer Boards, Inc., 16 Commerce Blvd., Middleboro, MA 02346) installed in a Noraxon
Figure 2. SkyFlex® plyometric shoes
Pentium 133 computer. The digitized information was then analyzed using the Noraxon Myoresearch 97 data collection software that accompanies the Telemyo8 EMG system. Because velocity of muscle contraction is a factor in the EMG activity produced by a muscle, an electric metronome was used to standardize the speed of the tested activity.

**Procedure**

Before participation in the tested activities, the subjects were required to perform five standing barbell squats at 75 percent of their body weight. This was done to minimize risk of injury by ensuring that each subject had adequate lower extremity muscle strength to complete the tested activities. All subjects were instructed in the proper squat technique as described by Augustsson et al. 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 as designed by Zipp (Figure 3). To reduce skin impedance, hair over the area of electrode placement was shaved and the skin was cleaned with rubbing alcohol prior to application of the electrodes. The electrodes were placed two centimeters apart on the skin over the designated muscle points parallel to the muscle fibers. Placing the electrodes parallel to the muscle fibers allows for conduction in a fixed set of muscle fibers, thus decreasing the chance of recording erroneous conduction velocity.
**Vastus Lateralis** - along a line ¼ the distance from the lateral knee joint line to the ASIS and over the belly of the vastus lateralis

**Anterior Tibialis** - over the muscle belly 1/3 the distance from the inferior patellar pole to the lateral malleolus

**Peroneus Longus** - ¼ the distance from the fibular head to the lateral malleolus

**Gastrocnemius** - over the muscle belly 1/3 the distance of the leg (fibular head to calcaneous)

**Figure 3.** Electrode placement sites
Table 3. Surface Electrode Placement

<table>
<thead>
<tr>
<th>MUSCLE</th>
<th>MEASUREMENTS FOR ELECTRODE PLACEMENT</th>
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<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. 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 B). 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 A). 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 A). Twenty seven subjects completed the study and were used for data collection and analysis. One subject participating in the experimental group was excluded from the study secondary to pre-existing ankle instability. Another subject was unable to complete the study due to the onset of achilles pain following the first week of training. And the final subject did not report for the final vertical jump measurement thus discluding him from data analysis.
### Table 4. Control Group Characteristics (n=14)

<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 5. 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 (figure 3.?) are modified low-cut shoes with a 2-1/2 inch extended Airlon Flexfit® sock liner and a 1 cm thick platform that measures 7-1/4x6-1/2 inches. The platform is attached to the sole of the shoe, therefore preventing the heel from striking the ground during training activities. The shoe was designed to increase the amount of stretch the achilles tendon receives before the heel touches the ground, thus speeding up the stretch reflex allowing muscles to reach maximal strength in the shortest amount of time possible. This theoretically increases the amount of work done by the gastrocnemius/soleus complex thus enhancing training. The extended Airlon Flexfit® sock liner was formulated to
increase proprioception thus reducing the risk of injury at the ankle. It also warms the ankle and adds security to the foot in the shoe.

The vertical jump height was measured by using a device called the VerTec (Sports Imports, Inc., Columbus, OH). The portable VerTec is a unit that has an adjustable upright pole that allows measurement of varying degrees of vertical jumps. At the top of the pole is 2 feet of horizontal plastic strips in half-inch increments (Figure 4). Vertical jump is measured by the highest plastic strip the subject is able to displace. A baseline measurement involved having the subject first walk under the VerTec with his elbow, wrist, and hand in an extended position and the shoulder in neutral elevation/depression. To initiate the vertical jump, each subject first stood parallel to the VerTec's plastic strips and then turned 45° to either the right or left.22 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 al20. Each subject placed the
Figure 4. VerTec® vertical height measurement device
barbell on his shoulders, then flexed at the hips and knees until his thighs were parallel to
the floor, and finally pushed back to a vertical position.

