THE EFFECTS OF PLYOMETRIC BOUNDING UPON ANAEROBIC LEG STRENGTH AND ANEROBIC LEG POWER

ZAFAR AHMED

THE EFFECTS OF PLYOMETRIC BOUNDING

UPON ANAEROBIC LEG STRENGTH

AND ANEROBIC LEG POWER

An Abstract

Presented to

the Graduate Council of

Austin Peay State University

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

---

by

Zafar Ahmed

August 1984

ABSTRACT

The purpose of this study was to determine the effects of plyometric bounding upon anaerobic leg strength and anaerobic leg power. Seven adult college male volunteers were randomly assigned to either an experimental or control group. The experimental group participated in a six-week plyometric bounding training program. All subjects were tested for anaerobic leg strength and anaerobic leg power utilizing the Cybex II Isokinetics and Margaria Step-Test protocols. Data collected in this study were analyzed by analysis of covariance. From the analysis of the data, no significant differences were found between the experimental and control groups due to the effects of plyometric bounding training.

THE EFFECTS OF PLYOMETRIC BOUNDING UPON ANAEROBIC LEG STRENGTH AND ANAEROBIC LEG POWER

A Thesis

Presented to

the Graduate Council of

Austin Peay State University

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

---

by

Zafar Ahmed

August 1984

To the Graduate Council:

I am submitting herewith a Thesis written by Zafar Ahmed entitled "The Effects of Plyometric Bounding Upon Anaerobic Leg Strength and Anaerobic Leg Power." I recommend that it be accepted in partial fulfillment of the requirement for the degree of Master of Science with a major in Health and Physical Education.

Luke E. Thomas
Major Professor

We have read this Thesis
and recommend its acceptance:

Joe Brown
Second Committee Member

[signature]
Third Committee Member

Accepted for the
Graduate Council:

William H. Ellis
Dean of the Graduate School

ACKNOWLEDGEMENTS

The author wishes to express sincere appreciation to Dr. Luke Edward Thomas, Associate Professor of Health and Physical Education, Austin Peay State University, for his aid, guidance and time given during the entire study.

Appreciation is extended to Dr. Billy Joe Brown and his staff for their valuable assistance in making this study possible.

Additionally, the author wishes to thank Dr. George Fisher for his cooperation and understanding during the study.

TABLE OF CONTENTS

PAGE

LIST OF TABLES

Chapter I

INTRODUCTION

Recently, the Russians and East Europeans have been setting precedents in modern training principles and techniques. Extensive research in sports medicine has greatly contributed to their most recent successes in Olympic participation. During the 1972 Munich Olympics, the Russian Gold Medalist Sprinter Valerity Borzov (100 meters and 200 meters) exhibited a novel locomotor training activity descried as "Plyometrics." Much of his success has been attributed to this relatively new and unique training regimen (Wilt, 1976a; Ecker, 1975).

Plyometrics is a derivative of the Greek word "plethyein," which means to increase and isometric. However, after much deliberation a precise definition of plyometrics is not evident. Wilt (1976a) defines plyometrics as "exercise or training drills used in producing an overload of isometric type muscle action which involves the stretch reflex in muscles."

The basic principle underlying plyometric activities is a modern concept, "muscles contract far more forcefully and efficiently if they are pre-stretched" (Wilt, 1976a).

During an eccentric contraction, when a muscle is pre-stretched, stretch receptors in the specific muscle cause proprioceptive nerves to brake this action, and provided a smooth transition occurs, a positive concentric acceleration may be elicited. This gathering phase is characteristically referred to as the "stretch" or "myotatic reflex" (Wilt, 1976a).

An eccentric contraction occurs when a muscle is loaded sufficiently to lengthen it, even though it may be trying to shorten. Conversely, a concentric contraction is a shortening of the muscle, and acts anatognistic to the eccentric mode.

The "myotatic reflex" is the backbone of plyometric exercises because the eccentric/concentric synergism elicited by overloading causes very powerful muscular contractions. During plyometrics the rate of stretch (speed) is more important than the magnitude, and to achieve optimal results the concentric contraction must ensue the pre-stretched eccentric contraction. The rate of stretch is an important concept because it emphasizes speed, thus enabling the athlete to bridge the gap between sheer strength and power.

A simple analogy to this physiological explanation could be derived with an inanimate body, such as a rubber ball. When a ball is deformed as it hits the ground, it acquires stored energy (potential energy). Subsequently, as the ball rebounds to its original shape and height of release, the stored energy is released (kinetic energy). This characteristic is exhibited by the muscular contraction which ensues the gathering phase. The gathered potential energy at this braking action is released, producing a powerful concentric contraction.

Plyometric training is a new concept among North American coaches and athletes. Recent studies in investigating its practicality have focused primarily upon track and field jumpers, throwers, and sprinters. Much of the literature is devoted to power athletes. For training purposes, several variations of plyometric exercises are apparent today, such as: depth-jumping, box-drills, and hopping drills just to name a few. The applications of plyometric exercises are virtually inexhaustible and are only limited by one's imagination (Reiff, 1980).

Within the context of this study, the specific mode of plyometric training to be utilized is "bounding." Therefore, a precise definition of this training activity is justified. Bounding is a form of anaerobic leg exercise which employs the dynamic movements of the hip, knee, and ankle extensors and flexors. It is an exaggeration of the running motion, with a distinctive leg propulsion in the driving phase of the running stride. As the runner descends into the recovery phase, the alternative leg is propelled forcefully, thus effecting a distinctive rhythmic motion by both legs in their driving phase.

In retrospect, it seems as though virtually all studies have devoted the specificity of plyometrics to the power regimen of physical activity such as jumping drills for jumpers, and hopping drills for sprinters. Therefore, the purpose of this investigation was to assess the value of plyometric bounding upon anaerobic leg strength and power among adult college males.

Importance of the Study

Our Russian and East European counterparts have been the trend setters in modern training procedures, as evidenced by their contributions with plyometrics. Unfortunately, the majority of literature submitted on behalf of this novel activity is purely theoretical. Therefore, a scientific investigation seems to be warranted to ... the validity of plyometrics. From this investigation one may be able to justify the practicality of plyometric exercises and their relationship to modern training principles.

Statement of the Problem

The purpose of this study was to determine the effects of plyometric bounding training upon anaerobic leg strength and anaerobic leg power.

Statement of the Hypothesis

There would be a significant difference among control and experimental groups due to the effects of plyometric bounding.

