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

Jay R. Armstrong
University of North Dakota

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THE EFFECTS OF PLYOMETRIC AND TREADMILL TRAINING
ON BALANCE AND REACTION TIME IN HIGH SCHOOL AGED ATHLETES

by

Jay R. Armstrong
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 Jay R. Armstrong 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.

[Signatures]

(Faculty Preceptor)

(Graduate School Advisor)

(Chairperson, Physical Therapy)
PERMISSION

Title . The Effects of Plyometric and Treadmill Training on Balance and Reaction Time in High School Aged Athletes

Department . Physical Therapy

Degree . Master of Physical Therapy

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Signature ________________________________

Date 12-15-00
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ACKNOWLEDGMENTS

There are way too many people I need to thank. I need to start with my parents and brothers. You can choose your friends, but you can't choose your family. It's a good thing mine is always there for me, and they're fun to hang out with. I have to thank my classmates, especially a couple of road trippers, for making PT school at UND more than fun. Thanks for the memories. Meridee Danks; without you, I'd be working on this for a few years more at least. Thanks for the guidance. Lastly, I have to thank Marcus Sorenson and Andrea Richter for working on this study with me, too bad it would be so much easier the second time around.
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

Balance and reaction times are essential to the success of athletes in most any sports. All competitive athletes have a desire to succeed in whichever sport they choose to participate. These athletes train with goals of being bigger, stronger, and faster than their competition. Many different training programs claim that they have what it takes to give athletes an edge over their competition. One method of training that is used more frequently today to enhance athletic performance is plyometrics, which is a specific part of the Frappier Acceleration® Program (Frappier Acceleration® Inc, Fargo ND).

Problem Statement

There is minimal research published concerning plyometrics and its impact on an athlete’s performance during sports. Additionally, there is no current published research available regarding the effects of plyometrics on balance or reaction times in adolescent athletes or in the number of young athletes who are participating in sport training programs. More research is needed to validate the use of this training in improving balance and reaction time.

Purpose of Study

This study was completed to determine the effect of a plyometric and treadmill training protocol in improving balance and reaction times. High school athletes were recruited for this study to determine if participation in a 20-session training program is
effective in improving balance and decreasing reaction times when measured using the NeuroCom® Balance Master.

Significance of Study

Data collected by this study will provide information on the changes of balance and reaction times in subjects after participating in plyometric training sessions. There are many people who will benefit from this information including physical therapists, coaches, athletic trainers, personal trainers, and the athletes themselves who want to maximize their performances. This information will help to validate and promote the use of plyometrics in training for athletes of all ages.

Research Questions

This study will compare the results of balance tested before and after completion of a 20-session plyometric and treadmill training program. The questions that will be answered during this research are: 1) Does plyometric and treadmill training improve balance in high school athletes? 2) Does plyometric and treadmill training improve reaction time in high school athletes?

Hypothesis

The hypothesis for this study is that high school athletes who participate in a 20-session plyometric and treadmill training session will have a significant increase in their balance. These same athletes are hypothesized to have a decrease in their reaction times when comparing pre-assessment and post-assessment. The null hypothesis is that the athletes will have no significant change in their balance or reaction times.
CHAPTER II
LITERATURE REVIEW

There are many different components of this study. The following is a review of
the literature, which will provide a better understanding of the study and its results.

Muscle Function

Muscle spindles provide sensory information about changes in the length and
tension of muscle fibers. They are responsible for reaction to the stretch of any given
muscle. The muscle spindle functions to detect, respond to, and modify changes in the
length of muscle fibers. Using this reflex action, muscle spindles begin a stronger muscle
contraction to reduce the stretch. This is known as the stretch-shorten cycle, or stretch­
reflex. A simplified example of a stretch reflex is if a person catches a box in
outstretched arms, which they expect to weigh three pounds, when in actuality it weighs
fifteen pounds. The person’s arms are displaced in a downward direction, and the stretch
is detected. The afferent fibers in the spindle carry an impulse to the spinal cord, which
then sends and efferent stimulus back to the muscle to activate the stretched fibers. The
end result is that the outstretched arms, displaced initially, are returned to their original
position to maintain a constant limb position. This sequence of events is defined as a
reflex because it does not involve the higher control centers of the central nervous
system, the afferent stimulus only goes to the spinal cord, and is sent directly back to the
muscle as an efferent stimulus.\textsuperscript{2-4}
Plyometrics