Subjects were randomly assigned to either the control (n=14) or the experimental
(n=15) groups. The control group participated in a preset training regimen while wearing
athletic shoes. The experimental group participated in the same preset training regimen
while wearing SkyFlex® plyometric shoes. The preset training regimen used was the one
described in the SkyFlex® intermediate protocol (appendix B). 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 B). 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

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

Walking

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

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

<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 7 shows the percent of average EMG activity in the four muscle groups of vertical jumping with SkyFlex® plyometric training shoes as a percentage of vertical jumping with traditional athletic shoes. As compared to a traditional shoe, the average
Figure 5. Averaged selected lower extremity EMG muscle activity during walking with traditional athletic shoes
Figure 6. Averaged selected lower extremity EMG muscle activity during walking with SkyFlex plyometric shoes
EMG activity 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.

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 7. 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 8 contains the initial and final mean vertical jump heights of the two groups. Although there was a significant increase within the SkyFlex® training group, upon analysis of the ANCOVA test, the SkyFlex® training group did not demonstrate an increase in vertical
jump height that was significantly higher than the traditional training (Figure 9). Table 9 contains the initial means and adjusted means for the two groups. Additional statistical tests verified that all assumptions of ANCOVA were met. The power for the effect of the shoes on jump height was .057.

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

<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 7. EMG activity during walking with traditional athletic and SkyFlex plyometric shoes.
Figure 8. EMG activity during vertical jump with traditional athletic and SkyFlex plyometric shoes.
Figure 9. Mean change in vertical jump height of the two training groups
CHAPTER 5

DISCUSSION

The manufacturer of the SkyFlex® system claim that athletes who use their product and program will increase their vertical jump by up to six inches with notable improvement in four weeks.¹ The results of this study, however, indicate that while plyometric shoes significantly increase the amount of EMG activity in the anterior tibialis and gastrocnemius during normal gait, there was no significant difference in the amount of vertical jump height increase of athletes who trained with the SkyFlex® system in comparison to those who trained following a plyometric program with traditional athletic shoes. The results of this study support the study conducted by Cook et al³ where they demonstrated no significant increase in vertical jump height of athletes who trained with plyometric shoes. This study followed the basic structure of Cook’s, however, we incorporated an additional element, EMG analysis of muscle activity while wearing plyometric shoes, in an attempt to justify previous findings.

The results of our study showed a significant increase in the amount of EMG activity of the anterior tibialis and gastrocnemius while wearing plyometric shoes, as compared to traditional athletic shoes during normal gait, but no significant increase was noted while wearing them during vertical jump. This supports the claims of manufacturers that the anterior shift of the athletes body-weight, which prevents the heel from touching the ground during gait and plyometric drills, changes the lever arm of the
gastrocnemius causing the muscle to become more active. The increase in the activity of the anterior tibialis may be attributed to the platform attached to the forefoot producing a greater plantarflexion tendency during the swing phase which would require the anterior tibialis to be more active in order to maintain the required dorsiflexion for foot clearance during this phase of gait. Again, no significant increase was noted in EMG activity during the vertical jump. One possible reason for the variation between gait and vertical jump may be that during vertical jump because a forced squat countermovement is initially performed, a downward weight shift results, thus nullifying the change in the lever arm of the gastrocnemius that is seen in gait.16

Several studies have been conducted that support the claim that plyometric exercises do in fact produce a significant increase in vertical jump height. Brown et al10 demonstrated that plyometric training increased the vertical jump performance of high school basketball players. Blattner and Noble9 showed that again plyometric training increased the vertical jump height in high school athletes, but that it did not produce results that were more significant than those produced following isokinetic training. And Steben and Steben demonstrated significant improvements in high jump and triple jump performance among athletes participating in plyometric training. The manufacturers of the plyometric shoe, however, hypothesized that by adding the plyometric shoe to plyometric training drills the stretch reflex would be further optimized and vertical jump height would increase to a greater extent.13 The results of our study show this theory to be inconclusive, and were not supported by our study.

