2001

The Effects of Plyometrics and Treadmill Training on Balance and Reaction Time in High School Aged Athletes

Marcus Sorenson
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/415

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 zeinebyousif@library.und.edu.
THE EFFECTS OF PLYOMETRICS AND TREADMILL TRAINING ON BALANCE AND REACTION TIME IN HIGH SCHOOL AGED ATHLETES

by

Marcus Sorenson
Bachelor of Science in Physical Therapy
University of North Dakota, 2000

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
2001
This Independent Study, submitted by Marcus Sorenson 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 The Effects of Plyometrics and Treadmill Training on Balance and Reaction Time in High School Aged Athletes

Department Physical Therapy

Degree Master of Physical Therapy

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 [Signature]

Date 12-15-00
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>LIST OF FIGURES</td>
<td>vii</td>
</tr>
<tr>
<td>LIST OF TABLES</td>
<td>viii</td>
</tr>
<tr>
<td>ACKNOWLEDGEMENTS</td>
<td>ix</td>
</tr>
<tr>
<td>ABSTRACT</td>
<td>x</td>
</tr>
</tbody>
</table>

## CHAPTER

### I INTRODUCTION

- Problem Statement ................................................................. 1
- Purpose of Study and Research Questions ........................................ 2
- Significance of Study ............................................................... 3
- Hypothesis .................................................................................. 3

### II LITERATURE REVIEW

- Physiology of Skeletal Muscles .................................................. 4
- Plyometrics .................................................................................. 5
- Treadmill Training ........................................................................ 5
- Balance ......................................................................................... 7
- Reaction Time ............................................................................... 9
- Training an Athlete ...................................................................... 10

### III METHODOLOGY

- Subjects ....................................................................................... 12
## Table of Contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Instrumentation</td>
<td>13</td>
</tr>
<tr>
<td>Pilot Study</td>
<td>15</td>
</tr>
<tr>
<td>Intra-rater Reliability</td>
<td>15</td>
</tr>
<tr>
<td>Inter-rater Reliability</td>
<td>15</td>
</tr>
<tr>
<td>Pearson Correlation Coefficient Interpretation</td>
<td>17</td>
</tr>
<tr>
<td>Pre-Assessment</td>
<td>18</td>
</tr>
<tr>
<td>Sports Acceleration Protocol</td>
<td>18</td>
</tr>
<tr>
<td>Plyometrics</td>
<td>19</td>
</tr>
<tr>
<td>Treadmill Training</td>
<td>21</td>
</tr>
<tr>
<td>Post-Assessment</td>
<td>23</td>
</tr>
<tr>
<td>Data Analysis</td>
<td>24</td>
</tr>
<tr>
<td>Reporting of Results</td>
<td>24</td>
</tr>
<tr>
<td><strong>IV RESULTS</strong></td>
<td>25</td>
</tr>
<tr>
<td>Subject Profile</td>
<td>25</td>
</tr>
<tr>
<td>Research Questions</td>
<td>25</td>
</tr>
<tr>
<td>Results for Limits of Stability</td>
<td>26</td>
</tr>
<tr>
<td>Results for Lunge</td>
<td>27</td>
</tr>
<tr>
<td><strong>V DISCUSSION</strong></td>
<td>29</td>
</tr>
<tr>
<td>Results with Plyometric and Treadmill Training</td>
<td>29</td>
</tr>
<tr>
<td>Limitations</td>
<td>31</td>
</tr>
<tr>
<td>Conclusion</td>
<td>34</td>
</tr>
<tr>
<td><strong>APPENDIX A</strong></td>
<td>37</td>
</tr>
<tr>
<td><strong>APPENDIX B</strong></td>
<td>44</td>
</tr>
<tr>
<td>Figure</td>
<td>Page</td>
</tr>
<tr>
<td>--------</td>
<td>------</td>
</tr>
<tr>
<td>1. Neurocom® Balance Master</td>
<td>14</td>
</tr>
<tr>
<td>2. Four square plyometric pattern</td>
<td>20</td>
</tr>
<tr>
<td>3. Four square plyometric pattern with numbers</td>
<td>20</td>
</tr>
<tr>
<td>4. Munoz plyometric pattern</td>
<td>20</td>
</tr>
<tr>
<td>5. Munoz plyometric pattern with numbers</td>
<td>20</td>
</tr>
<tr>
<td>6. Different sized boxes used in plyometrics</td>
<td>21</td>
</tr>
<tr>
<td>7. Super Treadmill set at an angle</td>
<td>22</td>
</tr>
<tr>
<td>8. Athlete bounding on Super Treadmill with sprintcords</td>
<td>23</td>
</tr>
<tr>
<td>9. Directions of limits of stability test</td>
<td>49</td>
</tr>
</tbody>
</table>
### LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Intra-rater Reliability for Limits of Stability</td>
<td>16</td>
</tr>
<tr>
<td>2. Intra-rater Reliability for Lunge</td>
<td>16</td>
</tr>
<tr>
<td>3. Inter-rater Reliability for Limits of Stability</td>
<td>16</td>
</tr>
<tr>
<td>4. Inter-rater Reliability for Lunge</td>
<td>17</td>
</tr>
<tr>
<td>5. Inter-rater Correlation Coefficient Interpretation</td>
<td>17</td>
</tr>
<tr>
<td>6. Results for Limits of Stability Pre- and Post-Assessment Tests: Mean, Standard Deviation, z-scores, and Probability</td>
<td>26</td>
</tr>
<tr>
<td>7. Results for Lunge Pre- and Post-Assessment Tests: Mean, Standard Deviation, z-scores, and Probability</td>
<td>27</td>
</tr>
</tbody>
</table>
ACKNOWLEDGEMENTS

I would like to start by thanking the physical therapy faculty at UND. Your wisdom has guided and challenged me. A special thanks goes to Meridee Danks for being my faculty advisor. Her help and insight into this project has been wonderful. I would also like to thank Dr. Renae Mabey for all of her help with the statistical data.

I would like to thank John Frappier for all of his research and work on acceleration training, and for creating the acceleration program where we conducted this study. I would like to especially thank Beth Ness and the entire faculty at Altru Sports Acceleration. Your patience and encouragement has been well appreciated.

I would like to thank all of my friends at UND. Thank you to Andrea Richter and Jay Armstrong for being my partners throughout this project. I would also like to thank my Brothers at Sigma Phi Epsilon. Without your friendship, I never would have survived college.

Last, but definitely not least, I would like to thank my family. Only through your support would I have ever gone this far. Also, thank you to the most special person in my life, my wonderful wife Shannon. I have been very fortunate. I love you all. Thank you.
ABSTRACT

High school athletes’ involvement in sports acceleration training has grown in recent years. Athletes use acceleration programs to help gain an edge over their competition. One way to gain that edge is by improving balance and reaction time. These two components are important in a wide variety of sports. Both help to minimize injury and increase the skill level and performance of the athlete. Although balance and reaction time are essential in sports, there is currently no research available involving these components.

The purpose of this study is to determine if the Altru Health Institute’s Sports Acceleration plyometric and treadmill training program increases balance and reaction time in high school athletes. The NeuroCom® Balance Master was utilized to test balance and reaction time. Data were obtained by assessing nineteen high school athletes involved in the Sports Acceleration program at Altru Health Institute during the summer of 2000.

Both balance and reaction time significantly improved after an acceleration program consisting of plyometric and treadmill training. It is recommended that further research studies are undertaken on this subject to improve the training and ultimately the performance of athletes.
CHAPTER I
INTRODUCTION

Sports are a very important part of the American culture. People love to watch their favorite athlete or team win, and hate to watch them lose. Athletes are put under extreme pressure to win. They train endless hours to become bigger, faster, and better.

There have been a plethora of studies and theories on how to train and make an athlete faster. It has been shown that leg strength is an essential element to produce speed, strength, and quickness in an athlete.\textsuperscript{1-3} Coaches have used drills such as plyometrics as a way to develop explosive power and leg speed.\textsuperscript{2} Even exercise physiologists have been utilized in training of athletes and have developed a variety of theories and concepts on how muscles work and how to train them. Different theories, such as the Specific Adaptation to Imposed Demand (SAID) principle, address specific metabolic pathways for the development of speed. With all these different methods of training an athlete, it is important to do further research on the benefits of different types of training.

When training an athlete it is important to look at every aspect of the athlete. Both balance and reaction time are essential components in sports. Balance is part of everything that humans do. It is the body's ability to go outside one's center of gravity, while maintaining enough body control to avoid falling.\textsuperscript{4} Balance has also been shown to be the single most important aspect of athletic ability because it is required and
utilized during all types of movement. Whether a person is walking, standing still, or playing a high-level sport, the person's ability to maintain proper balance is crucial. Improving balance can improve the way one moves.

Along with balance, qualities such as quickness, speed, and the ability to react to a given stimulus are often the only differences between winning and losing a sport. If one athlete can react to a given situation even a fraction of a second faster than another, it would be easy to assume that the quicker athlete would have an advantage over the slower one. It is this reaction time that is so crucial in all sports. By doing activities that require "fast feet" and quick decision making, it is possible to improve this aspect of the athlete.

Problem Statement

Sports acceleration programs are forming all over the country. Many of these programs offer advanced training in plyometrics, sprinting biomechanics, and weight lifting. Very little, if any, research has been done to show how plyometrics and treadmill training affect balance and reaction time, which are essential components for an athlete to possess.

Purpose of Study and Research Questions

The purpose of this study is to determine if plyometric and treadmill training can improve balance and reaction time in high school athletes. This study will try to answer the following research questions:

1. Is there a significant improvement in balance following plyometric and treadmill training?
2. Is there a significant improvement in reaction time following plyometric and treadmill training?

Significance of Study

The training program used for this study was the Sports Acceleration Program at Altru Health Institute in Grand Forks, North Dakota. This program uses a variety of techniques such as plyometrics, treadmill training, and weight lifting. This study will objectively measure the effects of plyometric and treadmill training on balance and reaction time in high school athletes.