Delimitations of the Study

1. Volunteer college-aged males from Austin Peay State University participated in this study.

2. Athletes did not participate in the study.

3. The plyometric bounding training group trained for six-weeks, three times per week.

Limitations of the Study

1. There was no attempt to rigidly control the subjects outside activities, such as weight training.

2. The investigator had no control upon the maintenance of bodyweight for all subjects throughout the study.

3. There was no attempt to rigidly control individual subjects motivation.

Definitions

Anaerobic Leg Power: Amount of work force per unit of time (Fox and Mathews, 1976).

Anaerobic Leg Strength: Capacity of a muscle to exert force in one maximum effort (Fox and Mathews, 1976).

Bounding: An explosive low, long hop. The take-off leg should be fully extended and the free knee driven parallel to the ground. The arm action is that of running (Humphrey, 1980).

Concentric Contraction: The shortening of a muscle during contraction (Fox and Mathews, 1976).

Eccentric Contraction: The muscle lengthens while contracting, developing tension (Fox and Mathews, 1976).

Isometric Contraction: Contraction in which the muscle generates force, but there is no observable movement (Fox and Mathews, 1976).

Isokinetic Contraction: Muscular contraction in which a muscle puts force against a variable resistance (Fox and Mathews, 1976).

Plyometric Exercises: Exercises or training drills which involve the stretch reflex in muscles (Bell and Steben, 1978).

Proprioception: Sensory organs found in muscles, joints, and tendons which give information concerning movements and positions of the body (Fox and Mathews, 1976).

Stretch Reflex: Basic neural mechanisms for maintenance of muscle tonus (Fox and Mathews, 1976).

Chapter II

REVIEW OF LITERATURE

Scientific evidence concerning plyometrics and its practical applications is scarce. Conversely, empirical evidence concerning plyometrics and its practicality is bountiful. This review of literature will serve to familiarize the layperson with existing research.

This chapter has been classified according to the type of literature available concerning plyometrics. Section I deals with experimental studies of plyometrics. The papers focus primarily upon comparative research in isotonic, isometric, and isokinetic regimens of exercise.

Section II encompasses a wealth of literature in plyometrics; unfortunately though, all of this research is empirically founded. Primarily speaking, this section advocates training procedures and serves as an excellent technical supplement.

Experimental Research

Within the context of this section there is very little research available. However, for the minute research existing, those specific studies provide a firm foundation for the theoretical implications for plyometrics.

From a chronological perspective the first contributing editors (Verkoshansky and Chernousov, 1974) were Russians. The investigators attempted to investigate the effects of plyometric exercises upon sprinters.

These researchers utilized short-jumps (various forms of momentaneous take-offs) and long-jumps (multiple take-offs on one leg or from leg to leg for distances of 30, 60, and 100 meters) as their form of plyometric activities. Verkoshansky and Chernousov (1974) hypothesized that "short-jump exercises ensure the development of starting acceleration, and long-jumps raise the level of specialized speed strength endurance and maximum running speed." Furthermore, the researchers stipulated that a combination program of short and long-jump exercises would elicit an overall development of sprinting ability.

Due to these three basic tenets, three experimental groups were formed with twenty subjects each. Over a nine month period Group A executed short-jumps, Group B executed long-jumps, and Group C executed the combined program of plyometric exercises.

For their testing protocol the investigators used: sprinting speed tests of 30, 60, and 100 meters, jumping for distance (with triple and ten-fold jumps from place), time taken to execute jumps from leg to leg for 30 meters, and stride frequency running in place for 10 seconds. Speed, improved technique, and frequency of stride movement are essential characteristics for overall sprinting ability and the tests serve to evaluate as such.

Verkoshansky and Chernousov (1974) concluded from their study: short-jumps substantially influenced starting acceleration and reactive abilities, long-jumps enhanced maximum running speed plus speed endurance, and the combination program (Group C) elicited a summation effect of both training regimens. Group C exhibited the greatest increments of performance from all the tests.

One of the first American studies submitted by Gordon Scoles employed depth-jumping as a means of plyometric exercises (1978). Thirty-four volunteer adult college male physical education students were randomly assigned to one of three groups. Group one (N=9) served as the experimental subjects and trained in depth-jumps twice weekly. Group two (N=9) participated in flexibility exercises (as suggested by the Williams Series of Physical Fitness) twice weekly. Group three (N=8) served as the control group and were instructed not to participate in depth-jumps or flexibility.

Scoles utilized the vertical-jump and the standing long-jump in the testing protocol (1978). From the statistical analysis (simple one-way analysis of variance) the researcher indicated that the experimental group (depth-jumps) exhibited minor increments of performance (mean increase of 4.3 percent in the vertical-jump, and a mean increase of 2.9 percent in the standing long-jump). However, Scoles clearly stipulated that the observed increments were statistically significant only at the .25 alpha level (1978).

Blattner and Noble contributed greatly with their comparative research on isokinetics versus plyometrics (1979). Forty-eight volunteer male subjects were randomly assigned to one of three groups, and the vertical-jump was employed as the testing protocol.

Group one (N=12) participated in isokinetic exercises upon the Mini-Gym 16 bx leaper leg press machine for ten weeks. Group two (N=11) participated in depth-jumping (three sets of ten repetitions) twice weekly. Vest weights were used by the depth-jumping subjects to amplify the overload stresses. Group three (N=15) served as the control subjects.

From an analysis of covariance the researchers concluded that neither training program was more effective. The mean gains from both groups were comparable as the correlation between pretest and post-test scores was high at 0.92.

An elaborate study was submitted by Polhemus, Osina, Burkharadt, and Patterson in an attempt to evaluate the effects of weight training versus weights and plyometrics (1980). Twenty-seven adult male volunteers participated in the study during a six-week period as the vertical-jump, standing long-jump, and the forty-yard dash were used in the testing protocol.

Group one (N=13) was the control group and they participated in weight training (bench-press, power clean, half-squat, and military-press). Group two (N=14) served as the experimental subjects and participated in weight training plus plyometrics. After each weight session the plyometric exercises performed were: running drill with ankle weights, and depth-jumps with vest weights.

The study was conducted over a six-week period, and an analysis of variance was used to compare the means in seeking statistical differences among groups. At the .01 alpha level the plyometric group out performed the control group significantly. Polhemus et al. concluded that the plyometric regimen made significant changes in the vertical-jump, standing long-jump, and forty-yard dash performances (1980).