One possible reason for this inconclusiveness is that plyometric drills alone maximally potentiate the stretch reflex, and that by increasing the magnitude of the
eccentric muscle stretch the established cycle is being disrupted. It has been hypothesized that the rate of the stretch is more important than the magnitude.\(^6,7\) Although an increase in length has at times shown an increase in the force of the concentric contraction, the magnitude of the increase has not been established.\(^5\) This leads to the conclusion that the plyometric shoe may be overlengthening the muscle, thus taking away the benefits of the quick stretch. Another possible reason for this lack of increased improvement is that if the muscle is being overstretched the golgi tendon reflex may be being elicited which inhibits rather than facilitates the myotatic reflex from the muscle spindle resulting in a loss of training effects.\(^{23,24}\)

When examining the combined results of the two portions of this study it is unclear as to why there is an obvious significant increase in the amount of EMG activity of the gastrocnemius when wearing the plyometric shoes, but that no training carryover, as measured by vertical jump height, was noted when subjects trained in these shoes versus traditional athletic shoes. The results, however, support the findings of Bangerter in his study which concluded that hip and knee extensors are the primary producers of muscle force in a vertical jump, and the plantarflexors contribute very little. The calf muscles are more likely used as positioners and resistors to the forces superimposed on them.

**Limitations of Study**

There were several limitations within this study. The small number of subjects who participated in the EMG portion poses the problem that any deviation in the EMG in one subject may result in drastic changes in the overall average. In addition, it was hard
to synchronize the velocity of the subjects during their vertical jump, which may alter the relative amount of EMG recorded.

All other limitations noted were present in the vertical jump training protocol portion of the study. First of all, our training program was only four weeks whereas most of the training protocols in the literature are 8-12 weeks. Second, the subjects were monitored at only the first workout of the four week training session, unless questions arose, therefore compliance was a verbal agreement. In addition, the subjects were required to workout three times per week, but the spacing of those days was not defined nor was the number of days they rested prior to each recorded jump. Finally, the subjects participating in the study all had a variety of athletic ability. Some of the subjects were elite college athletes which allows us to question whether or not they had already obtained their maximum vertical jump height.

**Future Research**

Future research concerning plyometric training shoes may involve the EMG analysis of hip and trunk extensors in addition to the previously analyzed muscles due to their apparent influence in power production during vertical jump. Another suggestion would be to have subjects perform the training protocol for an additional four to six weeks and to delineate the days they are to perform their workouts to provide for more consistency.

**Clinical Implications**

Athletes and coaches are constantly searching for tools that will enhance athletic performance. Plyometric shoes are one method currently being utilized by several athletic programs, however, because of the results of this study coaches and athletes
should realize that traditional plyometrics may be just as effective as this additional tool, and will most likely decrease the risk of injury. This research also demonstrates the need to critically analyze the unresearched training benefits of “new” training techniques before acquiring unneeded expense and imposing an increased chance of injury on an athlete. In addition, the results of this study indicate that specific training of the gastrocnemius may not be the most effective way to enhance vertical jump height, and that muscles such as the knee and hip extensors should also be targeted in a training program.
APPENDIX A
**UNIVERSITY OF NORTH DAKOTA HUMAN SUBJECTS REVIEW FORM**

**FOR NEW PROJECTS OR PROCEDURAL REVISIONS TO APPROVED PROJECTS INVOLVING HUMAN SUBJECTS**

**PRINCIPAL INVESTIGATOR:** Thomas Mohr, Sue Buckley, Myles Haugen, Brian Laumb, Heather Phillips  
**TELEPHONE:** 777-2813

**DATE:** 6/10/97  
**ADDRESS TO WHICH NOTICE OF APPROVAL SHOULD BE SENT:** PO Box 9037, Dept. Of Physical Therapy, UND

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

**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  
- [ ] THESIS RESEARCH  
- [x] STUDENT RESEARCH PROJECT  
- [ ] CHANGE IN PROCEDURE FOR A PREVIOUSLY APPROVED PROJECT