Every athlete involved in this study will have his or her balance and reaction time measured on the NeuroCom® Balance Master. This is a clinically accepted machine used to give objective data on many aspects of balance and reaction time.8 The results of this study will provide physical therapists, coaches, and anyone involved in training athletes, crucial information about the importance of balance and reaction time in athletes.

Hypothesis

The hypothesis in this study is that after a high school athlete has successfully completed a sports acceleration program consisting of both plyometrics and treadmill training, reaction time and balance will improve. The null hypothesis is that after a high school athlete has successfully completed a sports acceleration program consisting of both plyometrics and treadmill training, reaction time and balance will not improve.
CHAPTER II

LITERATURE REVIEW

Many qualities are needed to make an athlete successful. It takes speed, skill, and determination to be able to compete successfully on the athletic fields. One way many athletes choose to gain an edge over their competition is to break down the components required to be successful in their sport and train to improve each individual component. With speed, balance, and reaction time all being intricate aspects of most sports, many athletes train these specific areas to help them become faster, quicker, and more controlled in their movements.

When discussing speed development, it is essential to first differentiate between two different types of exercise: aerobic and anaerobic exercise. The primary difference is that aerobic involves endurance exercises and anaerobic involves power exercises. Aerobic exercise uses the breakdown of oxygen to produce energy. It generally involves long duration, low intensity activities such as jogging or swimming at a slow pace. Anaerobic exercise, however, utilizes the breakdown of carbohydrates through the physiological process of glycolysis. This generally includes high intensity, low duration activities such as heavy weight lifting, sprinting, jumping, and plyometrics.

Most sports involve a combination of the two exercise types with an emphasis on the anaerobic component to improve the athlete's ability to produce speed and power.
When determining which type of exercise is most beneficial for the athlete, it is important to analyze the physiology of the muscle.

**Physiology of Skeletal Muscles**

Human skeletal muscle is made up of many different components. Two of these components, the golgi tendon organs and muscle spindles, help make up the elasticity of muscles.\(^2,9-11\) Golgi tendon organs are activated by slow, intense stretches that result in a reflexive, relaxation of contractions.\(^2,11\) Muscle spindles, however, are not just sensitive to the length of the stretch, they are also affected by how fast the muscle is stretched. Activation of the muscle spindle creates a rapid, reflexive contraction while the muscle is being stretched. This reflexive contraction has been termed the stretch reflex.\(^12\)

Research has shown that when a muscle is stretched, potential energy is stored in the muscle, due to the stretch reflex.\(^13\) When a contracted muscle is placed on stretch, it is able to absorb 100% more energy than a passive muscle placed under the same amount of stretch. Margaria et al\(^15\) have observed that an exercise consisting of bending the knees immediately followed with extension of the knees, to return the person to an upright standing position, will require less energy if the extension takes place immediately after the flexion. This is caused by the stretch reflex and the potential energy stored in the muscle during the flexion of the knees. If the muscle is allowed to relax, the potential energy will be turned into heat and the following extension contraction will not be as strong.

**Plyometrics**

Plyometric training is one type of exercise that utilizes the muscle’s stretch reflex to develop power.\(^2,10,11,16\) Plyometrics use a variety of different jumping, bounding,
catching, and hopping drills, at a fast and intense pace. This type of training is used to develop both speed and power while exercising in an anaerobic environment.\textsuperscript{7,17-19}

The rapid jumping associated with plyometrics is responsible for the stretch reflex in the athlete's legs. As soon as the foot hits the ground after an athlete jumps, the knees bend and the quadriceps muscle is contracted eccentrically (the muscle lengthens). This will place the muscle on stretch. If the athlete quickly jumps again, the knees straighten and the quadriceps muscle is contracted concentrically (the muscle shortens). Due to the stretch reflex, the potential energy absorbed during the active muscle stretch produces a stronger concentric contraction. This is the primary theory behind all plyometric training.\textsuperscript{11,17}

The use of plyometrics has also been found to help prevent injuries, especially in female athletes.\textsuperscript{20,21} In sports involving jumping and landing, as in basketball and volleyball, injuries are extremely common. In a study conducted on female basketball players, Gray et al\textsuperscript{21} reported 58\% of all injuries occurred when the athlete was landing from a jump and 72\% of these injuries involved the knee joint. Although some physical factors such as joint laxity and anatomical angle of the knee cannot be modified, some exercises have been shown to decrease the amount of injuries. Hewett et al\textsuperscript{20} found female athletes who were trained in an exercise program that involved plyometrics were injured 3.6 times less than female athletes who were not trained.

Plyometric exercises have also been shown to be more efficient and effective in producing power and explosiveness than non-plyometric exercises. Thys et al\textsuperscript{15} found subjects who performed plyometric exercises were more efficient, produced a higher
amount of average power, increased the work of the contracted muscles, and accelerated faster than when compared to performing non-plyometric exercises.

Treadmill Training

Along with plyometrics, treadmill training has been used to increase speed of athletes for many years. There can be many advantages to training on a treadmill, as opposed to running outside. By running on a treadmill, the athlete does not have to work against environmental conditions such as wind resistance and uneven terrain. The treadmill can also be elevated to stimulate the stretch reflex in the gastrocnemius and other lower extremity muscles.

Training programs generally include several short duration runs at a high intensity. This allows the athlete to build power and speed during running, while exercising in an anaerobic environment. The treadmill also forces the athlete to focus on proper technique which will carry over to a more efficient and effective running style.

Balance

One of the most essential components to all movement is balance. Whenever a person sits, stands, walks, or runs, it is balance that prevents falling. It is especially important for an athlete to have good balance. Poor balance often leads to poor technique and the development of injuries. When trying to understand how to improve balance, it is important to first breakdown the three components that make up balance: vision, proprioception, and vestibular input.

Visual input is one of the main ways that people maintain proper balance. The brain uses input from the eyes to assess the body’s position compared to the surrounding environment. When an athlete sees a change in the terrain, the brain will send impulses
to the legs and other muscles of the body. Stabilizing musculature will help maintain an upright posture and prevent the athlete from falling over. This can be assessed by closing one or both eyes, or to train in a dimly lit room.

Proprioception is a specialized variation of the sensory modality of touch that comes from the sensation of joint movement and joint position. As a person walks or runs, proprioceptive input from the ankle gives feedback which informs the brain of the surrounding terrain. A study by Gross found that after an ankle injury, there is an increased probability for re-injury as a result of decreased sensory input from ankle joint receptors. This may lead to abnormal body positioning and diminished postural reflexes.

All joints give proprioceptive feedback, which will alert the body when balance is being threatened. During the rapid jumping of plyometrics, the ankles and knees give the brain information about the surface being jumped on, and the amount of force displaced through the joints. Proprioception can be assessed by standing or running on different types of surfaces.

Vestibular feedback is given to the brain through the fluid in the semicircular canals found in the inner ear. When the head is moved, fluid in the semicircular canals send feedback to the brain. An example of this can be experienced by spinning repetitively. When stopped, it may feel like the body is still spinning. The moving fluid in the semicircular canals creates the sensation that the body is still moving. The vestibular system is often only assessed when there is damage to the athlete’s proprioception and vision.

To ensure efficient balance, an athlete must possess each of the different components that make up balance. When an athlete runs, proprioceptive feedback is
given through the ankles and hips to prevent falling. Vision is required to make cutbacks, observe surrounding terrain, and to compare where the body is in reference to the environment. Vestibular feedback is produced every time the athlete moves the head by jumping or moving quickly.

Unity of the different components of balance is important because balance does not work in isolation. When balance is being challenged, the entire body reacts to stabilize and adjust itself.\textsuperscript{5} It takes each of the three components of balance working together to make an athlete successful.

Balance not only keeps the athlete upright during movement, it can also help to reduce injuries.\textsuperscript{5} Balance awareness decreases the potential for injury by speeding up response times and decreasing unnecessary movements. This not only helps keep the athlete safe, it also improves performance.

Reaction Time

Reaction time is the amount of time needed for the body to react to a given stimulus.\textsuperscript{23} The body reacts to different stimuli in several ways. A simple reflex, such as moving the hand away after touching a hot burner, is a type of reaction that requires very little conscious thought and is not usually trained to improve performance. An athlete, however, must first interpret different stimuli and then react to it. The ability to rapidly, and correctly, react to a given situation is often the only difference between an all-star athlete, and someone who gets cut from the team.

In many sports, especially ball sports played at a fast pace, perception and decision making skills are more likely to act as the limiting factors to performance than are the technical and skilled aspects of the game.\textsuperscript{6} The faster a person is able to react to a
given situation, the more quickly they will be able to move in a controlled manner. There is a strong link between reaction time, movement time, and balancing ability. They are all intricate and necessary components of movement.

Reaction time is a skill that can be modified and improved. The fundamental concept that must be focused on when trying to improve reaction time is that repetition of a specific stimulus only improves the reaction to that specific stimulus. An expert in a specific sport is able to react to a given stimulus by viewing the situation and using knowledge from previous interactions with that stimulus to predict what will happen before it actually does. Also, by repeating a specific movement during practice, an athlete is able to interpret a stimulus and create the desired movement at a faster rate than someone who is not familiar with that movement. An example of this is when a second baseman in baseball is able to view how the batter swings, interpret where the ball will be hit, and move in that direction to catch the ball, all at the exact moment the ball is hit.