In summary, the studies conducted by Scoles (1978) and Blattner and Noble (1979) did not procure statistically significant data, although both studies exhibited minute increments of performance with the use of plyometric exercises.

Conversely, Polemus et al. conducted a successful study employing weights with plyometrics (1980). From this study the researchers proved that plyometrics do enhance performance. Verkoshansky and Chernousov (1974) also submitted a successful study, although it lacked some detail. The Russian researchers validated the specificity of short-jumps, long-jumps, and the combined program.

A lot of speculation does exist about plyometrics in the scientific context. The varied results established from these studies prove that more rigorous research is warranted. Blattner and Noble (1979) suggested that many interstudy differences in the research available made it virtually impossible for a firm theoretical framework. Furthermore, confounded translation from foreign literature seriously impede the progress of favorable research. In the ensuing section a wealth of literature exists in an empirical framework. It also sereves as an excellent technical supplement.

Empirical Research

The technical supplement is the backbone of this investigation because it is directly related to the training procedures. Within the context of this section all the research is empirically founded and is relatively consistent in the theoretical framework.

American researchers Fred Wilt (1975) and Vern Gambetta (1978) have contributed greatly with their writings about plyometric exercises. Most, if not all the related literature, has an opening introduction as to the necessity of this exercise regimen.

Although Russian athletes have employed plyometric exercises as early as 1968, the American contingent was not exposed to it until

Valeriy Borzov in Munich 1972 (Wilt, 1976a). Since then there has been a gradual but steadfast development of the utilization of plyometric exercises in individual training programs. Today, numerous large universities with well established track and field programs use this exercise regimen with sprinters, jumpers, and throwers alike.

Five basic tenets underline the true plyometric training concept, and have been agreed upon by all researchers: (a) maximum tension is produced when a muscle is stretched rapidly, (b) the faster the muscle is lengthened the greater the tension, (c) the rate of stretch (speed) is more important than the magnitude, (d) use the overload principle--strength can only be increased if muscle works at greater intensity than normal, and (e) do not change the basic pattern of the movement which you are trying to imitate (Wilt, 1976b; Gambetta, 1978).

Essentially, these basic tenets are in accordance with the principle of specificity, the principle of overload, and the principle of progressive resistance (Fox and Mathews, 1976).

In addition to these basic tenets most researchers agree that technique is a vital aspect of plyometric exercises, especially if the exercises adhere to the principles of specificity (Reiff, 1980). The subsequent guidelines are suggested for specific technique: maintain upright posture, use the arms and emphasize quickness off the ground (Henson, 1980). Bell and Steben (1978) emphasize that plyometrics are quite strenuous and should be used according to the strength and age of the athletes.

Wilt states that the old theory where muscles should be relaxed prior to being contracted is false (1976b). Conversely, muscles that are subjected to a prior eccentric contraction (pre-stretched) will react far more forcefully and efficiently, thus amplifying the importance of plyometrics.

Two cases in point, the golf swing and baseball batting, are an end result of the starting movement in the opposite direction. The braking action that is produced from the wind-up results in a positive acceleration in the intended direction.

The numerous advantages in utilizing plyometrics have been cited by some authors. Hensen emphasized that quickness off the ground is a key element since jumpers spend "the least amount of time in contact with the ground," and sprinters "are very light upon their feet" (1980). Ecker stipulates that through plyometrics leg strength can be increased, and due to this stride length may be enhanced (1975). This factor could improve sprinting ability.

From its obvious connotations, a significant aspect related by all researchers is that plyometrics bridge the gap between sheer strength and power (Gambetta, 1977). Plyometrics enable the individual to react more powerfully.

The following points amplify the argument beween weight programs and plyometrics. Because of the obvious advantages of plyometrics in the locomotor and neuromuscular apparatus, Verkoshansky clearly advocates the importance of any type of plyometric training activity. From a technical standpoint, plyometric activities are more specific in nature (Verkoshansky, 1966). Polhemus et al. proved that both weights and plyometrics in a regimented nature are beneficial (1980).

There are a variety of drills existing today, and Bell and Steben suggest that to prevent injury one must introduce plyometrics in terms of quality, quantity, and frequency (1978). At the University of Indiana plyometric exercises are increased according to the feedback of the athletes (Reiff, 1980). A maximum number of two days per week is spent on plyometric drills with the athletes' regular training program.

Of all the drills existing to date, depth-jumps are the most popular. Introduced by Verkoshansky, these jumps entail a downward jump from a height, landing on the ground, then exploding back upward to a height approximately equal to what one started from (1974). These jumps are also referred to as box drills, wherein this drill is performed in rapid succession from one box to another with emphasis on the quickness off the ground (Bell and Steben, 1978). Also emphasized with the quickness off the ground is a fast, active take-off after landing. (Hopping on both legs, on one leg, and/or alternating legs are employed in the box drills with 20 to 40 repetitions.)

Power bounds are another form of plyometrics (Miller, 1980). Similar to Verkoshansky's multiple bounds, the key to these bounds is to have hips come in front of the feet as the athlete takes off. They may be done upon grassy surfaces and the distance may vary depending upon the athlete. Hopping and stair running are also good examples of plyometric exercises.

A variety of definitions exist concerning bounding. Humphrey describes bounding as "an explosive low, long hop. The take-off leg should be fully extended and the free knee driven parallel to the ground. The arm action is that of running (1980)." The investigator emphasized that this bounding drill be executed five to ten times over a distance of fifty to one hundred yards.

Verkoshansky has alluded that the most important principle underlying the plyometric concept is the principle of dynamic conformity (specificity) (1967). The investigator stipulates that these types of exercises enable the muscle to switch from yielding to overcoming work, especially during the amorization phase (braking action).

To reiterate, Verkoshansky proved that in a specific nature plyometrics have significant influence upon starting acceleration (short-jumps), maximal running speed and speed endurance (long-jumps) (1967).

All the empirical studies provided a consistent framework in a technical aspect. The principle of specificity is the most applicable, since exercises must adhere to the direct nature of one's competitive regimen. Verkoshansky alluded to this as the principle of dynamic conformity (1967).

Very little literature exists as to the training specifications of plyometric exercises. Most of the focus is upon box drills or depth-jumping and for bounding it is virtually nonexistent. As Reiff stipulated, the training regimen is subject to individual interpretation according to the strength and feedback of the athletes (1980).