**DISSEMINATION/THESIS ADVISER, OR STUDENT ADVISER:** Thomas Mohr, PT, Phd

**PROPOSED PROJECT:** [ ] INVOLVES NEW DRUGS (IND)  
[ ] USE OF DRUG  
[ ] INVOLVES NON-APPROVED USE  
[ ] COOPERATING INSTITUTION

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

- [ ] MINORS (<18 YEARS)  
- [ ] PREGNANT WOMEN  
- [ ] MENTALLY DISABLED  
- [ ] FETUSES  
- [ ] MENTALLY RETARDED  
- [ ] PRISONERS  
- [ ] ABORTUSES  
- [x] UND STUDENTS (>18 YEARS)

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

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

**Status:** Submitted; Date 4/15/98  
**Approved; Date 4/15/98  
**Pending________**

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

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

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

Methods:

Part One (N = 10)
Prior to the walking and jumping trials, each subject's age, height, and weight will be recorded. During the trial, we will measure 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:**

Principal Investigators

Project Director or Student Adviser

Training or Center Grant Director

(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 with consist of instruction in and performance of each exercise with an investigator. Following the first instructive session, you will be exercising at home and at your convenience. A random assignment will determine whether you perform these exercises with plyometric training shoes or traditional athletic shoes.

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

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

Your name will not be used in any reports of the results of this study. Any information that is obtained in connection with this study and that can be identified with you will remain confidential and will be disclosed only with your permission. The data will be identified by a number known only by the investigator. The investigator or participant may stop the experiment at any time if the participant is experiencing discomfort, pain, fatigue, or any other symptoms that may be detrimental to his/her health. Your decision whether or not to participate will not prejudice your future relationship with the Physical Therapy Department or the University of North Dakota. If you decide to participate, you are free to discontinue participation at any time without prejudice.
The investigator involved is available to answer any questions you have concerning this study. In addition, you are encouraged to ask any questions concerning this study that you may have in the future. Questions may be asked by calling Dr. Thomas Mohr at (701) 777-2831. A copy of this consent form is available to all participants in the study.

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

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

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

Participant's Signature  Date

Witness (not the scientist)  Date
APPENDIX B
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 ________________
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.
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 bent 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. **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.

6. **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.

7. **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.

8. **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!!
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.
### Individual Trial Data From Subjects

#### Integrated EMG Activity in Walking  Vastus Lateralis

<table>
<thead>
<tr>
<th>Subject</th>
<th>( \mu V ) Traditional Athletic Shoe</th>
<th>( \mu V ) SkyFlex Plyometric Shoe</th>
<th>Difference (%)</th>
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Average: 120.8%
Standard Deviation: 28.9%

#### Integrated EMG Activity in Walking  Anterior Tibialis

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<th>( \mu V ) SkyFlex Plyometric Shoe</th>
<th>Difference (%)</th>
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Average: 186.5%
Standard Deviation: 62.9%

#### Integrated EMG Activity in Walking  Gastrocnemius

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<th>( \mu V ) SkyFlex Plyometric Shoe</th>
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Standard Deviation: 50.3%
Individual Trial Data From Subjects (cont’d)

Integrated EMG Activity in Walking  *Peroneus Longus*

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Average: 143.0%  
Standard Deviation: 61.6%

Integrated EMG Activity in Vertical Jump  *Vastus Lateralis*

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Average: 101.2%  
Standard Deviation: 19.9%

Integrated EMG Activity in Vertical Jump  *Anterior Tibialis*

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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>( \mu V ) Traditional Athletic Shoe</th>
<th>( \mu V ) SkyFlex Plyometric Shoe</th>
<th>Difference (%)</th>
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Average 113.8%  
Standard Deviation 22.7%

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

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

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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)
REFERENCES