The basis for plyometrics is “a quick powerful movement involving a prestretching of the muscle, thereby activating the stretch-shortening cycle” (Wilk et al p. 225).\(^5\) Plyometrics consist of exercises which allow a muscle to reach a maximal contraction in as short a time as possible. Plyometrics, or “jump training” has been around for many years in many different forms, and the Russians are credited with developing the first approach to application of the exercises yielding results.\(^3,5\) Research has shown that this type of training enhances an athlete’s ability to rapidly develop force and enhance dynamic competitive performances such as jumping or sprinting.\(^6,7\) Plyometric training is becoming increasingly popular due to research completed in recent years and because athletes wish to make use of the benefits. The advantages of performing plyometric exercises are numerous; increased force of eccentric contractions, increased vertical jump height, horizontal jumping ability, increased speed, and increased speed of force development.\(^3,4,8,9\) Plyometric training and its stretch-shortening has also been shown to enhance muscle mechanical efficiency more than comparative exercises performed in only shortening conditions.\(^10\)

Plyometric training enhances the ability of athletes to utilize the benefits, both neural and elastic, of the stretch reflex.\(^3,6,9,11\) Using plyometric techniques that load muscles eccentrically, the athletes are not only trying to elicit a stretch-reflex, but they are trying to use it for their benefit by enhancing performance during the subsequent concentric contraction. Athletes and coaches uphold the idea that plyometric exercises connect strength to power and feel that this is a way to enhance competitive performances.\(^6\)
There is evidence that plyometrics are not always as beneficial as some research make them appear. Kramer et al\textsuperscript{12} suggest that plyometric training is only beneficial to the athlete if the exercises are performed during pre-season training only. Other research done by Humphries et al\textsuperscript{8} show a serious potential for injury due to the extremely high eccentric impact forces during landings. The most common joints and structures involved reported were of the lower limb. The problems reported include cartilage degeneration, stress fractures, shin splints, and tendonitis. A study by Fowler et al\textsuperscript{11} reported a significant decrease in stature following plyometric drop jumping and pendulum exercises. This loss of stature was attributed to spinal loading, and the subsequent loss of intervertebral disc height.

Sports Acceleration

The training program used in this study specifically was the Altru Health Institute’s Sports Acceleration Program in Grand Forks, ND. This program was initiated by John Frappier, MS in Fargo, ND in 1986. This program consists of many unrivaled training methods and unique equipment. Some of the equipment used includes the Super Treadmill, a wooden plyometric floor similar to a basketball gym floor, sprint cords, Plyo Press, and Pro Multi-hip.

The basis for the Frappier Acceleration program is the principle of Specific Adaptation to Imposed Demand, or SAID. The training protocol is made up of short duration and high intensity exercises, which target the ATP-PC and lactate energy production systems. These systems produce most of the body’s energy during the exercises that comprise the Frappier Acceleration\textsuperscript{®} program. The training sets are from four to twenty seconds in length to utilize both the lactate energy production, which
produces the most energy from ten seconds to two minutes of exertion, and the ATP-PC system, which produces most of the energy during exertions of less than ten seconds. In addition to the SAID concept, Frappier Acceleration® training also incorporates several other components including the stretch reflex, the golgi tendon organ reflex, and also the motor engram concept.

