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THE EFFECTS OF PLYOMETRIC TRAINING ON SELECTED
PARAMETERS OF STRENGTH, POWER AND FIELD HOCKEY PERFORMANCE

A Thesis

by

Cathy L. Lowe

July 1985

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A Thesis

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Cathy L. Lowe

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ABSTRACT

THE EFFECTS OF PLYOMETRIC TRAINING ON SELECTED PARAMETERS OF STRENGTH, POWER, AND FIELD HOCKEY PERFORMANCE (July 1985)

Cathy Lee Lowe, B.S., Longwood College

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The purposes of this investigation were to examine the effects of an upper and lower body plyometric training program on the: (a) 1 Repetition Maximum (RM) parallel squat; (b) 1 RM supine bench press; (c) Power Index; (d) peak power and time to peak power of an anaerobic capacity bicycle test; (e) sport specific performance task in the 16 yard dash; and (f) accuracy and velocity of the field hockey drive.

The study utilized 33 female subjects, divided into two groups. One group acted as a control group (group A) and the other group was an experimental group (group B). Group A (n=16) trained for 13 weeks in a periodization weight training program. Group B (n=17) trained in an identical periodization program, however, the training protocol included upper and lower body plyometrics for 8 of the 13 weeks of the training. The training protocol consisted of sessions three days per week for 13 weeks and ranged from one to two hours in duration. Group B performed the plyometric training after the weight training session, starting in the sixth week of periodization after a strength base

had been established. Strength was determined by: (a) 1 RM parallel squat and (b) 1 RM supine bench press. Power was determined by using the vertical jump and the Lewis Formula to produce a Power Index. Anaerobic capacity was determined by a modified Wingate Cycle Ergometer Test which yielded two variables: (a) a peak power variable and (b) time to reach the peak variable. Two sport specific performance tasks were used in the evaluation procedures. First, the 16 yard dash was used as a sport specific task and secondly, the speed and accuracy of the field hockey drive was evaluated as a sport specific skill.

Pre and post data were collected on eight variables for the six tests. The data for all variables were analyzed using a grouped Analysis of Variance (ANOVA) with repeated measures. The alpha level of .05 was utilized to determine significance.

Plyometric training did not produce significant increases in the variables tested for the female subjects in this study. Significant gains were not found in either group when a comparison was made between the pre and post test results in the speed of the field hockey drive. Significant gains were made in all other areas of strength, power, peak power variable and time to peak power variable in the anaerobic capacity test for both groups A and B. Gains were also seen in the performance task areas of the 16 yard dash, and the accuracy test of the field hockey drive. These gains were attributed to the periodization weight training program which has been shown to improve performance in the areas of strength and power.

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THE EFFECTS OF PLYOMETRIC TRAINING ON SELECTED
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CHAPTER 1

Introduction

New methods and improved techniques to attempt a bridging of the gap between strength and speed are characteristically sought by both athletes and coaches. The growing popularity and re-established acceptance of plyometrics in this country (Chu, 1984; Hensen, 1980) may be a viable contribution to such a search, which would enhance the joining of the strength and speed elements. Chu and Plummer (1984) define plyometrics as any drill or exercise whose purpose is to link sheer strength and speed of movement to produce an explosive-reactive movement. Plyometric drills or exercises affect two major properties of muscular function. The two major properties of muscular function which are affected by plyometrics are more specifically the storage of elastic energy and the stretch reflex mechanism. When such two factors are developed through plyometrics the performance of the athlete can be enhanced. The scientific basis for plyometric training suggests that when a muscle is pre-stretched from its natural length before a quick contraction, a greater force is exerted by the muscle. A plyometric exercise includes two types of muscle contractions. The first contraction is an eccentric

contraction which is defined as a contraction where the muscle lengthens while developing tension to overcome external force. The second contraction is a concentric contraction which is defined as a contraction where the muscle shortens to develop tension to overcome resistance. A plyometric exercise is an exercise which contains an eccentric contraction followed immediately by a concentric contraction (Wilt, 1975).

At present, programs which frequently utilize plyometrics with a weight training program are primarily found in the sport of track and field (Costello, 1974; Garhammer, 1979; Humphrey, 1980; Jarver, 1980; Miller & Power, 1981). Other athletes in weightlifting, football, and basketball are actively starting to use plyometrics as a form of training (Goebel, 1984; Polhemus & Burkhardt, 1980; Polhemus, Osina, Burkhardt & Patterson, 1980).