Chapter III

PROCEDURES

Overview of the Study

Seven volunteer college-aged males participated in a study to investigate the effects of plyometric bounding upon anaerobic leg strength and anaerobic leg power. The subjects were randomly assigned to one of two groups, control (N=4) and experimental (N=3).

During an eight-week period the experimental subjects participated in a plyometric bounding training program. Coincidentally, the control subjects executed regular daily activities throughout the training period.

The testing protocol administered to all subjects was Cybex II Isokinetics and the Margaria Step-Test. Hip, knee, and ankle extension/flexion was procured in the Cybex II protocol in an attempt to assess isokinetic leg strength and power. The Margaria Step-Test was employed to assay subjects' leg power quotients.

Data were analyzed by an analysis of covariance with pretest scores serving as the covariate.

Selecting and Grouping of Subjects

Seven college-aged males volunteered to participate in this study, and were randomly assigned to either an experimental or control group. The selection of subjects was restricted to a population sample of Austin Peay State University males, and informed consent (with a confidentiality release) (Appendix A) was obtained from each subject in accordance with the guidelines outlined by the Austin Peay State University Human Research Committee.

Testing

All Cybex II testing procedures took place in the Austin Peay State University Dunn Center Human Performance Laboratory. Subsequently, the Margaria Step-Test protocol was administered upon the main floor steps of the Dunn Center Gym area.

Pretesting procedures took place on week one of the study, during the period October 9th until 25th. Throughout weeks two until seven the plyometric training process occurred. During week eight, December 7th until 13th, post-test procedures were elicited in similar fashion to pretest procedures.

Testing and Training Apparel

Throughout this study all subject were instructed to wear regular gym shorts, tee-shirts, and a pair of running flats.

Testing Equipment

Cybex II Isokinetic Dynamometer: This is a standard isokinetic equipment system which consists of two upright tables for knee testing and one low flat treatment table for other joint patterns. This system makes it possible to test major body joints such as the hip, knee, and ankle. For each of the specific joint patterns individual adapters are selected and stabilized upon the dynamometer input shaft. Adjustment holes are fabricated upon the input adapters so as to properly accommodate subjects' leverage positioning.

For the entire isokinetic testing protocol, peak torque values of strength and power were recorded in foot pounds per second (ft. lbs/sec). Speed adjustments were elicited by the Cybex II speed selector (0-300 degrees per second at 0-50 rpm), and the stylus recordings were monitored upon the Cybex II single channel multi-scale recorder. Standard torque values, as suggested by the Handbook of Isolated Joint Testing and Exercise (Appendix B), were elicited upon the Cybex II isokinetic dynamometer (0-360 foot pounds).

Calibrations of the dynamometer before and after each testing period were accomplished by placing known weights on the lever arm, both statically and dynamically. Velocity calibrations were elicited by the number of complete revolutions of the input shaft in one minute. All calibrations were performed daily to ensure that the small electronic drifts of the dynamometer did not alter torque readings. Total methodological error was calculated to be 4 percent as recommended by the Cybex II manual.

Margaria Step-Test: In the Margaria protocol, all measurements were recorded with the Dekan Automatic Performance Analyzer to the nearest one-hundredth of a second. The timing mechanism was elicited by the automatic place mats upon the 4th (start) and 12th (stop) steps respectively. All subjects began the ascent with a six-feet flying start. Calibration procedures for the Margaria protocol were elicited utilizing the Lafayette instruments automatic time clocks.

Testing Procedures

At the beginning of the study all subjects were briefed and informed consent forms were completed. Each subject was assessed for height and body weight with a Detecto Physicians Scale. Subsequently the Cybex II and Margaria protocols were administered.

In the Cybex II protocol hip, knee, and ankle extension/flexion were administered, and only peak torque values were recorded.

Cybex II Hip Extension/Flexion: Individual subjects were instructed to lie supine upon the Cybex II upper body exercise and testing table (U.B.X.T.) as the investigator stabilized the pelvis and torso with wide velcro straps.

After an adequate warm-up each subject was instructed to extend and flex the entire leg and hip joint maximally three times. The suggested speed for this test is low (30^{o}/sec) and as such this test served as a measurement of anaerobic leg strength.

Cybex II Knee Extension/Flexion: Individual subjects were positioned in the respective upright table (right or left leg) for thigh stabilization. To evaluate strength each subject performed three maximal repetitions at a low speed (60^{o}/sec). Consequently, to evaluate power, high speed movements (240^{o}/sec) were performed maximally until fatigue.

After an adequate warm-up each subject was instructed to extend and flex the lower leg at the knee joint. The right and left legs were tested separately as peak torque values were recorded at both speeds.

Cybex II Plantar and Dorsiflexion: Individual subjects were laid flat upon the upright table with the back rest flat. The universal adapter with the plantar/dorsiflexion footplate was applied as the subject lay prone upon the table with a stabilized pelvis.

With an adequate warm-up three maximal efforts were procured to assay anaerobic leg stength at a low speed (30°/sec). Consequently, to evaluate power, each subject was asked to perform maximally until fatigue at high speed (180°/sec).

Margaria Step-Test: Several variations are evident (3 step versus 2 step) but the orthodox two step method was utilized. The test is a twelve stair speed climb and is measured in one-hundredths of a second. In an effort to evaluate anaerobic leg power each subject was instructed to sprint up the stairs, two at a time. Stepping upon the start and stop place mats, time was recorded upon the automatic performance analyzer. Five trials were performed by each subject with the fastest and slowest times deleted. An average of the remaining three times was recorded. All step-test results were recorded in foot pounds per second.

Training Procedures

The majority of literature devoted to training procedures focuses upon depth-jumping, box-drills, and hopping. Scarcely any information exists with regard to plyometric bounding. For plyometric exercises most researchers advocate twice weekly sessions for a seasons preparations (10 weeks) (Gambetta, 1978). But this is suggested primarily for depth-jumping, which is more strenuous than bounding. Due to the lack of evidence concerning bounding training procedures, the investigator adhered to standard training principles of strength and power regimens (Fox & Mathews, 1976).

Six weeks were allocated for the training period. The principle of progressive resistance was adhered to, as each week the volume of jumps increased. Feedback from the plyometric group subjects and their response to the exercise was an important consideration.

Throughout this study three sets of drills were done with a full recovery between each set. An 8, 10, 12 repetition method was elicited as a walk back recovery was used between repetitions. The author employed a two-day recovery between successive training sessions (Monday-Wednesday-Friday basis).