The objectives the Frappier Acceleration program attempts to help all of its participants achieve include the following:

1. increase maximum sprint speed
2. increase anaerobic tolerance
3. improve sprinting biomechanics
4. increased proprioception
5. improved body composition
6. enhanced self-esteem.

The key components that are targeted for enhancement to meet the previous objectives include sprint mechanics, neuromuscular coordination, anaerobic conditioning, and muscle physiology. The Frappier Acceleration® program boasts average improvements of two-tenths of a second in the 40-yard dash and a 20-foot sprint on ice, and four inches added on to a vertical jump.13-15

NeuroCom® Balance Master

The NeuroCom® Balance Master (NBM) is a computer controlled balance assessment tool consisting of two nine inch by 60 inch force plates that determine the location of the theoretical center of gravity (COG) while being able to adjust for the subject’s height. The computer gives feedback and measures postural sway and the
subject’s ability to maintain the COG in a specified area. This system is a useful tool in assessing static and dynamic balance, while giving the patients constant visual feedback on the position of their COG. Two tests which were chosen for this study include the limits of stability test and the forward lunge test.

**Limits of Stability**

The limits of stability (LOS) is the farthest patients can transpose their COG without changing their base of support by stepping or falling. The criterion this test measures include reaction time, movement velocity, directional control, endpoint excursion, and maximal excursion. These criteria are defined in Appendix A. The procedure used for assessing the subjects during this study is described later in the Methodology chapter.

**Forward Lunge**

The forward lunge test is performed by lunging forward with one leg then returning to a standing position. Six trials are performed, three of them with the left leg, and the other three with the right leg. The test assesses four different areas including distance, time, impact force, and force impulse. These parameters are defined in Appendix A, and an explanation of administering the test is given in the Methodology Chapter.

**Balance**

Balance is the human body being in equilibrium, and specifically the body’s ability to maintain its center of gravity directly above its base of support. This control is possible by the skeletal muscles controlling the positions of the body’s parts against gravity, whether the person is static or dynamic. There are three main elements
functioning to provide the body information about its motion. These elements include visual, vestibular, and somatosensory system inputs. The central nervous system (CNS) is the key which interprets all the signals sent to it from these systems, and the CNS then uses the muscular system’s adjustments to control balance. The visual portion of sensory input gives feedback to the body about its orientation and interaction with the environment. This is also known as visual proprioception. Poor vision and defects in the visual field can have a negative effect on a person’s balance.\textsuperscript{18,19}

Input from the vestibular system clues the body in to changes in angular and linear acceleration and also the deceleration forces occurring during most quick movements, such as those found in most athletics contests. Although the vestibular system helps greatly in relaying information to the body about its relationship with gravity, this system primarily functions in stabilizing gaze during head movements, regulating muscle tone, and the activation of postural muscles.\textsuperscript{18,20}

The somatosensory input is important due to the fact that it directly interprets the relationship between the body and the surface with which it has contact. This system consists of cutaneous sensation, muscle proprioception, and joint proprioception.\textsuperscript{18,20} The awareness of the contact is due to the stimuli generated in receptors located in muscles, tendons, skin, joints, and viscera.\textsuperscript{1}

**Reaction Time**

Reflexes are different in each person, and their quickness is determined by each person’s genetic makeup. They are therefore inborn, and cannot be improved through training. Reflexes also cannot be consciously controlled and so are involuntary. Adversely, reaction time is the time from when a stimulus is presented to the initiation of
movement, and can be improved by training. An example of reflexes versus reaction time is in a hockey goaltender making a glove save on a slap shot. This would be a quick reaction time, which the goalie has practiced for years. An example of a reflex would be a person touching a hot pan they did not know was hot. That person’s reflexes would pull their hand away without conscious control. Quick reaction times are necessary for athletes to meet the demands of their sports, and to succeed. Many methods of training are available and utilized to quicken reactions such as tai chi, martial arts, dancing, weightlifting, and plyometrics.
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 B. 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 C.