Training an Athlete

There are many other components to consider when training an athlete. Without functional leg strength, the athlete will not develop speed, power, or have the ability to perform at a high level. The athlete must also understand that the only way to gain strength is to train harder than the time before.1,16

There are several ways to develop strength. The use of free weights can be an efficient way to build strength. This will allow motion in all three planes of movement and will require the stabilization from several other muscles to control the exercise.16,19 A study of female long-distance runners also found that those who lifted weights were
able to improve their performance and had a decreased risk of injuries, when compared to runners who did not include weight lifting in their training.\textsuperscript{18}

The functional component of the activity used to train an athlete is also an important aspect to look at. The more functional the environment is in training, the more versatile the athlete will be in handling the stresses incurred by the sport.\textsuperscript{3} Utilizing multiple-joint movements in training, the athlete is taught to use the entire body to perform the exercise. This is much safer than trying to get the motion at just one joint, which would increase the risk of injury. Therefore, exercises such as plyometrics and treadmill training can be a functional, and safe method to challenge and train athletes from a wide variety of sports.

Some people believe that early specialization in a single sport is required in order to develop into a professional athlete. This myth can be quite misleading and can actually be damaging for an athlete. It is important for a young person to develop a wide variety of movement patterns, which can be taught by participating in a variety of different sports and activities.\textsuperscript{24} If an athlete has a background of learned movements, it is easier to acquire sport-specific skills later in life. The athlete will also be less prone to injury because the body will be prepared for a wide variety of movements.
CHAPTER III
METHODOLOGY

This study was approved by the University of North Dakota and Altru Health System's Institutional Review Board (IRB) for the use of subjects under the age of 18 years old. A copy of the IRB application and letter of approval has been included in Appendix A. Prior to testing, all subjects were informed about the aspects of this study, and that their participation was voluntary. Written permission was obtained from both the participant and his or her legal guardian prior to testing. A copy of the consent form is provided in Appendix B.

Subjects

Participants in this study were selected from high school athletes taking part in the Frappier Acceleration® (Frappier Acceleration® Inc., Fargo ND) program at Altru Health Institute during the summer of 2000. Specific requirements for this study were as follows:

1. 18 years of age or younger

2. participating in upcoming high school sport

3. registered for both the plyometric and treadmill training (eight plyometric sessions, twelve treadmill sessions).

A total of 25 subjects were recruited for pre-assessment. Nineteen subjects consisting of ten males and nine females completed the entire program and were post-assessed. The
length of the training program varied from six to nine weeks depending on the participant’s scheduling. The six subjects that were not post-assessed either did not complete the program, moved from the area, or were unavailable for post-assessment testing.

Instrumentation

All subjects were tested on the NeuroCom® Balance Master version 7.0 (NeuroCom International Inc., Clackamus Ore). The NeuroCom® Balance Master (NBM) is a clinically accepted machine, commonly used in physical therapy, that provides objective data on balance.25 It can be used as both a diagnostic and a rehabilitative tool. The NBM consists of two nine-inch by sixty-inch force plates connected to a computer operating system. When a subject performs testing activities on the force plate, a variety of information is interpreted by the computer such as comparing strength differences between legs, balance and coordination problems, and reaction time to a visual stimulus. Visual feedback is provided to both the tester and the subject on the computer screen.

One advantage in using the NBM to analyze an athlete is that the information received can be used to evaluate an entire activity, not just a single muscle group.26 This can give much more functional information than something that focuses on only one specific joint or movement.

The NBM has been found to be both reliable and valid in clinical studies. In a study performed by Liston et al8 involving balance of post-stroke patients, the NBM was compared against two other manually administered tests commonly used in physical therapy to determine balance: the Berg Balance Scale and the Gait Velocity Test. The
NBM was found to have a very strong reliability in all tests involving dynamic shifts of center of gravity, especially in the limits of stability test. Validity of the dynamic activities was also found to be accurate with the NBM. This study shows that the NBM can be considered an appropriate and reliable tool used to measure and study balance. Figure 1 is a picture of the NBM.
Pilot Study

The testers followed the NBM manual and completed an instrumentation course to become proficient in its operation. The instrumentation course was a two-credit course provided at the University of North Dakota Physical Therapy Department as a way to learn about and become familiar with the NBM. A pilot study was performed in order to determine inter-reliability and intra-reliability of the two testers for the limits of stability and lunge tests.

Ten subjects ranging in ages between 21 and 60, consisting of both males and females, were tested for the pilot study. All testing was performed on the NBM in the research room of the University of North Dakota Physical Therapy Department. Each subject performed both the limits of stability and the forward lunge test for each of the two researchers administering the tests. The subjects were then tested once again by both researchers at least two days after the initial testing.

**Intra-rater Reliability**

A Pearson correlation coefficient was calculated from a repeated measures analysis of variance (ANOVA) in order to assess test-retest reliability for each tester. Results are shown in Tables 1 and 2.

**Inter-rater Reliability**

A Pearson correlation coefficient was calculated from a repeated measure ANOVA to determine reliability between each tester. Results are shown in Tables 3 and 4.
Table 1. Intra-rater Reliability for Limits of Stability

<table>
<thead>
<tr>
<th>Limits of Stability</th>
<th>Tester 1</th>
<th>Tester 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Movement Velocity Forward</td>
<td>.8918</td>
<td>.7019</td>
</tr>
<tr>
<td>Movement Velocity Backward</td>
<td>.5500</td>
<td>.9475</td>
</tr>
<tr>
<td>Movement Velocity Left</td>
<td>.7465</td>
<td>.7180</td>
</tr>
<tr>
<td>Endpoint Excursion Forward</td>
<td>.7652</td>
<td>.8093</td>
</tr>
<tr>
<td>Endpoint Excursion Backward</td>
<td>.7061</td>
<td>.7478</td>
</tr>
<tr>
<td>Maximal Excursion Backward</td>
<td>.7504</td>
<td>.8031</td>
</tr>
<tr>
<td>Maximal Excursion Right</td>
<td>.7920</td>
<td>.5567</td>
</tr>
<tr>
<td>Directional Control Forward</td>
<td>.8662</td>
<td>.7405</td>
</tr>
<tr>
<td>Directional Control Backward</td>
<td>.5483</td>
<td>.6867</td>
</tr>
<tr>
<td>Directional Control Right</td>
<td>.7626</td>
<td>.8187</td>
</tr>
</tbody>
</table>

Table 2. Intra-rater Reliability for Lunge

<table>
<thead>
<tr>
<th>Lunge</th>
<th>Tester 1</th>
<th>Tester 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance – Right side</td>
<td>.9121</td>
<td>.9766</td>
</tr>
<tr>
<td>Distance- Left side</td>
<td>.9465</td>
<td>.9405</td>
</tr>
<tr>
<td>Impact Index – Right side</td>
<td>.9192</td>
<td>.8994</td>
</tr>
<tr>
<td>Impact Index – Left side</td>
<td>.8220</td>
<td>.9105</td>
</tr>
<tr>
<td>Contact Time – Right side</td>
<td>.9570</td>
<td>.8518</td>
</tr>
<tr>
<td>Contact Time – Left side</td>
<td>.8366</td>
<td>.8087</td>
</tr>
<tr>
<td>Force Impulse – Right side</td>
<td>.9570</td>
<td>.8711</td>
</tr>
<tr>
<td>Force Impulse – Left side</td>
<td>.8473</td>
<td>.8544</td>
</tr>
</tbody>
</table>

Table 3. Inter-rater Reliability for Limits of Stability

<table>
<thead>
<tr>
<th>Limits of Stability</th>
<th>Tester 1 – Tester 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Movement Velocity Forward</td>
<td>.8887</td>
</tr>
<tr>
<td>Movement Velocity Backward</td>
<td>.7250</td>
</tr>
<tr>
<td>Movement Velocity Left</td>
<td>.8164</td>
</tr>
<tr>
<td>Endpoint Excursion Forward</td>
<td>.9159</td>
</tr>
<tr>
<td>Endpoint Excursion Backward</td>
<td>.6617</td>
</tr>
<tr>
<td>Maximal Excursion Backward</td>
<td>.8421</td>
</tr>
<tr>
<td>Maximal Excursion Right</td>
<td>.7226</td>
</tr>
<tr>
<td>Directional Control Forward</td>
<td>.8670</td>
</tr>
<tr>
<td>Directional Control Backward</td>
<td>.8499</td>
</tr>
<tr>
<td>Directional Control Right</td>
<td>.6968</td>
</tr>
</tbody>
</table>
Table 4. Inter-rater Reliability for Lunge

<table>
<thead>
<tr>
<th>Lunge</th>
<th>Tester 1 – Tester 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance – Right side</td>
<td>.9812</td>
</tr>
<tr>
<td>Distance – Left side</td>
<td>.9590</td>
</tr>
<tr>
<td>Impact Index – Right side</td>
<td>.9056</td>
</tr>
<tr>
<td>Impact Index – Left side</td>
<td>.9388</td>
</tr>
<tr>
<td>Contact Time – Right side</td>
<td>.9156</td>
</tr>
<tr>
<td>Contact Time – Left side</td>
<td>.7791</td>
</tr>
<tr>
<td>Force Impulse – Right side</td>
<td>.9229</td>
</tr>
<tr>
<td>Force Impulse – Left side</td>
<td>.8402</td>
</tr>
</tbody>
</table>

Pearson Correlation Coefficient Interpretation

There are no standard values set for acceptable reliability when calculating Pearson correlation coefficient. Values vary between 0.00, which represents no correlation at all, and 1.00, which represents 100% correlation. Using the Pearson correlation coefficient interpretation listed in Table 5, values were obtained for intra-rater and inter-rater reliability of both the limits of stability and lunge test. The limits of stability test shows moderate to very high reliability with numbers ranging from .5483-.9475. The lunge test shows high to very high reliability with numbers ranging from .8402-.9812. Table 5.