The present lack of information and supporting data on the plyometric effects upon selected parameters of field hockey performance stimulated further investigation into the use of plyometrics as a training protocol. The following experiment was conducted in order to evaluate the effects of an upper and lower body plyometric protocol upon selected parameters of strength, power, and field hockey performance in female subjects.

Statement of Purpose

The purposes of the investigation are to examine the effects of upper and lower body plyometric training on the following selected parameters in strength, power, and field hockey performance: (a) strength by one repetition maximum (1 RM) of the supine bench press and parallel squat; (b) anaerobic power by

use of the Sargent Jump test and the Lewis Formula (Power Index (kg-m/sec) = $\sqrt{\text{vertical jump (m)}} \times \text{body weight (kg)} \times \sqrt{4.9}$); (c) anaerobic capacity by the Wingate Cycle Ergometer Test (modified); and (d) field hockey performance by the 16 yard dash coupled with the velocity and accuracy of the field hockey drive.

Review of Literature

According to Chu (1983) plyometrics are drills or exercises aimed at linking sheer strength and speed of movement to produce an explosive-reactive type movement often referred to as "power". The drills utilized in plyometrics produce concentric muscle contraction immediately following an eccentric contraction. A much stronger concentric contraction is produced when preceded by an eccentric contraction as opposed to one made without pre-stretching (Miller & Power, 1981; Scoles, 1978; Wilt, 1975).

In plyometrics, neuromuscular patterns are built and cause specific metabolic occurrences beyond morphological-functional changes in muscle groups involved in the drill (Bosco, Komi, Pulli, Pitteru & Montonev, 1982). To aid in the understanding of the complex changes taking place and due to the belief by some researchers insisting upon plyometrics being built upon a strength base (Coaches Roundtable, 1984; Scoles, 1978), the following review of literature will concentrate on four areas. The four areas are: (a) the physiological concepts of plyometric training; (b) plyometrics; (c) periodization; and (d) related studies.

Physiological Concept

Two major physiological effects take place under plyometric

training. The first effect is the storage of elastic energy and secondly the stretch reflex mechanism of the muscle (Mann, 1981a). To understand these two effects it is necessary to proceed into both the mechanical and neuromuscular concepts of the muscle.

The elastic ability of the muscle is related to its mechanical structure which includes contractile and viscoelastic elements. The viscoelastic elements are composed of elastic elements in series (EES), and elastic elements in parallel (EEP) (Bosco et al., 1982). According to Komi (1984) the EES is far more important than the EEP for storage of elastic energy when an active muscle is stretched. The EEP is composed most likely of sarcolemma and the connective tissue elements of the endomysium, perimysium, and epimysium which surround the individual fibers, bundles, and the whole muscle, respectively. The EEP is thought to give the passive muscle its resistive tension when stretched. Whereas the EES, partially located in the tendon, has a considerable portion in the cross-bridges between the actin and myosin filaments, allowing for the storage of elastic energy.

Komi (1984) cited two studies by Stienen et al. (1978), and Curtin (1974) which found that the life time of a cross-bridge is relatively short, from 15 milliseconds to 120 ms. The life time of the cross-bridge refers to the length of time when a single myosin filament is attached to the active site found on the actin filament which in turn provides the mechanism by which the muscle can contract. Therefore, it is important that the utilization of the stored elastic energy in the stretch and shortening transient period are short. If a long stretch occurs, sacromere "slipping"

may occur due to the detachment of the cross-bridges resulting in lost elastic potential of the respective cross-bridges (Bosco et al., 1982; Komi, 1984). In order to receive full benefit of stored elastic energy, the development of a neurophysiological response is needed. The response needed accentuates the importance of the second physiological development of plyometric training, the strength reflex.

The stretch or myotatic reflex is a potentiating mechanism which responds to the rate of a muscle stretch. The stretch reflex has the quickest known response to stimuli, due mainly to the mono-synaptic reflex directly connected from the sensory neuron to the motor neuron. The myotatic/stretch reflex serves three functions once stimulated: (a) elicits contraction of the muscle which was stretched; (b) elicits contractions from synergist or muscles surrounding the stretched muscle; and (c) inhibits the antagonist or muscles wanting to produce an opposite movement (Chu & Plummer, 1984). The stretch reflex is brought about by a proprioceptor called the muscle spindle.

Proprioceptors are organs throughout the body which monitor sensory reports on orientation, angle of joint, degree of muscle shortening/length, and velocity of stretch. The sensory reports from the proprioceptors to the central nervous system (CNS) come from the muscles, tendons, ligaments and joints.