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.\(^{17}\) 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.\(^{22}\) 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 al\(^{23}\) 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.

Figure 1. NeuroCom® Balance Master
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>
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<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>
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<tr>
<td>Endpoint Excursion Forward</td>
<td>.7652</td>
<td>.8093</td>
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<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>
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<tr>
<td>Directional Control Forward</td>
<td>.8662</td>
<td>.7405</td>
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<tr>
<td>Directional Control Backward</td>
<td>.5483</td>
<td>.6867</td>
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<tr>
<td>Directional Control Right</td>
<td>.7626</td>
<td>.8187</td>
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Table 2. Intra-rater Reliability for Lunge

<table>
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<tr>
<th>Lunge</th>
<th>Tester 1</th>
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<tbody>
<tr>
<td>Distance – Right side</td>
<td>.9121</td>
<td>.9766</td>
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<tr>
<td>Distance- Left side</td>
<td>.9465</td>
<td>.9405</td>
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<tr>
<td>Impact Index – Right side</td>
<td>.9192</td>
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<td>Impact Index – Left side</td>
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<tr>
<td>Contact Time – Right side</td>
<td>.9570</td>
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<td>Contact Time – Left side</td>
<td>.8366</td>
<td>.8087</td>
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<tr>
<td>Force Impulse – Right side</td>
<td>.9570</td>
<td>.8711</td>
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<tr>
<td>Force Impulse – Left side</td>
<td>.8473</td>
<td>.8544</td>
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Table 3. Inter-rater Reliability for Limits of Stability

<table>
<thead>
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<tr>
<td>Movement Velocity Forward</td>
<td>.8887</td>
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<td>Movement Velocity Backward</td>
<td>.7250</td>
</tr>
<tr>
<td>Movement Velocity Left</td>
<td>.8164</td>
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<tr>
<td>Endpoint Excursion Forward</td>
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<td>.6617</td>
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<td>Maximal Excursion Backward</td>
<td>.8421</td>
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<td>Maximal Excursion Right</td>
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<tr>
<td>Directional Control Forward</td>
<td>.8670</td>
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<tr>
<td>Directional Control Backward</td>
<td>.8499</td>
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<tr>
<td>Directional Control Right</td>
<td>.6968</td>
</tr>
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</table>
Table 4. Inter-rater Reliability for Lunge

<table>
<thead>
<tr>
<th>Lunge</th>
<th>Tester 1 – Tester 2</th>
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<tbody>
<tr>
<td>Distance – Right side</td>
<td>.9812</td>
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<tr>
<td>Distance – Left side</td>
<td>.9590</td>
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<tr>
<td>Impact Index – Right side</td>
<td>.9056</td>
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<td>Impact Index – Left side</td>
<td>.9388</td>
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<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>
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<th>Correlation</th>
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<td>Little if any</td>
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<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 bare foot during the test, to ensure conditions would be equal during their post-assessment. By being bare foot, 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 D.

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 E.

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\(^{®}\) 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\(^{®}\). 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 F.

Figure 2. Four square plyometric pattern  
Figure 3. Four square plyometric pattern with numbers
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 F.

Figure 4. Munoz plyometric pattern

Figure 5. Munoz plyometric pattern with numbers

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.
Figure 6. Different sized boxes used in plyometrics

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 G.

Figure 7. Super Treadmill set at an incline

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.² 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® 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>
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<th>SD</th>
<th>z</th>
<th>p</th>
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<td>0.56</td>
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<td></td>
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</tr>
<tr>
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<td>10.80</td>
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</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>
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<td>59.47</td>
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<td>9.79</td>
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</tr>
<tr>
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<td>0.60</td>
<td>0.15</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Force Impulse</td>
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<td>82.58</td>
<td>55.23</td>
<td>-1.83</td>
<td>0.07</td>
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<tr>
<td>Right Side (%BWseconds)</td>
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<td>66.37</td>
<td>15.01</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Force Impulse</td>
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<td>79.11</td>
<td>31.04</td>
<td>-2.42</td>
<td>0.02d</td>
</tr>
<tr>
<td>Left Side (%BWseconds)</td>
<td>2</td>
<td>66.47</td>
<td>14.62</td>
<td></td>
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</tr>
</tbody>
</table>