Inter-rater Correlation Coefficient Interpretation

<table>
<thead>
<tr>
<th>Description of Strengths</th>
<th>Correlation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Little if any</td>
<td>0.00-0.25</td>
</tr>
<tr>
<td>Low</td>
<td>0.26-0.49</td>
</tr>
<tr>
<td>Moderate</td>
<td>0.50-0.69</td>
</tr>
<tr>
<td>High</td>
<td>0.70-0.89</td>
</tr>
<tr>
<td>Very High</td>
<td>0.90-1.00</td>
</tr>
</tbody>
</table>
Pre-Assessment

All athletes were assessed on the NBM prior to the beginning of their training at Altru Health Institute’s Sports Acceleration program. Subjects were given a random number based on their order of testing, in order to maintain subject confidentiality. The athlete’s height and date of birth were recorded on his/her NBM file. Completing the limits of stability and forward lunge tests on the NBM assessed the subjects’ current balance and reaction time. Athletes were required to be barefoot during the test, to ensure conditions would be equal during their post-assessment. By being barefoot, variables such as shoe height and traction were eliminated.

Each of the two tests used in this study, limits of stability and forward lunge, were performed as described in the NBM operator’s manual. Each athlete performed the limits of stability test twice, the first being a practice round and the second being the scored trial. The forward lunge was performed with three lunges on each leg and the score was averaged between the three trials. An in-depth copy of the procedures for the limits of stability and forward lunge, as stated in the NBM operator’s manual, is found in Appendix C.

Verbal directions for completing each test were scripted and read to the athlete, prior to testing, to ensure the two researchers were giving the same directions to every athlete. A copy of the scripted verbal instructions, given to the subjects before each test, is found in Appendix D.

Sports Acceleration Protocol

The Sports Acceleration protocol at Altru Health Institute is one of the many clinics by Frappier. A typical protocol entails eight plyometric sessions and twelve
treadmill sessions. Each session varies slightly in duration, intensity, and technique. The basic concept behind the program is based on the principle of Specific Adaptation to Imposed Demand, which states that specific metabolic pathways are targeted in order to produce speed.\(^2\)

**Plyometrics**

The plyometric portion of Frappier Acceleration\(^\circ\) training consists of a specially designed plyo floor, boxes of varying heights, various floor patterns, and resistance cords similar to the sprintcords used in the treadmill portion. The patterns used by the athletes during their training sessions are numbered, and correspond to the numbers listed in the sample protocols.

Figure 2 is an example of a floor pattern used in a lower extremity plyometric session at Frappier Acceleration\(^\circ\). Each space in the pattern represents a different number. Figure 3 shows the numbers that each space represents in Figure 2. The trainer uses the pattern to create a program in which the athlete must jump into a preset order of the different spaces. A copy of a typical plyometric session using this floor pattern is found in Appendix E.

Plyometric floor patterns can vary in the number of spaces and degree of difficulty. Changing the shape of the figure and making the spaces farther apart are two ways to challenge the athlete. Figure 4, the Munoz pattern, shows a more advanced floor pattern used in lower extremity plyometrics. As with Figure 2, each of the different spaces is assigned a different number. Figure 5 shows the numbers assigned to the different spaces in Figure 4. An example of an actual plyometric work out using this floor pattern is found in Appendix E.
Another component that is often used in plyometric training is the use of boxes of varying heights from six inches to 24 inches. When an athlete jumps on or off a box, the stretch reflex allows potential energy to be stored in the quadriceps muscle. This increase in energy results in a stronger contraction of the quadriceps muscle. Figure 6 is a picture of several different box heights in which the athlete may use to jump on or off during a plyometric session.
Treadmill Training

The Super Treadmill, which was designed by Acceleration Products® Inc. (Acceleration Products® Inc., Fargo ND), provides a speed range from 0-28 miles per hour and can be raised to an angle of inclination of 40 percent and a decline angle of 10 percent. During training, these unequaled treadmills can be raised and lowered hydraulically to allow the athlete to train at a variety of inclinations. This training tool is an essential component to the Frappier Acceleration® program. Figure 7 is a picture of the Super Treadmill used in the Frappier Acceleration® program.

The Super Treadmill is designed to help athletes improve their speed while reducing 30 to 60 percent of force at the knee upon foot strike. The incline capabilities of the Super Treadmill, combined with running at increased speeds while holding on to the front grab bar and emphasizing hip flexion, hip extension, and bounding, help each athlete learn and maintain several key components of running. These components include knee drive, proper pelvic and trunk position, forceful contraction of the lower
extremity, optimal stride length, and properly coordinated upper extremity movement.

An example of a treadmill training session is included in Appendix F.

Another key component of the treadmill running program is the application of sprintcords. These cords are used during each level of training from the beginner's level one, through the advanced level four. Sprintcords are equipment used during running treadmill sessions and also during plyometric floor work. The cords are attached to the athlete's thighs and lower legs approximately half way between the hip and knee joints, and half way between the knee and ankle joints. The athletes complete the runs in their session at the prescribed speed and elevation, while holding on the front grab bar. These cords are patented resistance training equipment, and can also be implemented for sport-specific training.

Sprintcords are designed to allow proprioceptive recruitment of certain neuromusculature associated with sprinting and other sport related motions. This is achieved by loading the hip flexors throughout their range of motion until maximum hip
flexion is accomplished. With the sprintcords continuously pulling against the motion of hip flexion after the pre-swing phase of running, there is a marked extension of the hips before the recovery phase. Figure 8 is a picture of an athlete using the sprintcords while bounding on the Super Treadmill.

Figure 8. Athlete bounding on Super Treadmill with sprintcords

Along with the running program, hamstring cords are used to complement the training and give extra strengthening to the hamstring musculature. Repetitions of knee flexion using these cords for resistance are interspersed throughout the training, such as between sets on the treadmill.

Post-Assessment

Post-assessment was performed under the same conditions as the pre-assessment on each subject after completion of his or her last session at Altru Health Institute's Sports Acceleration program. Before performing the two tests, each subject was read the list of verbal instructions, as was performed in the pre-assessment. After completing the two tests, each subject was shown the data and given a brief explanation of the results.
Data Analysis

The results of this study show a comparison of the pre- and post-assessment of the limits of stability and lunge tests. Since the data was not normally distributed, a nonparametric Wilcoxon test and a paired samples \( t \) test were used to calculate the means, standard deviation, z-scores, probabilities, and standard error for each test. A two-tailed hypothesis was used and the level of significance was set at \( p<.05 \) for all tests. The results were then used to answer the research questions stated in the introduction.

Reporting of Results

Upon completion of this study, a summary of the results will be completed and sent to Altru Health Institute's Sports Acceleration program and Frappier Acceleration\(^\circ\) Inc. Copies of this independent study will be given to both the preceptor of this research project and the University of North Dakota Health Sciences Library. This study was completed to partially fulfill the requirements for the University of North Dakota School of Medicine and Health Sciences Master of Physical Therapy Program.
CHAPTER IV

RESULTS

The data from this study was collected from two NBM assessments. A nonparametric Wilcoxon test was used to determine if there were significant differences between pre- and post-assessment for the limits of stability and lunge tests.

Subject Profile

A total of nineteen subjects participated in this study consisting of ten males and nine females. The mean age was fifteen with a standard deviation of one. Athletes were involved in several different sports including football, basketball, track, volleyball, softball, baseball and golf. Basketball had the highest involvement followed by football. The average height was 5'10" for the males and 5'8" for the females. All participants reported no significant past medical history.

Research Questions

Does plyometric and treadmill training significantly improve balance in high school athletes? Does plyometric and treadmill training significantly improve reaction time in high school athletes? Dynamic balance is assessed through the lunge and limits of stability tests. Reaction time is primarily assessed through the lunge tests. The results for the limits of stability and lunge tests are discussed separately.
Results for Limits of Stability

The means and standard deviations for the selected variables are reported in Table 6. The data was not normally distributed so a nonparametric Wilcoxon test was used to see if a significant difference was present between the pre and post assessments.

The z-score and probability are also reported in Table 6. Tests that showed significant results are also indicated in the table.

Table 6. Results for Limits of Stability Pre- and Post-Assessment Tests: Mean, Standard Deviation, z-scores and Probability.

<table>
<thead>
<tr>
<th>Test</th>
<th>Test Time</th>
<th>M</th>
<th>SD</th>
<th>z</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Movement Velocity Forward (seconds)</td>
<td>1</td>
<td>7.04</td>
<td>1.89</td>
<td>-1.97</td>
<td>0.05a</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>7.94</td>
<td>2.53</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Movement Velocity Back (seconds)</td>
<td>1</td>
<td>6.06</td>
<td>1.63</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>5.59</td>
<td>1.44</td>
<td>-1.31</td>
<td>0.19</td>
</tr>
<tr>
<td>Movement Velocity Left (seconds)</td>
<td>1</td>
<td>9.90</td>
<td>2.85</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>8.78</td>
<td>2.21</td>
<td>-2.03</td>
<td>0.04b</td>
</tr>
<tr>
<td>Endpoint Excursion Forward (%LOS)</td>
<td>1</td>
<td>73.16</td>
<td>18.23</td>
<td>-0.58</td>
<td>0.56</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>76.37</td>
<td>20.34</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Endpoint Excursion Back (%LOS)</td>
<td>1</td>
<td>69.32</td>
<td>20.83</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>70.26</td>
<td>20.52</td>
<td>-0.24</td>
<td>0.81</td>
</tr>
<tr>
<td>Maximal Excursion Back (%LOS)</td>
<td>1</td>
<td>82.00</td>
<td>18.13</td>
<td>-1.26</td>
<td>0.21</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>79.64</td>
<td>15.24</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maximal Excursion Right (%LOS)</td>
<td>1</td>
<td>112.37</td>
<td>7.69</td>
<td>-0.42</td>
<td>0.68</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>111.79</td>
<td>7.65</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Directional Control Forward (%LOS)</td>
<td>1</td>
<td>75.32</td>
<td>8.61</td>
<td>-1.64</td>
<td>0.10</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>78.11</td>
<td>10.11</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Directional Control Back (%LOS)</td>
<td>1</td>
<td>66.05</td>
<td>18.18</td>
<td>-1.24</td>
<td>0.21</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>67.32</td>
<td>20.11</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Directional Control Right (%LOS)</td>
<td>1</td>
<td>73.53</td>
<td>7.85</td>
<td>-1.16</td>
<td>0.25</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>75.16</td>
<td>10.80</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

M=mean, SD=standard deviation, z=z-score, p=probability, LOS=limits of stability
a=Test 1 showed a significant improvement in score compared to Test 2
b=Test 1 showed a significant regression in score compared to Test 2
Results for Lunge

The means and standard deviations for the selected variables are reported in Table 7. The data was not normally distributed so a nonparametric Wilcoxon test was used to see if a significant difference was present between the pre- and post-assessment tests. The z-score and probability are also reported in Table 7. Tests that showed a significant result are indicated in the table as well.