Two specific muscle receptors in skeletal muscles are the Golgi tendon organ, which detects tension applied to the muscle during eccentric and concentric contraction, and muscle spindles, which detect changes in length of the muscle and the rate of

change in muscle fiber length (Chu, 1984; Chu, 1983; deVries, 1974). The muscle spindle utilizes an intrafusal fiber, lying within the body of the muscle or extrafusal fibers, to work as an elaborate sensory mechanism which transmits information to the CNS through the synaptic junction.

The stretching of a muscle activates the sensory nerve within the muscle spindle, which then sends an impulse to the CNS. These impulses activate the alpha motor neuron that innervates the regular muscle fibers, and consequently the muscle contracts. As the muscle shortens so does the spindle, thus stopping the sensory impulses and the muscle relaxes (Fox & Mathews, 1981).

It appears that the mechanical efficiency of the muscle facilitated by the stretch-reflex and the storage of elastic energy can be improved through plyometrics to enhance the performance of an athlete (Chu, 1984; Komi, 1984; Steben & Steben, 1981).

Plyometrics

Wilt (1975) stated the term "plyometrics" may have found its origin in the Greek word "pleythyein" meaning "to increase". The roots of the word have also been tied to the Greek origin "plio" meaning, more and "metric" to measure (Chu, 1983; Clutch, Wilton, McGowen & Bryce, 1983). The present interpretation of the term plyometrics is varied.

In some studies, plyometrics is often defined in terms of jump training and in-depth or depth jumping (Chu, 1983). However, as the "principles of specificity" (Bosco et al., 1982) have been applied to plyometric training the term could refer to any drill or exercise utilizing the stretch reflex to produce an explosive

reaction (Chu & Plummer, 1984). Furthermore, plyometrics can be defined in terms of any specific sporting skill if the exercises are "specific exercises which encompass a rapid stretching of a muscle(s) that is undergoing eccentric stress and followed by a concentric, rapid contraction of that muscle(s) for the purpose of developing a forceful movement over a short period of time" (Chu, 1983).

Chu (1983) described phases of plyometric exercises as containing an amortization phase, reactive/recovery phase and an active phase. The amortization phase contains the "cocking" or pre-stretch of the muscle. The reactive/recovery phase is the point in time where the muscle has completely stopped pre-stretching and has shifted over to the contraction phase. The third and final active phase is the forceful contraction of the muscle, pulling into play the stored elasticity and stretch reflex mechanisms (Chu, 1983; Coaches Roundtable, 1984; O'Bryant, 1984).

Most studies examining the effects of plyometrics use only depth jumps as the focused protocol due to the specificity of its contribution on leg strength and the vertical jump (Clutch et al., 1983; Hinkel, 1984; Polhemus & Burkhardt, 1980; Polhemus et al., 1980; Scoles, 1978). Other studies looked at specific neuromuscular and physiological developments which related to plyometrics (Bosco, Komi & Ito, 1981; Bosco et al. 1982; Bosco & Komi, 1980; Hakkinen & Komi, 1982; Komi & Bosco, 1978; Steben and Steben, 1981).

Clutch et al. (1983) conducted two experiments to determine the effect of depth jumps and weight training on leg strength and

vertical jump. In the first experiment 12 males from a weight training class were placed in one of three jumping protocols: (1) maximum vertical jump; (2) 0.3 m depth jumps; and (3) 0.75 m and 1.10 m depth jumps. The results of the study after 12 weeks of treatment indicated that depth jumps when combined with weight training were no more effective than a program of regular maximum jumps. The second experiment used 32 male subjects, 50 percent trained, 50 percent untrained. The same protocols from experiment 1 were used. The results were similar to experiment 1. The researchers suggested a plyometric program for a longer training time period could exhibit greater gains.

Polhemus, Burkhardt, Osina and Patterson (1980) while researching the effects of plyometric training with ankle and vest weight on conventional weight training programs for men, found significant gains in the plyometric group only. The gains were in the performance levels of the vertical jump, standing long jump and 40 yard dash. The study utilized 26 subjects for a six week period. It was suggested that the protocol obeyed the Law of Specificity, indicative of the significant results gained. The weighted plyometric drills included: (a) running drills and (b) depth jumping.