M=mean, SD=standard deviation, z=z-score, p=probability, BH=body height, BW=body weight
a=Test 1 showed a significant improvement in score compared to Test 2
b=Test 1 showed a significant improvement in score compared to Test 2
c=Test 1 showed a significant improvement in score compared to Test 2
d=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

During this study, the following research questions were addressed: 1) Does plyometric and treadmill training improve balance in high school athletes? 2) Does plyometric and treadmill training improve reaction time in high school athletes? Results were shown in the previous chapter, and will now be discussed.

Forward Lunge Test

The lunge testing was completed with eight sub-tests that proved to be reliable. Out of these eight sub-tests, four gave statistically significant results. Right and left distance, mean scores, expressed as a percentage of the individual subject’s body height, are reported in Table 7. These numbers show that when comparing the pre-assessment to the post-assessment, both the right and left distances increased. The distance stepped on the right side increased to 60.79% of body height, up from 55.16% of body height. The left side distance went from 55.05% body height to 59.47% body height. Both these results show that the subjects tested stepped farther during lunge testing after completion of a program consisting of plyometric and treadmill training. There are several possible explanations for this increase. One explanation could be that the subject’s flexibility had improved from running on an inclined treadmill and performing plyometric training. Another reason for the increase in mean distance lunged could be the increased strength that is associated with an anaerobic training regimen. The increased distance could also
be attributed to an increase in balance and confidence after completing the plyometric and treadmill training program.

The next sub-test with a significant change in score was the left side contact time. This sub-test shows how much time the subject’s extremity spent in direct contact with the NBM force plate in between the eccentric contraction to decelerated the body, and the concentric contraction to propel the body back to starting position. In order to show an improvement, the data would have to show a decrease in the mean. The results in Table 7 show that the mean left side contact time did decrease from 0.75 seconds to 0.60 seconds. There are several explanations for the lowering of contact time. These include: 1) the increases of muscle strength and balance, 2) the nature of plyometric training, which is an eccentric contraction followed by a concentric contraction, and 3) the subject’s reaction times decreased after the training program was completed.

The fourth sub-test to show improvement was the left sided force impulse, expressed as a percent of the individual’s body weight. For this test to show improvement, the number reported as a mean would have decreased, which it did for the left side. This mean went down to 66.47% body weight from 79.11% body weight. For the force impulse to decrease, the subjects would have to use less force when they contact the force plate. The results show that the subjects did indeed use less force with their left leg. Reasons for the decrease are attributed to an increase in balance, strength, flexibility, reaction time, and a general increase in the subject’s movement control.

The improvements in left distance, contact time, and force impulse could possibly be attributed to the majority of the population being right hand dominant. If the subjects were mostly right hand dominant, then the tests that assessed the right side may not have
had as much room for improvement. The left side may have had much more room to improve in these tests. The dominance of the subjects tested was not known, so there is still no clear reason why the tests of the left side improved over the right side.

Limits of Stability Test

From the limits of stability testing, the results gave the researchers ten reliable tests, although only two of them were statistically significant. Movement velocity forward’s mean, expressed in degrees per second went up from 70.4 degrees per second to 79.4 degrees per second, meaning that the subjects moved towards the front faster during the post-assessment. This change is the result of increased strength and an increase in balance. The other significant test was movement velocity left, which showed a decrease in velocity from 9.90 degrees per second to 8.78 degrees per second. A reason for this decrease is that there were two different testers, and during the pilot study it was shown that there could be deficits in inter-rater reliability. The limits of stability showed very unreliable results, and this can be possibly be attributed to several reasons. One of the reasons might be the limits of stability test is a better assessment tool for pathologic balance deficits such as persons with a stroke. Another possibility again could be the researcher error from the use of two researchers.