During Phase I, weeks one and two, thirty yards were covered. During Phase II, weeks three and four, forty yards were covered. During Phase III, weeks five and six, fifty yards were covered. An example of the training program is presented in Table 1.

Table 1

Experimental Group
Training Program

Pretest

	MONDAY	WEDNESDAY	FRIDAY	
Week 1 Oct. 26/1	3 (8 x 30)	3 (8 x 30)	3 (10 x 30)	Phase I 30 Yards
Week 2 Nov. 2/8	3 (10 x 30)	3 (12 x 30)	3 (12 X 30)	
Week 3 Nov. 9/15	3 (8 x 40)	3 (8 x 40)	3 (10 x 40)	Phase II 40 Yards
Week 4 Nov. 16/22	3 (10 x 40)	3 (12 X 40)	3 (12 x 40)	
Week 5 Nov. 23/29	3 (8 x 50)	3 (8 x 50)	3 (10 x 50)	Phase III 50 Yards
Week 6 Nov. 30/6	3 (10 x 50)	3 (12 x 50)	3 (12 x 50)	

POST-TEST

Statistical Analysis

Separate analyses of covariance were utilized for each of the twenty-one variables listed in Table 2. Pretest scores served as the covariate so as to adjust for any initial differences among the subjects.

Table 2

Dependent Variables

1. Hip Extension Right Leg (30^{o}/sec.).
2. Hip Extension Left Leg (30^{o}/sec.).
3. Hip Flexion Right Leg (30^{o}/sec.).
4. Hip Flexion Left Leg (30^{o}/sec.).
5. Knee Extension Right Leg (60^{o}/sec.).
6. Knee Extension Left Leg (60^{o}/sec.).
7. Knee Flexion Right Leg (60^{o}/sec.).
8. Knee Flexion Left Leg (60^{o}/sec.).
9. Plantarflexion Right Leg (30^{o}/sec.).
10. Plantarflexion Left Leg (30^{o}/sec.).
11. Dorsiflexion Right Leg (30^{o}/sec.).
12. Dorsiflexion Left Leg (30^{o}/sec.).
13. Knee Extension Right Leg (240^{o}/sec.).
14. Knee Extension Left Leg (240^{o}/sec.).
15. Knee Flexion Right Leg (240^{o}/sec.).
16. Knee Flexion Left Leg (240^{o}/sec.).
17. Plantarflexion Right Leg (180^{o}/sec.).
18. Plantarflexion Left Leg (180^{o}/sec.).
19. Dorsiflexion Right Leg (180^{o}/sec.).
20. Dorsiflexion Left Leg (180^{o}/sec.).
21. Margaria Step-Test (ft.lbs./sec.).

Chapter IV

ANALYSIS OF DATA

Twelve male college students volunteered and were randomly assigned to experimental (N=6) and control (N=6) groups. By the end of the study five subjects dropped out. During the post-testing procedures the experimental group was reduced to three subjects and the control group was reduced to four subjects. From the experimental group two subjects developed severe shin splints, and one subjet experienced a sprained neck from a freak cheerleading accident.

Anthropometric data for each subject are presented in Appendix C. Pretest and post-test body weights were provided since this has a direct effect upon the calculation of Margaria Step-Test quotients. Appendices D through H display a comparison of pretest and post-test (delineated by the suffix a) results of the Cybex II Isokinetic data. All of these data were presented in foot pounds per second. Appendix I contains data obtained in the pretesting and post-testing procedures for the Margaria Step-Test (also expressed in foot pounds per second). Pretest and post-test body weight measurements (in pounds) were included because body weight has a direct effect in the calculation of the step-test data.

Analysis of covariance was computed for each of the 21 dependent variables depicted in Table 2. As shown in Tables 3 through 21, the analysis of data indicated that there were no significant differences between the experimental and control groups for anaerobic leg strength and anaerobic leg power. With 1 and 4 degrees of freedom, the F-ratio for the group effect was not large enough to be significant at the .05 level of probability for any of the 21 statistical analyses. However, the covariate (pretest scores) was significant with 1 and 4 degrees of freedom. This may indicate there was a high degree of variability among subjects initial anaerobic leg strength and anaerobic leg power levels.

Table 3

Cybex II
Hip Extension Right Leg
30^{o}/sec.

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-ratio	P
Treatment	1	3319.80	3319.80	4.97	NS
Covariable	1	9170.81	9170.81		
Error	4	2671.39	667.85		
Total	6	15162.00			

F-ratio needed for significance: 1 and 4 df, .05 level = 7.71

Table 4

Cybex II
Hip Extension Left Leg
30^{o}/sec.

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-ratio	P
Treatment	1	1643.52	1643.52	2.31	NS
Covariable	1	8682.86	8682.86		
Error	4	2849.33	712.33		
Total	6	13175.71			

F-ratio needed for significance: 1 and 4 df, .05 level = 7.71

Table 5

Cybex II
Hip Flexion Right Leg
30^{o}/sec.

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-ratio	P
Treatment	1	105.66	105.66	0.17	NS
Covariable	1	2387.04	2387.04		
Error	4	2519.01	629.75		
Total	6	5117.37			

F-ratio needed for significance: 1 and 4 df, .05 level = 7.71

Table 6

Cybex II
Hip Flexion Left Leg
30^{o}/sec.

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-ratio	P
Treatment	1	157.11	157.11	0.24	NS
Covariable	1	4112.43	4112.43		
Error	4	2634.47	658.62		
Total	6	6904.01			

F-ratio needed for significance: 1 and 4 df, .05 level = 7.71

Table 7

Cybex II
Knee Extension Right Leg
60^{o}/sec.

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-ratio	P
Treatment	1	561.23	561.23	1.87	NS
Covariable	1	11134.51	11134.51		
Error	4	1199.97	299.99		
Total	6	12895.71			

F-ratio needed for significance: 1 and 4 df, .05 level = 7.71

Table 8

Cybex II
Knee Extension Left Leg
60^{o}/sec.

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-ratio	P
Treatment	1	22.10	22.10	Ø.46	NS
Covariable	1	6879.43	6879.43		
Error	4	193.91	48.48		
Total	6	7095.44			

F-ratio needed for significance: 1 and 4 df, .05 level = 7.71

Table 9

Cybex II
Knee Flexion Right Leg
60^{o}/sec.