In a six week plyometric training period using collegiate football players, Polhemus and Burkhardt (1980) observed the effects of weight training versus the effects of weight training plus plyometric drills without ankle and vest weights compared to weight training with ankle and vest weights on performance in physical strength gains. The weight training program was

conventional in design. The plyometric drills with or without the weighted ankles and vest included: (1) running drills; (2) vertical depth jumping; and (3) horizontal jumps. The results of gains in the bench press, half squats, power clean, and military press showed statistically significant improvement in all three groups ($p < 0.01$). When compared to the other two groups the group who trained using plyometric drills with vest and ankle weights showed significant gains.

Scoles (1978) studied 26 subjects to investigate the effects of depth jumping on the vertical jump and standing long jump for adult college males. The study included three randomly designed groups defined as: group 1 (depth jumping); group 2 (flexibility); and group 3 (control). The eight week, two sessions a week training program involved either depth jumping from a bench height of 0.75 meters or flexibility exercise, or normal daily routine for groups, respectively. The findings of this study indicated the scores on both the vertical jump and standing long jump improved to a greater extent in the group trained with the depth jumping. However, the improvement gains did not reach a level of significance at the .05 level. The conclusion drawn indicated that the small number of subjects and type of subject in the experimental group contributed to the failure of statistical significance to appear in the depth jump group.

A study by Komi and Bosco (1978) was designed to further examine the performance in vertical jump by imposing different stretch loads on activated leg extensor muscles. The study had a second purpose which was to investigate the possible differences

in the storage capacity and utilization of elastic energy between men and women of comparable physical condition. Participants in the study performed vertical jumps on a force-platform with the following different initial starting positions: (1) squatting position in which no preparatory counter-movement was allowed. This performance was called a jump from a maintained (90 knee angle) static position (SJ); (2) from erect standing with allowances for counter-movement, called jump with counter-movement (CMJ); (3) from erect standing on different elevations then dropping directly on the force-platform with a followed jumping upward. This condition was called a drop-jump (DJ). The dropping heights were varied from 20 to 100 cm. In all testing conditions subjects kept hands on hips in order to maximize the force being exerted from the stored elastic energy in the leg extensors without the use of the arms. The results in general showed the female jump heights ranged from 54 to 67 percent below the male counterparts. In comparing the jump conditions, SJ was the least efficient as compared to the CMJ or DJ's performance. Both males and females increased the height of rise of the center of gravity in the drop jump, as the dropping height increased. In light of other obtained results in the study the researchers stated that the women were able to utilize most (90%) of the energy absorbed in the stretch phase of the CMJ, which was much higher than the male groups (48%, 50%). In contrast to women, the men were able to improve performance from much higher drops which indicated the stretch loads were much higher. It was appreciated that the observed sex difference in utilizing the potential elastic energy

may be due to the difference in body dimensions between men and women. Studies by Bosco et al. (1982) and Steben and Steben (1981) found that through jump training and depth jumping, gains in the testing protocols were less in the females when compared to the male counterparts.

To obtain the desired training effect of plyometrics through depth jumping an optimal elevated height should be used. The optimal height for depth jump training varied in extremes throughout the literature reviewed. As reported by Miller and Power (1981) the following heights have been stated as optimum heights by researchers: (1) 75 cm; (2) 80 cm; (3) 90 cm; (4) 100 cm; and (5) 200 to 320 cm.

Studies and training protocols reviewed have used varied heights: (1) Verkhoshanskiy (1973), males 2 ft. 5 1/2 in. to 3 ft. 7 1/4 in.; (2) Henson (1980), 20 in.; (3) Clutch et al. (1983), 0.3 m, 0.75 m, and 1.10 m; (4) Polhemus and Burkhardt (1980), 18 inches; (5) Komi and Bosco (1978), 20 to 100 cm; (6) Hinkel (1984) males and females, 45 cm; (7) Watkins (1982), males and females, 10 in., 18 in., 22 in.; (8) Humphrey (1980) 12 to 24 in.; (9) Scoles (1978) 0.75 m.

Chu (1984, 59) stated in view of Verkhoshanskiy's values of 75-110 cm optimum height for the depth jump, that though "researchers have used a range of heights from 50 cm to 3.2 m, the results appear to indicate the crucial factor to be choosing a height which allows the athlete to rebound from the landing surface a distance at least equal to their standing jump and reach score".

O'Bryant (1984) and Hinkel (1984) have made reference to the Russians insisting on an athlete squatting two times their own body weight before engaging in depth jumping. Many researchers acknowledged the need for a strength base before plyometrics for neuromuscular preparation and safety of the athletes, but not to the extent as stated by their Russian counterparts (Chu, 1984; Coaches Roundtable, 1984; Hensen, 1980; Mann, 1981a; Mann 1981b; O'Bryant, 1984).