This study and its results cannot be compared to findings from other studies even though plyometric and treadmill training programs have been shown as an excellent way to improve strength, speed, power, and flexibility. A comparison is not possible because there is no data available from previous studies comparing plyometric and/or treadmill training programs to balance and reaction times as was done in this study.
Limitations of the Study

There are many variables that surfaced during this study that presented themselves as limitations. The first of these limitations was the relatively narrow age gap of only three years, with the youngest being 15 and the oldest 18. This made the window for statistical significance much smaller than if a wider age range of subjects were tested.

The second limitation was the small number of subjects. Only nineteen of the original 25 subjects were available for post-testing, which gave a 24% drop out rate. One of the reasons for the non-compliance was that there was no specific time frame that the 20 training sessions had to be completed within, even though it is recommended to complete all sessions within six weeks. This freedom and lack of required scheduling allowed some of the subjects to not complete all their training sessions before their competitive seasons began.

A third limitation of the study was not using a control group for comparison of the results. If a control group were used, there would have been a baseline to compare to the experimental subjects. Also, the subjects themselves presented as a limitation to the results. Being that the subjects that were assessed for this study were adolescents, there is the possibility that they may not have been giving a full effort. This could be due to them not fully comprehending the implications for this study and why it was imperative for them to give their best effort during both limits of stability and lunge pre- and post-assessment.

Fourthly, the choices of limits of stability and lunge may not have been the most reliable or have provided the best results. Other tests on the NBM may have been better choices for this study. Besides the previous, a possible fifth limitation was the use of the
NeuroCom® Balance Master itself as a medium for assessing balance and reaction time. It is possible that there is a more reliable method for assessing balance and reaction times. During the pilot study, the researchers were not reliable in all tests, so not all of the data that was compiled could be analyzed. Even though the lunge was reliable in eight out of eight tests, the researchers were left reliable in only 10 of 20 limits of stability tests.

The sixth limitation includes a limited geographical area, and it is believed by the researchers that a seventh limitation is that the athletes were not given enough time to conquer the learning curve on the NBM. Finally, since there is no research that has previously been done comparing balance and reaction time to plyometric and treadmill training, the researchers could not know what to expect, or what to test.

Recommendations

There are many implications that have been found upon completion of this study. The researchers recommend for further studies to use a control group for a baseline, which will participate in other traditional forms of training such as a track running program and/or weightlifting. This control group will aid in showing results of the experimental subjects. The subjects used should be greater in number, from a larger geographic area, and include other demographics along with a variety of sports they participate in and their ages. This will help to increase the variability, and should be done for both the actual research study and any pilot study that is done. The athletes who are being tested on the NBM® would benefit from practice sessions on the platform in order to assist them in overcoming the learning curve that is associated with the program. The testing should be completed by only one researcher, and that tester should be proven to be reliable in all tests and sub-tests before initiation of research testing. This will allow for
the researchers to use all the tests and components they choose for their study. A final recommendation would be to use some other method of assessing both balance and reaction time in the subjects, as the NBM® proved to not be a very reliable method of assessment for the researchers. This is probably due to the researchers not having much time to practice or become reliable prior to the start of research testing of subjects. Other methods of measuring may include, a timed 40-yard dash and a rhythmic weight shift timed reaction test with a visual stimulus.

Conclusion

Balance and quick reaction times are not just important for all athletes, they are important skills of every person’s daily life. People of all ages and skill levels need fairly high levels of balance and adequate reaction times in order to do simple activities of everyday life. Athletes on the other hand need these components not just to increase skill level or to gain an edge over their competitors, but also to help increase body awareness and therefore reduce the risk of injuries to the athlete. There is no current research regarding the relationship of plyometric and treadmill training and its effects on balance and reaction times. Due to this lack of research on the topic, this study was undertaken with the desire to find if there is a significant improvement in balance and reaction times in high school athletes after completing a plyometric and treadmill training program.