Table 7. Results for Lunge Pre- and Post-Assessment Tests: Mean, Standard Deviation, z-scores and Probability.

<table>
<thead>
<tr>
<th>Test</th>
<th>Test Time</th>
<th>M</th>
<th>SD</th>
<th>z</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance</td>
<td>1</td>
<td>55.16</td>
<td>9.58</td>
<td>-2.47</td>
<td>0.01&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Right Side (%BH)</td>
<td>2</td>
<td>60.79</td>
<td>5.18</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distance</td>
<td>1</td>
<td>55.05</td>
<td>8.80</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left Side (%BH)</td>
<td>2</td>
<td>59.47</td>
<td>5.97</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Impact Index</td>
<td>1</td>
<td>38.58</td>
<td>13.51</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Right Side (%BW)</td>
<td>2</td>
<td>38.42</td>
<td>11.60</td>
<td>-0.06</td>
<td>0.95</td>
</tr>
<tr>
<td>Impact Index</td>
<td>1</td>
<td>35.21</td>
<td>12.48</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left Side (%BW)</td>
<td>2</td>
<td>35.95</td>
<td>9.79</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Contact Time</td>
<td>1</td>
<td>0.76</td>
<td>0.56</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Right Side (seconds)</td>
<td>2</td>
<td>0.60</td>
<td>0.15</td>
<td>-1.79</td>
<td>0.07</td>
</tr>
<tr>
<td>Contact Time</td>
<td>1</td>
<td>0.75</td>
<td>0.34</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left Side (seconds)</td>
<td>2</td>
<td>0.60</td>
<td>0.15</td>
<td>-2.68</td>
<td>0.01&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>Force Impulse</td>
<td>1</td>
<td>82.58</td>
<td>55.23</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Right Side (%BWseconds)</td>
<td>2</td>
<td>66.37</td>
<td>15.01</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Force Impulse</td>
<td>1</td>
<td>79.11</td>
<td>31.04</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left Side (%BWseconds)</td>
<td>2</td>
<td>66.47</td>
<td>14.62</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

M=mean, SD=standard deviation, z=z-score, p=probability, BH=body height, BW=body weight

<sup>a</sup>=Test 1 showed a significant improvement in score compared to Test 2
<sup>b</sup>=Test 1 showed a significant improvement in score compared to Test 2
<sup>c</sup>=Test 1 showed a significant improvement in score compared to Test 2
<sup>d</sup>=Test 1 showed a significant improvement in score compared to Test 2

Balance showed a significant change in score between pre- and post-assessment in the following tests: movement velocity forward and left, distance with the right and left leg, contact time with the left leg, and force impulse with the left leg. All of these
tests indicated an improvement in score except movement velocity left, which indicated a regression in score. Reaction time showed a significant improvement in score between pre- and post-assessment in the following tests: distance with the right and left leg, contact time with the left leg, and force impulse with the left leg.
CHAPTER V
DISCUSSION

Research has shown the importance of both balance and reaction time in athletes. One of the areas that research has lacked is the effect of a training program on both reaction time and balance in the same study. This is one of the primary reasons this independent study was performed. Realizing the importance of this type of research, the researchers developed this study to try to objectively show how acceleration training affects balance and reaction time in high school athletes. The results of this study will help validate the importance of sports acceleration training in athletes and give physical therapists objective data about plyometrics and treadmill training.

Results with Plyometric and Treadmill Training

Dynamic balance and reaction time can be shown to improve by several different tests. In the limits of stability test of this study, acceleration training was shown to significantly affect forward velocity and velocity to the left. This is significant because without an improvement of balance, a person would fall if they attempted to move at a faster pace. This is just one of the tests that showed an improvement in balance after plyometric and treadmill training.

In the lunge test, acceleration training was shown to significantly affect right and left distance per step, contact time of the left foot, and the force impulse of the left foot. When a person steps as far and as fast as he/she can, as in the lunge test, the center of
gravity is displaced forwardly, and then returns to normal when the foot is returned to the original starting position. It would take a significant improvement of balance to step farther without falling,\textsuperscript{25} as was observed in this test.

Contact time is the amount of time the foot is in contact with the ground after the person takes a step.\textsuperscript{25} A reduction in time after training, as was seen with the left foot, would show an improvement in balance. This can be assumed because in a position in which the legs are greatly displaced, as in the lunge test, balance is maintained by keeping contact between the feet and the ground. By decreasing the amount of time the feet are in contact with the ground, if balance were not improved, the person would fall.

A decrease in contact time during the lunge test will also show a significant improvement in reaction time.\textsuperscript{25} Prior to performing the lunge test, the researchers instructed the athletes to step as far and as fast as they could, and then return the foot the original starting position. Stepping as fast as possible requires quick movement by each athlete. By decreasing the amount of time the foot is in contact with the ground, the athlete's reaction time has been improved.

Force impulse is the amount of force placed on the ground when stepping forwards during the lunge test.\textsuperscript{25} This is a component of the lunge test that measures an athletes' ability to control his or her weight displacement. A decrease in force impulse shows an improvement in balance. By being able to control ones body while taking a step, less force is required to take that step. Also, by stepping quicker, less force is placed with the step before the foot is brought back to the starting position.
Limitations

As with many other research projects, this study had several limitations. The following limitations have been identified by the researchers: reliability of the researchers, limited sample size, limited variation of subjects, tests used, conflicting results on limits of stability test, and limited research on balance and reaction time. By presenting these limitations, the researchers hope to make further studies on balance and reaction time more efficient and reliable.

One of the main limitations in this study was the reliability of the two researchers who tested the subjects. The limits of stability test measures many different components of weight distribution. With the awkward sensation of shifting one’s center of gravity, this is a very difficult test to obtain very high reliability. The researchers were only able to become reliable on ten out of the twenty components of the limits of stability test during the pilot study. By not being highly reliable on every component of the limits of stability test during the pilot study, the researchers were unable to use the unreliable components during the actual study. The lunge test is much easier to administer than the limits of stability, and the researchers were able to produce very high reliability in every component of the test.

One way to address the problem of moderate reliability would be to perform a more in-depth pilot study. By increasing the number of participants in the pilot study, the chance for variation will decrease and the researchers have a better chance on becoming reliable in all of the different components of the tests. Also, if the researchers would have given the athletes in the study more time to practice the limits of stability test before scoring their test, the variation of their movements might have decreased and the
reliability of the researchers would have increased. Another possibility would be to use only one researcher to do the testing. Using every aspect of the tests might have been able to show stronger evidence in how plyometric and treadmill training affect balance and reaction time.

A second limitation in the study was the limited sample size being studied. In order to make global references from a study, it is important to have a sample size of at least thirty people. Although the study started off with 25 subjects, only 19 people were available to be post-assessed. This decline of people is from several different reasons. One of the reasons is due to people who had moved away from the area. This is one component that the researchers had no control over.

Another reason for the high attrition rate could be how this particular acceleration program is set up. In this program, an athlete has a given number of training sessions, usually 20, and has as much time as needed to complete the sessions. By performing the study in the summer, the researchers failed to take into account that many people go on vacation or are involved in different activities throughout the summer. These were some of the possible explanations why some participants involved in the study were unable to complete the program and get post-assessed.

One way to address this in future studies would be to start testing subjects at an earlier date to allow the athlete enough time to finish the program. Another possible solution would be to set time restrictions on the athlete and force them to complete the program in a given amount of time. This would limit variation and ensure that all athletes would finish the program.
A third limitation was the limited variation in the subjects involved. The subjects were picked for this study by being involved in Altru Health Institute’s Sports Acceleration program during the summer of 2000. By limiting subject profile to just athletes in one particular geographical area, there is an increased risk of a biased sample. Also, by performing the study only in the summer, there is decreased variation in the type of sports the athlete is training for. A greater variation in subject profile could have been obtained by selecting athletes involved in plyometric and treadmill training programs from a variety of acceleration programs throughout the year.

A fourth limitation involves the tests that were used in this study. The Neurocom® Balance Master (NBM) is a machine that can objectively measure balance very effectively, but proving the effect on reaction time is limited to only a few components of the limits of stability and lunge tests. The limits of stability test does have a reaction time component that would have been able to measure the effect on reaction time, however, the researchers were unable to prove reliability in this area during the pilot study. The researchers were then forced show an improvement in reaction time from just the contact time of the lunge test. In the future, using other tests, such as a timed sprint, subjective questionnaire, or a timed reaction test to different visual stimuli, in conjunction with the NBM, may provide more evidence for improvement of reaction time.

A fifth limitation was the conflicting results with the limits of stability test. A significant improvement was noted in the forward velocity, as was expected, but there was a significant decrease in velocity going to the left. This is a result that is very difficult to interpret. One possibility could be that the majority of subjects were right-
hand dominant and muscle imbalances prevented them from shifting their weight to the
left at a fast pace. Another possibility could be not enough practice time was allowed
before performing the actual test. In either of these cases, this is a result that was not
planned and cannot be reasonably explained.

A sixth limitation is the limited research studies available involving both balance
and reaction time. Several studies have been done on just one of these aspects of athletes,
but there have been zero studies the effects of plyometric and treadmill training on
balance and reaction time. Without having any studies to use prior to starting this study,
it was difficult to decide which tests to use and how to run the study.