Hensen (1980) has stated that stress placed on the muscles while performing plyometric drills is far greater than in more common slow concentric contractions. Mann (1981b) felt the weight training program should precede the bounding program to prevent injury though adequate strength levels in the effected joint and limb areas. The bounding program is itself progressing toward depth jumping. Stone and O'Bryant (1984), emphasized the introduction of a good strength base before plyometrics. O'Bryant (1984), and Coaches Roundtable (1984) strongly suggested when utilizing a 13 week double periodization weight training program, jump training should be introduced in the sixth week of the program and plyometrics may follow in the eighth week to insure a stable strength base.

Tschiene (1973) says "performances" in any sport are the result of specially organized and controlled interchanges between the athlete and external conditions. Costello (1978) believes the key to success in coaching today lies in the ability of breaking down the sport as simply as possible for the athlete. Incorporating these two ideas, combined with plyometrics may

offer a sport specific, progressive plyometric drill or exercise for any sport. Plyometric sport specific drills have been utilized in several sports (Costello, 1974; Goebel, 1984; Jarver, 1980; Mann, 1981b; Polhemus, 1981).

Goebel (1984) set up a program for jump training for women's basketball. The program included stretching exercises and a progressive plyometric program for 11 weeks. The purpose for the program was stated as to increase lower body power to increase running speed and jumping ability. Jarver (1980), Costello (1974) and Mann (1981b) provided similar skill specific programs for field events, sprinters/hurdlers and jumpers, respectively. No testing results from the three programs were given.

Several practical aspects and concepts in the development and administration of sport specific plyometric drills or exercises have been listed by several studies and papers (Coaches Roundtable, 1984; Hensen, 1980; Mann, 1981a; Mann, 1981b; Miller & Power, 1981; O'Bryant, 1984; Polhemus, 1981; Scoles, 1978; Verkhoshanskiy, 1966; Verkhoshanskiy, 1973; Wilt, 1975). The most comprehensive list of concepts used in designing drills and administering plyometric conditioning programs was presented by O'Bryant (1984) and the Coaches Roundtable (1984), which stated that a plyometrics program should: (a) alternate days of training (no two consecutive days); (b) start on double leg drills then progress to single leg drills; (c) use progressive resistance; (d) stress speed of drill and less on resistance; (e) use specificity of movement appropriate for the sport or activity; (f) use good footwear and padded surface for jumping to aid in support and

reduction in injury possibilities; (g) use a level of intensity, volume and frequency based on the athlete's strength level and experience; (h) use complete rest or low intensity exercises between jumping drills (example: stretch-relaxation); (i) discontinue depth jumping 10-14 days before competition; (j) use 6 to 10 sets of 8 to 10 repetitions; (k) use 10 to 15 minutes of rest between exercises; (l) stress that each exercise should be performed to maximum limits (to stimulate neuromuscular system); (m) build a good strength base before extensive plyometric drills; and (n) bounding skills for horizontal distance should be used to improve longitudinal jumping. When following these concepts in developing a plyometric training program it was felt that the safety and step-by-step progressions may produce greater gains for the athlete without compromise due to injury.

Periodization

As reported by O'Bryant (1982) periodization is a weight training program based on the concepts first examined by Matveyev in 1961. Matveyev applied principles of Selye's General Adaptation Syndrome (GAS), which incorporated a three-phase response pattern by organisms when exposed to stressors (Garhammer, 1979). Garhammer (1979) explained the three phases as applied to the athlete and the training program. He indicated the first phase dealt with an alarm stage, which is the initial response to stimulus. This could result in a temporary drop in performance caused by stiffness or soreness the first few days of a new program or cycle. The second phase is the resistance stage where the athlete's body makes some adaptations and the third

phase is exhaustion or "overtraining" due to all kinds of stress in the athlete's life and training program. When this level is reached then desired adaptations are no longer possible.