There was a significant improvement found in right and left lunge distance, along with left sided contact time and force impulse from the pre-assessment to the post-assessment of the lunge. A significant improvement was also found in movement velocity left and forward after analyzing the pre- and post-assessments from the limits of
stability. This shows that there was an effect of the plyometric and treadmill training program on the subject's balance and reaction times.

Due to balance and reaction time being overlooked and not assessed when training athletes for many different sports, this study was beneficial. The results from this study can be used for future studies and research, and applied to larger demographic groups, different sports, and different age groups.
APPENDIX A
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.
Forward Lunge

Data Range Note:
No Data Range.

Post Test Comments:

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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.
Limits Of Stability

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Data Range Note: No Data Range.
Post Test Comments:
APPENDIX B
Name: Meridee Danks, M.P.T.              Date: May 8, 2000
Address: P.O. Box 9037, School of Medicine and Health Sciences
Telephone Numbers: Work (701) 777-3861       Home (701) 772-0263
Department/College    Physical Therapy
Project Title: The Effects of Sports Acceleration Training on Balance and Reaction Time in High School Athletes

Your request to conduct the above named study at an Altru Health System facility involving employees or patients as participants, and/or requiring facility resources has been reviewed. The following action has been taken:

✓ Permission to conduct the study is granted

Permission to conduct the study will be granted upon completion of the following:

Permission to conduct the study is denied for the following reason(s):

RECOMMENDATIONS/REMARKS:

Virginia Enloe
Signature

Title

Date  5/8/00
Institutional Review Board  
Research Project Action Report

Date: May 5, 2000  
IRB #: P+013

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:

☑ Project approved. Next Scheduled review is on 5/19/00 12-15-00
   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 5/19/00

If 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 on _________________.
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 & letter

☐ Adverse event reviewed - Date of event _________________.

☐ Other

REMARKS:
All 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).

Date __________

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

If 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.

8410-0070 JULY 97
Human Subjects Review Form

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

Jay Armstrong, Andrea Richter, Marcus Sorenson

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

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

ABSTRACT

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 NeuroCo 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 firm 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: ___________________________ Date: 5-4-00

Project Director: ________________________________ Date: ________________________________

Research Coordinator: ____________________________ Date: ________________________________

Student Advisor (where applicable): ____________________________ Date: 5-4-00
APPENDIX C
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
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.
Forward Lunge

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.
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 straight as you can and hold it in box #. Are you ready? (Repeat for each trial, eight times)

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, three times 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.
PLYOMETRICS
Developed by: John P. Frappier, M.S.
Exercise Physiologist

Name: __________________________ Date: ______________________

Session 3, Level 1

1. 1 leg Plyo press @62% BW 2 sets 8 reps R ___________ L ___________
2. 1 leg Plyo press @77% BW 2 sets 8 reps R ___________ L ___________
3. 1 leg 6" Box 2 sets 12 reps R ___________ L ___________
4. 2 leg 12" Box 2 sets 12 reps _____________
5. 2 legs 18" Box 2 sets 12 reps _____________
6. 2 legs 24" Box 2 sets 12 steps _____________
   ** Attempt to simulate sprint striding technique **
7. 1 leg Plyo press TR @77% BW 3 sets 8 reps R ___________ L ___________
8. Box Jump 12" or Box 1-2, 2 foams Max in 15 sec. _____________
9. 1 leg Plyo press @100% 1RM 1 set 3 reps R ___________ L ___________
10. 1 leg Plyo press @92% 1RM 1 set 3 reps R ___________ L ___________
11. 1 leg Plyo press @85% 1RM 1 set 3 reps R ___________ L ___________
12. Four Square
    2 | 3
    1 | 4
   A. Box 1-2 Max in 10 sec. __________
   B. Box 1-2-3 Max in 10 sec. __________
   C. Box 1-2-3-4 Max in 10 sec. __________
   D. Box 1-3 Max in 10 sec. __________
   E. Box 1-2 Max in 15 sec. R ___________ L __________
   F. Box 1-2-3-4 Max in 15 sec. R ___________ L __________
13. Box Jump (Sprint Strides)
   A. 24" 14 Reps __________
   B. 20" 14 Reps __________
   C. 12" 14 Reps __________
   D. 8" 14 Reps __________
14. 2 legs Plyo press @77% 1RM 4 sets 5 reps _____________
15. Box jump 12" or Box 1-2 2 foams Max in 10 sec. _____________