Conclusion

Both plyometrics and treadmill training have been used to train athletes for many
years. It is important to provide physical therapists and coaches with objective research
on different exercises to allow for modification and improvement of training techniques.
By addressing these training techniques, it is the researchers desire to improve the
training and ultimately the performance of athletes.

This study has objectively shown the effects of plyometrics and treadmill training
on balance and reaction time in high school athletes. Significant improvement was
observed in the following tests: forward velocity during the limits of stability test, right
and left distance per step, contact time of the left foot, and force impulse of the left foot
during the lunge test. These results help validate the importance of plyometric and
treadmill training.

Further research on this topic is required to show how different types of training
affect balance and reaction time. It is recommended to future researchers that the
limitations presented in this study be considered in order to develop a more effective and reliable study.
Institutional Review Board
Research Project Action Report

Date: May 5, 2000
Principal Investigator: Marcus Sorenson, Jay Armstrong
Andrea Richter
Department: Physical Therapy
Phone #: 746-7888

Address to which notice of approval should be sent: Altru Health System Research Department

Research Coordinator: Same as Above
Phone #: 777-2831

Project Title: The Effects of the Sports Acceleration Training Program on Balance and Reaction Time in High School Aged Athletes

The above referenced project protocol and informed consent was reviewed by the Altru Health System Institutional Review Board on 5/19/00 and the following action was taken:

X Project approved. Next Scheduled review is on 5/19/01 18-15-00
If no date is given, then review will be required in 12 months. (See REMARKS SECTION for any special condition.)

☐ Project approved. EXPEDITED REVIEW NO.
Next scheduled review is on

☐ Project approved. EXEMPT CATEGORY NO.
No periodic review scheduled unless so stated in REMARKS SECTION.

☐ Project approval deferred. (See REMARKS SECTION for further information.)

☐ Project denied. (See REMARKS SECTION for further information.)

☐ Amendment approved

☐ Administrative change approved

☐ Protocol revision approved

☐ Revised consent form approved

☐ Adverse event reviewed - Date of event

☐ Other

REMARKS:
Any changes in protocol, adverse occurrences or deaths in the course of the research project must be reported immediately to the IRB chairperson or the IRB office (780-6161).

Signature of Chairperson or Designated IRB Member
Altru Health System Institutional Review Board

Date:

the proposed project is to be part of a research activity funded by a federal agency, a special assurance statement or a completed 596 Form may be required. Contact IRB office to obtain the required documents.
Institutional Review Board  
Research Project Action Report

Date: May 30, 2000  
IRB # PT-013

Principal Investigator: Jay Armstrong, Andrea Richter, Marcus Sorenson  
Department: Physical Therapy  
Phone #: 746-7888

Address to which notice of approval should be sent: Altru Health System Research Department

Research Coordinator: Same as above  
Phone #: 777-2831

Project Title: The Effects of the Sports Acceleration Training Program on Balance and Reaction Time in High School Aged Athletes

The above referenced project protocol and informed consent was reviewed by the Altru Health System Institutional Review Board on __________ and the following action was taken:

☑ Project approved. Next Scheduled review is __________

☐ If no date is given, then review will be required in 12 months. (See REMARKS SECTION for any special condition.)

☑ Project approved. EXPEDITED REVIEW NO. __________

☐ Next scheduled review is __________

☑ Project approved. EXEMPT CATEGORY NO. __________

☐ No periodic review scheduled unless so stated in REMARKS SECTION.

☑ Project approval deferred. (See REMARKS SECTION for further information.)

☑ Project denied. (See REMARKS SECTION for further information.)

☑ Amendment approved  
☐ Administrative change approved  
☐ Protocol revision approved  
☐ Revised consent form approved & letter  
☐ Adverse event reviewed - Date of event __________

☐ Other

REMARKS:

Any changes in protocol, adverse occurrences or deaths in the course of the research project must be reported immediately to the IRB chairperson or the IRB office (780-6161).

Signature of Chairperson or Designated IRB Member

Date __________

Altru Health System Institutional Review Board

The proposed project is to be part of a research activity funded by a federal agency, a special assurance statement or a completed 596 Form may be required. Contact IRB office to obtain the required documents.
Institutional Review Board

Human Subjects Review Form

For new projects or procedural revisions to approved projects involving human subjects.

Jay Armstrong, Andrea Richter, Marcus Sorensen
Phone #: Jay - 746-7888, Andrea - 588-4604, Marcus - 777-8836
Address to which notice of approval should be sent: P.O. Box 9037, Grand Forks, ND 58202-9037

Address to which notice of approval should be sent:
P.O. Box 9037, Grand Forks, ND 58202-9037

Institution: University of North Dakota Department: Physical Therapy

Research Coordinator(s): Same as above Phone #: 777-2831

Proposed Project Dates: June 1, 2000 - October 1, 2000

Project Title: The Effects of the Sports Acceleration Training Program on Balance and Reaction Time in High School Aged Athletes

IRB Project Number:

Funding Agencies (If applicable):

Type of Project: 0 New Project 0 Continuation 0 Renewal 0 Student Research Project

0 Dissertation or Thesis Research

Reports: 0 Administrative Change 0 Protocol Revision 0 Revised Consent Form

0 Amendments or Change in Project

Dissertation/Thesis Advisor, or Student Advisor: Meridee Danks, MPT (777-3861)

If any of your subjects fall in any of the following classifications, please indicate the classification:

0 Minors (< 18 Years) 0 Pregnant Women 0 Mentally Disabled 0 Fetuses 0 Mentally Retarded

0 Prisoners 0 Students 0 Abortuses 0 Control Group

If your project involves any human tissue, body fluids, pathological specimens, donated organs, fetal material, or placental materials, check here ______.

____ Expedited Review requested under item ______ (number) of HHS Regulations (see attached explanation)

____ Exempt Review requested under item ______ (number) of HHS Regulations (see attached explanation)

If your project has been/Will be submitted to another Institutional Review Board(s), please list name of Board(s):

UND cooperative agreement

Status of submission to another IRB: 0 Submitted; Date ______ 0 Approved; Date ______ 0 Pending

Any additional information should be documented on a separate sheet of paper.

1. ABSTRACT (Limit to 200 words or less and include justification or necessity for using human subjects. Attach additional sheet if necessary.)

High school age athletes' involvement in Sports Acceleration training has grown in recent years. Athletes use the Sports Acceleration program to help gain an edge over their competition. One way to gain that edge is by improving balance and reaction time. These two components are important in a wide variety of sports. They help to minimize injury and increase the skill level and performance of the athlete. The purpose of this study is to determine if the Altru Health Institute's Sports Acceleration plyometric and treadmill training increases balance and reaction time in high school age athletes. Data will be obtained by assessing high school athletes involved in the Sports Acceleration program at Altru Health Institute during the summer of 2000.
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 including data collection instruments where applicable.

2. PROTOCOL: (Describe procedures to which humans will be subjected.)

Subjects: Subjects will include high school athletes participating in the Altru Health Institute Sports Acceleration program during the summer of 2000. Subjects will be involved in both plyometric and treadmill training. Weight training during the program is optional, and will not exclude subjects from this study. Each subject will be 18 years of age or younger. Involvement in the study will be voluntary and informed consent will be obtained through a signed consent form by subjects and the subject's parent or legal guardian. Recruitment will be through word of mouth by Altru staff and/or researchers and subjects will be tested prior to the start of their Sports Acceleration training. Thirty subjects or more will be needed for this study. Subjects who do not complete the Sports Acceleration program will be dropped from the study.

Testing Procedure: Subject's balance and reaction time will be assessed on the NeuroCom Balance Master. It is a clinically accepted and reliable machine that is commonly used in physical therapy to assess balance. The subject stands on a forceplate that sends various data to a computer software program that then interprets the data. Subject's balance and reaction time will be assessed with the following tests using standardized testing procedures.

1. Limits of Stability: In standing, subjects will be required to shift their body weight and lean in eight directions while maintaining balance and keeping feet firmly on the forceplate. Directions include forward, backward, sideways, and diagonal. This tests a subject's reaction time and dynamic balance.

2. Forward Lunge: Subjects will be required to step forward as fast and as far as they can with one leg, then return to the starting position. There will be six trials total, three with the left leg and three with the right leg. This tests a subject's functional balance and reaction time.

All testing will be done at the Altru Health Institute physical therapy department. Subjects will be assessed on the first day of their respective training programs through Sports Acceleration. This assessment will be done during the initial Sports Acceleration evaluation, which is prior to their first training session. During the initial testing, each subject will be given a practice session and then be scored on the limits of stability and forward lunge tests. Final testing will be done during the sixth and final week of the Sports Acceleration training program.

Data Analysis: Data will be presented using descriptive and analytical statistics with an alpha level of .05. All subject information will remain confidential and a number known only by the researchers will identify individual data. Results will be reported in a way that ensures subject confidentiality. All data will be kept in a locked file at the University of North Dakota Department of Physical Therapy and data will be destroyed after three years.
3. **BENEFITS:** (Describe the benefits to the individual or society.)

Upon completion of this study, the data obtained will help determine the effectiveness of Sports Acceleration training in improving balance and reaction time for high school athletes. The possible improvements in balance and reaction time obtained through this training may increase skill level and performance in each athlete's respective sport and possible reduction of injuries. This study can be used as reference for future studies pertaining to balance and reaction times in training program participation.

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 associated with this study are minimal, but those that do exist will be controlled. The physical risks include loss of balance and/or fall, and will be controlled by the use of a spotter during each assessment. Clear and thorough instructions for the testing procedure and the subject's role in the research project will be given verbally before he or she is assessed on the NeuroCom Balance Master. Keeping all information confidential and not attaching names to any of the data collected will protect participant's respect and dignity. All participants will be informed of the confidentiality associated with this research. Subjects will be scheduled so that their privacy will be maintained and they will be provided a safe and controlled environment in which to be assessed. Information on the right to withdraw from this study at any time will be contained in the consent form that each participant will sign prior to the initial assessment.
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 who will be obtaining consent, where signed consent forms will be kept, and for what period of time.