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-ratio	P
Treatment	1	2.21	2.21	0.04	NS
Covariable	1	3044.50	3044.50		
Error	4	205.01	51.25		
Total	6	3251.72			

F-ratio needed for significance: 1 and 4 df, .05 level = 7.71

Table 10

Cybex II
Knee Flexion Left Leg
60^{o}/sec.

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-ratio	P
Treatment	1	0.69	0.69	0.01	NS
Covariable	1	4065.06	4065.06		
Error	4	4284.85	1071.21		
Total	6	8350.60			

F-ratio needed for significance: 1 and 4 df, .05 level = 7.71

Table 11

Cybex II
Plantarflexion Right Leg
30^{o}/sec.

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-ratio	P
Treatment	1	22.46	22.46	0.31	NS
Covariable	1	454.08	454.08		
Error	4	294.32	73.58		
Total	6	790.86			

F-ratio needed for significance: 1 and 4 df, .05 level = 7.71

Table 12

Cybex II
Plantarflexion Left Leg
30^{o}/sec.

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-ratio	P
Treatment	1	42.37	42.37	0.68	NS
Covariable	1	21.50	21.50		
Error	4	249.55	62.39		
Total	6	313.43			

F-ratio needed for significance: 1 and 4 df, .05 level = 7.71

Table 13

Cybex II
Dorsiflexion Right Leg
30^{o}/sec.

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-ratio	P
Treatment	1	15.53	15.53	1.86	NS
Covariable	1	281.08	281.08		
Error	4	33.40	8.35		
Total	6	330.01			

F-ratio needed for significance: 1 and 4 df, .05 level = 7.71

Table 14

Cybex II
Dorsiflexion Left Leg
30^{o}/sec.

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-ratio	P
Treatment	1	0.00	0.00	0.00	NS
Covariable	1	294.58	294.58		
Error	4	55.42	13.86		
Total	6	350.00			

F-ratio needed for significance: 1 and 4 df, .05 level = 7.71

Table 15

Cybex II
Knee Extension Right Leg
240^{o}/sec.

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-ratio	P
Treatment	1	92.27	92.27	1.01	NS
Covariable	1	2232.88	2232.88		
Error	4	364.22	91.07		
Total	6	2689.43			

F-ratio needed for significance: 1 and 4 df, .05 level = 7.71

Table 16

Cybex II
Knee Extension Left Leg
240^{o}/sec.

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-ratio	P
Treatment	1	41.97	41.97	0.93	NS
Covariable	1	1419.20	1419.20		
Error	4	179.68	44.92		
Total	6	1640.86			

F-ratio needed for significance: 1 and 4 df, .05 level = 7.71

Table 17

Cybex II
Knee Flexion Right Leg
240°/sec.

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-ratio	P
Treatment	1	54.07	54.07	1.31	NS
Covariable	1	1546.12	1546.12		
Error	4	164.66	41.12		
Total	6	1764.86			

F-ratio needed for significance: 1 and 4 df, .05 level = 7.71

Table 18

Cybex II
Knee Flexion Left Leg
240°/sec.

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-ratio	P
Treatment	1	3.93	3.93	0.19	NS
Covariable	1	830.16	830.16		
Error	4	83.36	20.84		
Total	6	917.43			

F-ratio needed for significance: 1 and 4 df, .05 level = 7.71

Table 19

Cybex II
Plantarflexion Right Leg
180^{o}/sec.

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-ratio	P
Treatment	1	10.65	10.65	2.49	NS
Covariable	1	1.21	1.21		
Error	4	17.10	4.28		
Total	6	28.86			

F-ratio needed for significance: 1 and 4 df, .05 level = 7.71

Table 20

Cybex II
Plantarflexion Left Leg
180^{o}/sec.

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-ratio	P
Treatment	1	2.57	2.57	0.10	NS
Covariable	1	67.36	67.36		
Error	4	107.79	26.95		
Total	6	177.71			

F-ratio needed for significance: 1 and 4 df, .05 level = 7.71

Table 21

Cybex II
Dorsiflexion Right Leg
180^{o}/sec.

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-ratio	P
Treatment	1	2.27	2.27	0.50	NS
Covariable	1	1.17	1.17		
Error	4	17.99	4.50		
Total	6	21.43			

F-ratio needed for significance: 1 and 4 df, .05 level = 7.71

Table 22

Cybex II
Dorsiflexion Left Leg
180^{o}/sec.

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-ratio	P
Treatment	1	0.96	0.96	0.36	NS
Covariable	1	21.15	21.15		
Error	4	10.75	2.69		
Total	6	32.86			

F-ratio needed for significance: 1 and 4 df, .05 level = 7.71

Table 23

Cybex II
Margaria Step-Test
(ft.lbs./sec.)

Source	Degrees of Freedom	Sum of Squares	Mean Square	F-ratio	P
Treatment	1	5.06	5.06	0.11	NS
Covariable	1	3968.90	3968.90		
Error	4	180.52	45.13		
Total	6	4154.48			

F-ratio needed for significance: 1 and 4 df, .05 level = 7.71

Chapter V

SUMMARY, FINDINGS, DISCUSSIONS AND CONCLUSIONS

Summary

The purpose of this study was to determine the effects of plyometric bounding upon anaerobic leg strength and anaerobic leg power. Seven adult college male volunteers were randomly assigned to an experimental (N=3) and control (N=4) group. The experimental group participated in a six-week plyometric bounding training program. All subjects were tested for anaerobic leg strength and anaerobic leg power utilizing the Cybex II Isokinetic and Margaria Step-Test protocols. Data collected in this study were analyzed by analysis of covariance.

Findings

Based upon the results of the study, the findings were as follows:

1. No significant differences were found in anaerobic leg strength due to the effects of plyometric bounding.

2. No significant differences were found in anaerobic leg power due to the effects of plyometric bounding.

Discussions

In the present study plyometric bounding showed no significant effect upon anaerobic leg strength and anaerobic leg power. Scoles showed that plyometric depth-jumping did not affect either vertical-jumping or standing long jump performances (1978). Also, Blattner and Noble stated that the effects of plyometric depth-jumping in comparison to isokinetic training yielded no significant data (1979).

Conversely, Verkoshansky proved that short and long-jump plyometric exercises do enhance overall sprinting ability (1974). And, Polhemus et al. clearly showed that plyometric depth-jumping in conjunction with weight training significantly affected the forty-yard dash, standing long-jump, and vertical-jumping ability (1980).