Notes: __________________________________________________________
# PLYOMETRICS

Developed by: John P. Frappier, M.S.
Exercise Physiologist

Name: ___________________________ Date: ___________________________

Session #1  Level II  Pre-training Test

## I. Four Square Formation

### BOTH LEGS

| A. Box 1-2   | 10 sec. |   |   |   |   | Average 6 |   | 2 | 3 |
| B. Box 1-4   | 10 sec. |   |   |   |   |           |   |   |   |
| C. Box 1-2-3 | 5 sec.  |   |   |   |   |           |   |   |   |
| D. Box 1-3-2 | 5 sec.  |   |   |   |   |           |   |   |   |
| E. Box 1-2-3-4 | 5 sec. |   |   |   |   | 1 |   |
| F. Box 1-4-3-2 | 5 sec. |   |   |   |   | 4 |   |
| G. Box 1-3   | 5 sec.  |   |   |   |   |           |   |   |   |
| H. Box 4-2   | 5 sec.  |   |   |   |   |           |   |   |   |

## II. Munoz Formation

### BOTH LEGS

| A. Box 1-2   | 5 sec.  |   |   |   |   |   |   | 3 | 3 |
| B. Box 1-4   | 5 sec.  |   |   |   |   |   |   | 3 | 4 |
| C. Box 2-5   | 5 sec.  |   |   |   |   |   |   | 3 | 3 |
| D. Box 2-3-4 | 5 sec.  |   |   |   |   |   |   | 3 | 2 |
| E. Box 1-2-3 | 5 sec.  |   |   |   |   |   |   | 1 | 3 |

| F. Box 1-2-3-4-5-6 | Total Time   | Average: |
|                   |             |   |

## III. Krümmie Formation

### BOTH LEGS

| A. Box 1-2-3-1 | 5 sec.  |   |   |   |   | Average 3 |   | 3 | 3 |
| B. Box 1-6-7-1 | 5 sec.  |   |   |   |   |           |   | 3 |   |
| C. Box 1-5-9-1 | 5 sec.  |   |   |   |   |           |   | 2 | 3 |
| D. Box 1-2-3-4-5-6 | 5 sec. |   |   |   |   |           |   | 3 | 3 |
| E. Box 1-2-5-8-7-6 | 5 sec. |   |   |   |   |           |   |   |   |
| F. Box 5-4-5-6-5 | 5 sec.  |   |   |   |   |           |   |   |   |
| G. Box 1-7-8-2   | 5 sec.  |   |   |   |   |           |   |   |   |

Notes: 

__________________________________________________________________________

__________________________________________________________________________

__________________________________________________________________________
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**  
**rev. 11/15/92**

**WORK OUT SHEET**

**NAME:** ___________________________  
**DATE:** ___________________________

**WORK OUT NUMBER:** LEVEL ONE  
**PROGRAM EIGHT**

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**NOTES:**

____________________________________

____________________________________

____________________________________

____________________________________

____________________________________

____________________________________
REFERENCES


22. Mandarino L. \textit{The Future of Balance Therapy and Sports}. Clackamus, Ore: NeuroCom\textsuperscript{®} Inc.