Attached is a copy of the consent form that will be distributed to all prospective participants for the research project along with the Sports Acceleration consent form. All consent forms and data collected will be kept in a locked office at the University of North Dakota Department of Physical Therapy. Information will be kept for a period of three years and after that time, it will be destroyed.

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

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

Eleanor Tveit, IRB Secretary  
1000 South Columbia Road  
Grand Forks, ND 58201  
701-780-6161

The policies and procedures on Use of Human Subjects in Altru Health System Institutions apply to all activities involving use of Human Subjects performed by personnel conducting such activities. No activities are to be initiated without prior review and approval of the Altru Health System Institutional Review Board.

Signatures:

Principal Investigator: [Signature]  
Date: 5-4-00

Project Director: [Signature]  
Date: ________________

Research Coordinator: [Signature]  
Date: ________________

Student Advisor (where applicable): [Signature]  
Date: 5-4-00
Dear Athlete,

You are receiving this letter because you are participating in the Sports Acceleration program at Altru Health Institute. During the summer of 2000, graduate students from the University of North Dakota Physical Therapy Program will be cooperating with the Sports Acceleration program at Altru Health Institute on a research project. We will be studying the effects of the plyometric portion of Sports Acceleration training on balance and reaction time in high school athletes. These two components are important to success no matter which sport you participate in at the high school level. They help each athlete to get an edge over their competition and minimize the chance of injuries. Your participation in this study will help gain knowledge of the Sports Acceleration plyometric training and its benefits to all athletes.

Enclosed is an information and consent form to participate in this study. Please read over this carefully and if you choose be a part of this research, bring the consent form signed by yourself and your parent or legal guardian to the first day of your Sports Acceleration training.

Thank you for your consideration and we strongly urge you be a part of our research project. If you have any questions or concerns, please feel free to call the graduate students at the following numbers: Jay Armstrong (701)746-7888, Andrea Richter (701)588-4604, Marcus Sorenson (701)777-9867 or contact our advisor Meridee Danks at (701)777-3861.

Sincerely,

Jay Armstrong, Andrea Richter, Marcus Sorenson
University of North Dakota Physical Therapy Students

Enclosure (1)
Information and Consent Form

Title: The Effects of the Sports Acceleration Training Program on Balance and Reaction Time in High School Aged Athletes

You are invited to participate in a study conducted by Andrea Richter, Jay Armstrong, and Marcus Sorenson, all graduate students in Physical Therapy at the University of North Dakota. The purpose of this study is to determine the effects of the Sports Acceleration program on balance and reaction time in high school aged athletes. The balance testing will be performed on the NeuroCom® Balance Master. It is a clinically accepted and reliable machine that is commonly used in physical therapy to assess balance and reaction time.

Participants involved in the plyometric and treadmill portion of the Sports Acceleration training program at Altru Health Institute, who are 18 years or younger, will be eligible for this study. Subjects will be tested on the NeuroCom® Balance Master on the first day, prior to the start of their Sports Acceleration training program, and then again during the sixth and final week of the program. All testing will be done at the Altru Health Institute Physical Therapy Department. Subjects who do not complete the training program will be dropped from the study.

Participation in this study is voluntary and you are free to discontinue participation at any time, up until final data has been collected. Participation in this study will in no way affect your relationship with the University of North Dakota, or Altru Health Institute.

Your involvement in this study will help to determine the effects of Sports Acceleration training on balance and reaction time. There will be few, if any, discomforts or inconveniences associated with participation in this study. Testing will take approximately 20 minutes for each of the two sessions. Participants will be tested on dynamic and functional balance. Clear and thorough instructions will be given before each of the two tests.

The results of this study and any subject information will remain confidential. A random number will be assigned to you and will be used to represent your data. Only the investigators will have access to this information. Records will be stored in a locked office at the Physical Therapy Department at the University of North Dakota. These records will be destroyed three years after the study has ended, unless they are required for future studies.

The risks associated during participation of this study are minimal, but those that do exist will be controlled. The physical risks could include loss of balance and falling. A spotter will be present during the testing process to ensure subject safety. Should injury occur during the testing process, you will receive appropriate medical attention. The investigators, along with Altru Health Institute and the University of North Dakota, are
not responsible for any such injury. You, or any third party payer, will be responsible for payments of any treatment needed.

The investigators are available to answer any questions you might have concerning this study now, or in the future. Questions may be answered by contacting Marcus Sorenson at (701)777-9867, Jay Armstrong at (701)746-7888, Andrea Richter at (701)588-4604, or our advisor Meridee Danks at (701)777-3861.

I have read all the above and all of my questions have been answered. My signature indicates that I willingly agree to participate in this study explained to me by Marcus Sorenson, Jay Armstrong, and/or Andrea Richter. I understand that my medical records and study records are confidential. However, representatives of the study sponsor, the U.S. Food and Drug Administration (FDA), or the Institutional Review Board (IRB) may need to inspect my medical and/or study records. By signing this consent, I am allowing this inspection.

Participant’s Signature

Date

I have read all the above and all of my questions have been answered. My signature indicates that I give my permission and consent to allow my child to participate in this study.

Parent or Guardian’s Signature

Date
TEST ADMINISTRATION PROCEDURE

Limits of Stability

According to the NBM manual, the limits of stability test (LOS) measures the extent a person can lean in a given direction without losing balance, stepping, or reaching for support. A person was placed on the NBM force plate as per instructions by the NBM initial LOS screen. During this test, the patient's center of gravity (COG) was shown as a cursor on a monitor found directly in front of them. As the subject shifted his/her weight, the cursor on the monitor showed the displacement of their COG.

Throughout the test, eight targets were displayed on the screen in a clockwise manner, 45 degrees apart from each other. The LOS consists of eight trials conducted in the following manner: forward, forward-right, right, backward-right, backward, backward-left, left, forward-left. Figure 7 is an example of what the LOS screen looks like in reference to the different boxes the person will try to get the target into. Once the subject was ready to begin, the tester clicked the mouse, which caused a "GO" and a blue circle in the designated target to appear on the screen. The subject shifted his/her weight as fast and as straight as possible to move the cursor to the designated target. The subject held the cursor in that target for eight seconds, so the machine could properly record the information. After the eight seconds, the individual then moved the cursor to the original, starting position and prepared to move to the next target. The first round of eight trials was a practice round, while the second round was a scored round. The practice round was to ensure the scoring was the actual dynamic ability, and not the ability to figure out the cursor control.
According to the NBM, the forward lunge test measures the following four components: distance, time, impact force and force impulse. The average length of a forward step expresses a percent of total body height. The average maximum force displaced during the forward lunge is a representation of a percentage of total body weight. By measuring these components, objective data can be produced to show changes in foot speed, body control, and coordination.

The subject was placed with his/her heels aligned to the back of the NBM force plate. After the subject was ready to begin the test, the tester clicked the mouse, which started the test. A "GO" sign was then shown on the monitor in front of the subject. The subject then stepped forward as far and as fast as he/she could, and then returned to the original starting position. Testing consists of three trials with the left foot, and then three trials with the right foot. The three trials were then averaged together.
LIMITS OF STABILITY TEST DESCRIPTIONS

Reaction Time: The amount of time in seconds between the appearance of the blue circle in the highlighted target signaling the patient to move and the initiation of movement.

Movement Velocity: The average speed measured in degrees per second the individual moves his/her center of gravity between 5% and 95% of the distance to the primary target.

Endpoint Excursion: The distance measured in % of limits of stability the individual moves his/her center of gravity on the primary attempt to reach the target.

Maximum Excursion: The farthest distance measured in % of limits of stability the individual is able to move his/her center of gravity during the trial.

Directional Control: The comparison between the amount of movement that is in the direction of the target and the amount of movement that is away from the target. This is measured in as a percent.
LUNGE TEST DESCRIPTIONS

**Distance:** The average length the lunge leg takes during the forward step. Measured as a percent of body height.

**Impact Index:** The average maximal force that the lunge leg transmits as it contacts the force plate surface during the forward step. Measured as a percent of body weight.

**Contact Time:** The average amount of time that the lunge foot is in contact with the force plate during the forward step. Measured in seconds.

**Force Impulse:** The average amount of work that the lunge leg performs during the landing and push off phase of the movement. Measured as a percent of body weight and seconds.
### Limits Of Stability

<table>
<thead>
<tr>
<th>Transition</th>
<th>RT (sec)</th>
<th>MVL (deg/sec)</th>
<th>EPE (%)</th>
<th>MXE (%)</th>
<th>DCL (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (F)</td>
<td>2.25</td>
<td>5.0</td>
<td>58</td>
<td>87</td>
<td>64</td>
</tr>
<tr>
<td>2 (RF)</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>3 (R)</td>
<td>0.56</td>
<td>7.2</td>
<td>60</td>
<td>84</td>
<td>71</td>
</tr>
<tr>
<td>4 (RB)</td>
<td>0.53</td>
<td>6.8</td>
<td>71</td>
<td>102</td>
<td>61</td>
</tr>
<tr>
<td>5 (B)</td>
<td>0.50</td>
<td>6.4</td>
<td>92</td>
<td>92</td>
<td>83</td>
</tr>
<tr>
<td>6 (LB)</td>
<td>0.69</td>
<td>6.3</td>
<td>79</td>
<td>98</td>
<td>74</td>
</tr>
<tr>
<td>7 (L)</td>
<td>0.51</td>
<td>4.4</td>
<td>87</td>
<td>95</td>
<td>87</td>
</tr>
<tr>
<td>8 (LF)</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
</tbody>
</table>

#### Reaction Time (RT)

<table>
<thead>
<tr>
<th>Direction</th>
<th>0.55</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forward</td>
<td></td>
</tr>
<tr>
<td>Back</td>
<td></td>
</tr>
<tr>
<td>Right</td>
<td></td>
</tr>
<tr>
<td>Left</td>
<td></td>
</tr>
<tr>
<td>Comp</td>
<td></td>
</tr>
</tbody>
</table>