Scoles' (1978) study indicated that an inadequate number of subjects and too short a training period (8 weeks) can limit the outcome of the study. Due to the high attrition rate of the present study, an inadequate sample size in the post-testing procedures was apparent.

Blattner and Noble (1979) and Scoles (1978) all stated that many interstudy differences have resulted in contradictory findings. Inadequate literature about training lengths and intensities may have limited the studies. Due to the lack of training literature on plyometric bounding the present study had to rely on conventional training principles and procedures. And, although six weeks is ample time to exhibit strength gains, it may not be sufficient enough for plyometric bounding.

Gambetta (1978) stated the importance of developing a good strength base before applying plyometrics. Verkoshansky's study showed the applications of varied plyometric exercises on qualified sprinters (1974). In an earlier publication Verkoshansky (1966) stated the importance of utilizing qualified athletes. As such, only

Class I Master of Sport Russian athletes qualify for plyometric training.

Although Polhemus et al. used adult college males, that study was done in conjunction with weight training (1980). A limitation of the present study may have been the utilization of non-qualified athletes. The complexity of plyometric bounding was a novel activity and may have had unfavorable effects on the neuromuscular system.

Conclusions

Based upon the findings of this study:

1. Plyometric bounding training has no significant effect upon anaerobic leg strength.

2. Plyometric bounding training has no significant effect upon anaerobic leg power.

BIBLIOGRAPHY

Periodicals

Blattner, S. E., & Noble, L. (1979). Relative effects of isokinetic and plyometric training on vertical jumping performance. Research Quarterly, 50(4), 583-588.

Ecker, T. (1975). Improving sprinting speed through strength training. Athletic Training, 55(8), 12, 83.

Gambetta, V. (1977). Technical supplement: Plyometric training. Athletica, 4(5), 15-16.

Gambetta, V. (1978). Plyometric training. Track and Field Quarterly Review, 78(1), 58-61.

Hensen, P. L. (1980). Depth jumping with box drills. Track and Field Quarterly Review, 80(4), 56-57.

Humphrey, S. (1980). Conditioning and training programs for jumpers. Track and Field Quarterly Review, 80(4), 52-55.

Miller, J. (1980). Plyometric Training for Greater Speed. National Strength Coaches Association Journal, 2(3), 20-22.

Polhemus, R., Osina, M., Burkhardt, E., & Patterson, M. (1980). The effect of plyometric training with ankle and vest weights on conventional weight training programs for men. Track and Field Quarterly Review, 80(4), 59-61.

Scoles, G. (1978). Depth jumping! Does it really work? Athletic Journal, 58(6), 48, 50, 74-76.

Verkoshansky, Y. (1966). Perspectives in the improvement of speed-strength preparation of jumpers. Track and Field, 9(11), 28-34.

Verkoshansky, Y. (1967). Are depth jumps useful? Track and Field, 12(9), 75-78.

Verkoshansky, U. V., & Chernousov, G. (1974). Jumps in the training of a sprinter. Track and Field, 9(16), 62-66.

Wilt, F. (1975). Plyometrics: What it is - how it works. Athletic Journal, 55(9), 76, 89, 90.

Wilt, F. (1976a). From the desk of Fred Wilt: Plyometrics. Track Technique, 61, 2024, 2054.

Wilt, F. (1976b). From the desk of Fred Wilt: Plyometrics. Track Technique, 63, 1992, 2022.

Texts

Bell, S., & Steben, R. (1978). Track and Field: An Administrative Approach to the Science of Coaching, New York, NY: Wiley.

DeVries, H. A. (1972). Laboratory Experiments in Physiology of Exercise. Dubuque, IA: William C. Brown.

Fox, E. L., & & Mathews, D. K. (1976). The Physiological Basis of Physical Education and Atheltics. Philadelphia, PA: W. B. Saunders.

Weber, J. C., & Lamb, D. R. (1970). Statistics and Research in Physical Education. St. Louis, MO: C. V. Mosby.

Wilmore, J. H. (1976). Athletic Training and Physical Fitness: Physiological Principles and Practices of the Conditioning Process. Boston, MA: Allyn and Bacon.

Manuals

Cybex: Isolated Joint Testing and Exercise. (1980). Lumex, Inc.

Unpublished Paper

Reiff, M. (1980, December). Plyometrics. (Paper presented for Physical Education 530, Indiana University, Advanced Theories of High Level Performance).

Appendix A

AUSTIN PEAY STATE UNIVERSITY
Department of Health and Physical Education
THESIS HEALTH 599
Informed Consent and Confidentiality Release

Date: ____________________

I, ____________, freely and voluntarily and with undue inducement or any element of force, fraud, deceit, duress, or other form of constraint or coercion, consent (give my consent for ____________) to be a participant in the research project entitled, "The Effects of Plyometric Bounding upon Anaerobic Leg Stength and Anaerobic Leg Power," to be conducted at Austin Peay St. Univ. Dunn Center, during the period Oct. 5, 1981, to Dec. 13, 1981, with Mr. Zafar Ahmed as Principal Investigator. The procedures which are experimental, have been explained to me and I understand them. They are as follows: A training program employed for the sole purpose of improving leg strength and power to enhance running performance. The attendant discomforts and risks reasonably to be expected by my participation in this study have been explained to me and are as follows: general leg fatique and leg soreness. Any benefits reasonably to be expected from my participation and any alternative procedures that might have been explained to me are as follows: the development of leg strength and power, improved flexibility, and enhanced running performance. I understand that this consent an data may be withdrawn at any time without prejudice. I have been given the right to ask and have answered any inquiry concerning the foregoing. Questions, if any, have been answered to my satisfaction, and I understand that all information will be kept in the strictest confidence. I have read and understood the above.

____________________ (Witness)

____________________ (Subject/Legally Authorized Representative)

Appendix B

Suggested Cybex II Test Speeds (Degrees per Second)

Testing/Exercise Pattern	"Strength" (peak torque) and Expanded Torque Curve Tests	Power and Endurance Tests* Typical Orthopedic Patients	Power and Endurance Tests* Athlete
Shoulder:			
Extension/Flexion Abduction/Adduction Internal/External Rotation All other shoulder patterns	60^{o}/sec.	180^{o}/sec.	240^{o}/sec. 300^{o}/sec.
Elbow:			
Extension/Flexion	60^{o}/sec.	180^{o}/sec.	240^{o}/sec.
Forearm:			
Pronation/Supination	30^{o}/sec.	120^{o}/sec.	180^{o}/sec.
Wrist:			
Extension/Flexion	30^{o}/sec.	120^{o}/sec.	180^{o}/sec.
Hip:			
Abduction/Adduction Extension/Flexion	30^{o}/sec. only. See important explanation of hip testing and exercise limitaions in "HIP..." section		
Internal/External Rotation	30^{o}/sec.	120^{o}/sec.	180^{o}/sec.
Knee:			
Extension/Flexion	60^{o}/sec.	180^{o}/sec.	240^{o}/sec.
Tibial Rotation	30^{o}/sec.	120^{o}/sec.	180^{o}/sec.
Ankle:			
Plantar/Dorsiflexion Inversion/Eversion	30^{o}/sec.	120^{o}/sec.	180^{o}/sec.