#### Movement Velocity (MVL)

<table>
<thead>
<tr>
<th>Direction</th>
<th>5.8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forward</td>
<td></td>
</tr>
<tr>
<td>Back</td>
<td></td>
</tr>
<tr>
<td>Right</td>
<td></td>
</tr>
<tr>
<td>Left</td>
<td></td>
</tr>
<tr>
<td>Comp</td>
<td></td>
</tr>
</tbody>
</table>

#### Endpoint & Max Excursions (EPE & MXE)

<table>
<thead>
<tr>
<th>Direction</th>
<th>75</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forward</td>
<td></td>
</tr>
<tr>
<td>Back</td>
<td></td>
</tr>
<tr>
<td>Right</td>
<td></td>
</tr>
<tr>
<td>Left</td>
<td></td>
</tr>
<tr>
<td>Comp</td>
<td></td>
</tr>
</tbody>
</table>

#### Directional Control (DCL)

<table>
<thead>
<tr>
<th>Direction</th>
<th>75</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forward</td>
<td></td>
</tr>
<tr>
<td>Back</td>
<td></td>
</tr>
<tr>
<td>Right</td>
<td></td>
</tr>
<tr>
<td>Left</td>
<td></td>
</tr>
<tr>
<td>Comp</td>
<td></td>
</tr>
</tbody>
</table>

**Data Range Note:** No Data Range.

**Post Test Comments:**

---

NeuroCom System Version 7.0.4, Copyright ©1989-2000 NeuroCom® International Inc. · All Rights Reserved
**Forward Lunge**

**Vertical Force**

% Body WT

**Distance**

% Body Ht

**Impact Index**

% Difference

**Contact Time**

% Difference

**Force Impulse**

% Body Wt - sec

**Data Range Note:**

No Data Range.

Post Test Comments:

**Name:** study, 10  
**ID:** ATID00013  
**Date of Birth:**  
**Height:**  
**Comments:**  
**Diagnosis:** Not Specified  
**Operator:** Sorenson, Marcus L  
**Referral Source:** Not Specified  
**File:** FD13.DRX  
**Date:** 8/3/2000  
**Time:** 8:59:56
APPENDIX D
VERBAL INSTRUCTIONS FOR SUBJECTS

Limits of Stability

The first test you will be performing is the limits of stability. You will stand with both of your feet on the Balance Master. At no time during the test can you lift either of your feet off of the Balance Master. As you shift your weight, the image of the person on the screen will move. You are allowed to use your arms and shift your hips as much as you would like, but you must not move your feet. Once the blue circle appears in the box, try to move the person as fast and as straight as you can. When each trial is finished, hold the person motionless in the center square until the next trial begins. You will try to keep the person motionless in the box until the person disappears. You will be tested in eight directions starting forward. The first attempt at all eight positions will be a practice round. You will then be tested and scored on the next try.

Hold the person in the center square until the computer says 'GO' then move the image of the person as fast and as straight as you can and hold it in box #_. Are you ready? (repeat for each trial, 8x)

Lunge

The second test you will be performing is the lunge test. You will begin with your heels on the line farthest back with your feet shoulder width apart. Once the screen says go you will step with your left foot as far and as fast as you can forward and then step back to the starting position. You will perform this three times with the left leg and then three times with the right leg.

Hold steady until the screen says 'GO' then step forward and backward as fast and as far as you can, and hold steady at the starting point. (repeat for each trial, 3x each leg)
AN EXAMPLE OF LEVEL II SESSION #1 PLYOMETRIC SESSION

In the protocol for level II session #1, using the four square formation for repetition E, the athlete would be told to jump between the four boxes starting in box one and jumping to the other three boxes consecutively. The athlete would jump from number to number on the floor with both legs as many times as they can in the allotted time, which in this case is five seconds. The ideal way to complete this exercise is by moving the lower extremity only while keeping the trunk in place over the center of the square. This would, in effect, cause the athlete’s lower extremities to resemble a cone shape while moving their feet from number to number.
I. Four Square Formation

**BOTH LEGS**

<table>
<thead>
<tr>
<th></th>
<th>Box Number</th>
<th>Time</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1-2</td>
<td>10 sec.</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>1-4</td>
<td>10 sec.</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>1-2-3</td>
<td>5 sec</td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>1-3-2</td>
<td>5 sec</td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>1-2-3-4</td>
<td>5 sec</td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>1-4-3-2</td>
<td>5 sec</td>
<td></td>
</tr>
<tr>
<td>G</td>
<td>1-3</td>
<td>5 sec</td>
<td></td>
</tr>
<tr>
<td>H</td>
<td>4-2</td>
<td>5 sec</td>
<td></td>
</tr>
</tbody>
</table>

**Average:**

\[
\begin{array}{c|c|c|c}
  & 1 & 2 & 3 \\
\hline
  & 6 & 2 & 3 \\
  & 7 & & \\
\end{array}
\]

II. Munoz Formation

**BOTH LEGS**

<table>
<thead>
<tr>
<th></th>
<th>Box Number</th>
<th>Time</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1-2</td>
<td>5 sec</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>1-4</td>
<td>5 sec</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>2-5</td>
<td>5 sec</td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>2-3-4</td>
<td>5 sec</td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>1-2-3</td>
<td>5 sec</td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>1-2-3-4-5-6</td>
<td>Total Time</td>
<td></td>
</tr>
</tbody>
</table>

**Average:**

\[
\begin{array}{c|c|c|c|c|c|c|c|c|c|c|c|c}
  & 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 & 9 & 10 & 11 & 12 \\
\hline
  & 5 & 3 & 3 & 3 & 3 & 3 & 3 & 3 & 3 & 3 & 3 & 3 \\
  & 6 & & & & & & & & & & & \\
\end{array}
\]

III. Krumrie Formation

**BOTH LEGS**

<table>
<thead>
<tr>
<th></th>
<th>Box Number</th>
<th>Time</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1-2-3-1</td>
<td>5 sec</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>1-6-7-1</td>
<td>5 sec</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>1-5-9-1</td>
<td>5 sec</td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>1-2-3-4-5-6</td>
<td>5 sec</td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>1-2-5-8-7-6</td>
<td>5 sec</td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>5-4-5-6-5</td>
<td>5 sec</td>
<td></td>
</tr>
<tr>
<td>G</td>
<td>1-7-8-2</td>
<td>5 sec</td>
<td></td>
</tr>
</tbody>
</table>

**Average:**

\[
\begin{array}{c|c|c|c|c|c|c|c|c|c|c|c|c}
  & 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 & 9 & 10 & 11 & 12 \\
\hline
  & 1 & 3 & 6 & 7 & 8 & 9 & & & & & & \\
\end{array}
\]

**Notes:**

---

---

---

---
APPENDIX F
AN EXAMPLE OF LEVEL 1, PROGRAM 8 TREADMILL SESSION

During this session, the athlete would warm up first, then complete all the repetitions and sets at each of the listed speed, elevations, and durations. For example, during run number five, treadmill would be set at 11.5 miles per hour with an elevation of 25%. The athlete would complete four sets of the required time at this treadmill setting. The time for this run is shown to be :06/:04 (RUN/HOLD), which means that after the athlete mounts the treadmill, as soon as he/she lets go of the front grab bar, the time starts. The person runs for the first six seconds without assistance, and then holds on to the front grab bar for the last four seconds, then dismounts the treadmill.
ACCELERATION TRAINING PROGRAM
PROTOCOL NUMBER 3

WORK OUT SHEET

NAME: ___________________________ DATE: ___________________________

WORK OUT NUMBER: LEVEL ONE PROGRAM EIGHT

<table>
<thead>
<tr>
<th>NO.</th>
<th>PRE H.R.</th>
<th>SPEED</th>
<th>SETS</th>
<th>%ELEV.</th>
<th>TIME</th>
<th>POST H.R.</th>
</tr>
</thead>
<tbody>
<tr>
<td>WARM-UP</td>
<td>7.4</td>
<td>1</td>
<td>5</td>
<td>1:00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.</td>
<td></td>
<td>8.0</td>
<td>1</td>
<td>15</td>
<td>:10</td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td></td>
<td>10.0</td>
<td>1</td>
<td>15</td>
<td>:10</td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td></td>
<td>10.0</td>
<td>1</td>
<td>20</td>
<td>:10</td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td></td>
<td>10.0</td>
<td>1</td>
<td>25</td>
<td>:10</td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td></td>
<td>11.5</td>
<td>4</td>
<td>25</td>
<td>:06/:04</td>
<td></td>
</tr>
<tr>
<td>6.</td>
<td></td>
<td>10.0</td>
<td>4</td>
<td>25</td>
<td>:10</td>
<td></td>
</tr>
<tr>
<td>7.</td>
<td></td>
<td>10.0</td>
<td>3</td>
<td>25</td>
<td>:10</td>
<td></td>
</tr>
<tr>
<td>8.</td>
<td></td>
<td>10.5</td>
<td>4</td>
<td>30</td>
<td>:06</td>
<td></td>
</tr>
<tr>
<td>9.</td>
<td></td>
<td>12.0</td>
<td>4</td>
<td>32.5</td>
<td>:08</td>
<td></td>
</tr>
<tr>
<td>10.</td>
<td></td>
<td>10.0</td>
<td>1</td>
<td>35</td>
<td>:10/:10/:10</td>
<td></td>
</tr>
</tbody>
</table>

NOTES:

__________________________________________________________________________

__________________________________________________________________________

__________________________________________________________________________

__________________________________________________________________________

__________________________________________________________________________
REFERENCES

1. Gambetta V. Leg strength for sports performance. Available at:


3. Gambetta V, Gray G. Following the functional path. Available at:

4. Gray G, Gambetta V. Functional balance. Available at:


9. Cahill BR, Misner JE, Boileau RA. The clinical importance of the anaerobic energy