* Some patients may not be able to achieve the suggested power and endurance test speed. A possible alternative in these cases is to perform the "strength" and expanded torque curve test at 30^{o}/sec. Then, increase the test speed in 10^{o}/sec. increments and have the patient perform two or three maximum pain-free efforts at each speed. The object is to find the highest speed at which the patient can produce force and to have a record of the patient's force capability over the range of speeds of which he is capable for comparison later in the rehabilitation program.

Appendix C

Anthropometric Data

SUBJECTS	AGE	HEIGHT	WEIGHT
Experimental (N=3)	(years)	(inches)	(pounds)
1	24.7	74.3	204.0 Pre / 206.0-Post
2	21.8	70.0	155.5 Pre / 151.0 Post
3	21.7	71.0	215.2 Pre / 221.0 Post
CONTROL (N=4)	AGE	HEIGHT	WEIGHT
1	27.4	69.8	152.0 Pre / 151.8 Post
2	22.0	70.3	167.0 Pre / 165.3 Post
3	33.5	67.0	147.0 Pre / 148.3 Post
4	18.4	72.5	143.5 Pre / 143.3 Post
EXPERIMENTAL -VS- CONTROL	AGE	HEIGHT	WEIGHT
(E) N=3	22.7	71.8	191.6 Pre / 192.7 Post
(C) N=4	25.3	69.9	152.4 Pre / 152.2 Post

Appendix D

Cybex II Isokinetics Protocol

Hip Extension/Hip Flexion

30^{o}/sec.

(E) (N=3)	Extension Right Leg	Extension Left Leg	Flexion Right Leg	Flexion Left Leg
1	209	228	132	108
1a	222	228	132	146
2	177	135	72	62
2a	155	144	48	60
3	180	220	120	108
3a	122	240	120	142

(C) (N=4)	Extension Right Leg	Extension Left Leg	Flexion Right Leg	Flexion Left Leg
1	180	201	84	78
1a	129	145	72	68
2	98	126	76	72
2a	114	159	75	90
3	102	122	38	36
3a	108	126	90	82
4	143	144	90	93
4a	114	130	96	98

Appendix E

Cybex II Isokinetics Protocol

Knee Extension/Knee Flexion

60^{o}/sec.

(E) (N=3)	Extension Right Leg	Extension Left Leg	Flexion Right Leg	Flexion Left Leg
1	226	216	108	122
1a	228	203	132	135
2	128	114	67	78
2a	100	114	78	88
3	180	198	98	126
3a	148	176	115	128

(C) (N=4)	Extension Right Leg	Extension Left Leg	Flexion Right Leg	Flexion Left Leg
1	114	132	72	70
1a	90	125	72	72
2	118	132	56	66
2a	133	114	70	63
3	118	132	78	90
3a	111	123	95	100
4	135	150	72	81
4a	118	144	86	94

Appendix F

Cybex II Isokinetics Protocol

Knee Extension/Knee Flexion

240^{o}/sec.

(E) (N=3)	Extension Right Leg	Extension Left Leg	Flexion Right Leg	Flexion Left Leg
1	76	80	72	60
1a	96	84	78	66
2	47	45	36	38
2a	50	54	42	46
3	70	68	57	50
3a	63	58	57	48

(C) (N=4)	Extension Right Leg	Extension Left Leg	Flexion Right Leg	Flexion Left Leg
1	48	54	45	42
1a	44	53	36	41
2	24	24	15	18
2a	36	30	24	24
3	48	48	37	36
3a	46	43	44	43
4	49	48	43	36
4a	45	48	42	42

Appendix G

Cybex II Isokinetics Protocol

Plantar/Dorsiflexion

30°/sec.

(E) (N=3)	Plantarflexion Right Leg	Plantarflexion Left Leg	Dorsiflexion Right Leg	Dorsiflexion Left Leg
1	79	70	33	33
1a	78	72	30	36
2	46	82	12	14
2a	63	54	16	14
3	74	66	18	19
3a	74	66	18	19

(C) (N=4)	Plantarflexion Right Leg	Plantarflexion Left Leg	Dorsiflexion Right Leg	Dorsiflexion Left Leg
1	48	57	20	24
1a	48	55	24	20
2	44	46	30	24
2a	56	54	31	30
3	63	60	20	22
3a	69	66	16	24
4	43	40	24	20
4a	46	58	24	19

Appendix H

Cybex II Isokinetics Protocol

Plantar/Dorsiflexion

180°/sec.

(E) (N=3)	Plantarflexion Right Leg	Plantarflexion Left Leg	Dorsiflexion Right Leg	Dorsiflexion Left Leg
1	12	16	9	7
1a	18	15	12	8
2	10	12	5	5
2a	14	19	9	6
3	18	18	12	12
3a	14	12	9	10

(C) (N=4)	Plantarflexion Right Leg	Plantarflexion Left Leg	Dorsiflexion Right Leg	Dorsiflexion Left Leg
1	8	8	6	6
1a	12	9	9	6
2	6	7	3	4
2a	12	9	9	6
3	18	18	9	9
3a	12	24	6	12
4	16	15	13	10
4a	15	14	11	9

Appendix I

Margaria Step-Test Protocol

(E) (N-3)	Body Weight (pounds)	Quotients ft.lbs/sec.
1	204.0	1159.1
1a	206.0	1170.5
2	155.5	706.8
2a	151.0	662.3
3	215.3	596.9
3a	221.0	969.3

(C) (N=4)	Body Weight (pounds)	ft.lbs/sec.
1	152.0	737.9
1a	151.8	751.2
2	167.0	719.0
2a	165.3	682.9
3	147.0	666.2
3a	148.3	667.8
4	143.5	736.3
4a	143.3	787.1