The whole principle of periodization is the successful quality and quantity combinations in the proper mixture of volume, intensity, and technique or specificity, to initiate a peaking point near the end of the athlete's season (Stone, O'Bryant & Garhammer, 1981; O'Bryant, 1982). The four phases of periodization and respective training emphasis are: (a) Hypertrophy, high volume-low intensity; (b) Basic Strength, moderate volume-high intensity; (c) Strength-Power, low volume-high intensity; and (d) Active Rest, very low volume-very low intensity (Stone et al., 1981; Stone, O'Bryant, Garhammer, McMillan & Rozenek, 1982). The inclusion of the hypertrophy phase in periodization initially prepares the body to gain much more strength in the following phases (Moritani and deVries, 1979). Research has shown that training on the periodization theoretical model as compared to more traditional weight programs produces greater gains in strength and power and also in gaining and retaining lean body weight (O'Bryant, 1982; Stowers, McMillan, Scala, Davis, Wilson & Stone, 1983; Stone et al., 1982). Periodization is a training program which gives optimum gains in strength, power and lean body weight, along with bringing performances to a peak or optimum level while guarding against "overtraining". Many researchers, coaches and athletes recognize the need in reaching peak performance at a specific time while guarding against overtraining (Garhammer, 1979; Kruger, 1973; Riley, 1978).

Related Studies

During the 1984 Summer Olympic Games the members of the Women's United States Field Hockey Squad participated for the first time in Olympic competition. Placing third, the U.S. team had the top scorer of the tournament, Beth Anders. Top world-class female players drive the hockey ball in excess speeds of 90 mph.

The penalty corner, in the game of field hockey, is a shot on goal taken at the top of the circle, 16 yards from the mouth of the goal cage. It is in this game situation where Anders emphasized over and over again how a powerful and accurate drive can terminate into a goal for the team. Many goals made in this situation determine the final outcome of the game (Blackmon, 1984).

A defender can assist the goalie during a penalty corner but must sprint from the endline 16 yards to the top of the circle to do so. The defender can be crucial in the downfall of a penalty corner if quick enough (Wein, 1981).

In recent studies (Hendrick, 1981; Lowe, 1984) it was found that when hockey players tried to drive the ball as forcefully as possible, the ball would lift. The cause of the lifting action was attributed to the player making adjustments in the biomechanical mechanism of the drive by shifting both body weight and the head back, just before the stick and the ball made contact. The lifting action did in most cases render the ball less accurate. Klatt (1977) when looking at characteristics of

successful short corners, stated that speed and accuracy were two prime elements.

Emmert (1984) when talking about the slap shot in ice hockey, which is very similar in movement patterns to the field hockey drive, indicated the following muscle groups as primary to the backswing part of the stroke; deltoideus, pectoralis major, and biceps brachii. For the beginning of the action phase the muscles involved were the external and internal obliques, anterior deltoid and pectoralis major. The muscles used during the contact and follow-through stages were the teres major, triceps, deltoideus, latissimus dorsi, and the external and internal obliques. The added action of the hips and lower extremities generated additional force in the appropriate direction of the shot.

Null Hypotheses

The following null hypotheses were tested in this study:

1. There will be no difference between the periodization and periodization/plyometric groups in the means for changes in strength measurements after 13 weeks of training.
2. There will be no difference between the periodization and periodization/plyometric groups in the means for change in power measurements after 13 weeks of training.
3. There will be no difference between the periodization and periodization/plyometric groups in the means for change in the accuracy and velocity of the field hockey drive.

Research Hypotheses

The following research hypotheses were tested during this study:

1. Plyometric training of the upper and lower body will result in a greater significant increase in the strength measures of the 1 RM squat and 1 RM bench press than periodization training alone at the end of the 13 week training period.

2. Plyometric training of the upper and lower body will result in a greater significant increase in the power measures of the modified Wingate Cycle Ergometer and the Vertical Jump Test converted to power, than periodization training alone at the end of the 13 week training period.

3. Plyometric training of the upper and lower body will result in a greater significant increase in the performance test of the accuracy and velocity of the field hockey drive than periodization training alone at the end of the 13 week training period.

Operational Definitions

Terms used herein are defined as follows:

Plyometrics. Upper and lower body exercises and drills containing three phases: amortization phase, reactive/recovery phase and active phase.

Double periodization. Weight training protocol yielding "peaking", power and strength gains after 13 weeks of training.

1 Repetition Maximum (1 RM). Maximum amount of weight lifted for one repetition.

Assumptions

During this study the following assumptions will be made:

1. Each subject will put forth maximum effort in both training and testing sessions.
2. Subjects participating in this study will not participate in any other modes of training.
3. Subjects participating in this study will not undergo any significant dietary modifications during training.
4. Subjects have no prior expectations concerning effectiveness of the different treatments.
5. Individual levels of training were similar for each experiment group.
6. Performance scores reflect learning as well as physiological adaptations.

Delimitations

1. No diet restrictions will be imposed on subjects.
2. A sample of 48 subjects include the women's field hockey team and other female students from Appalachian State University.
3. The weight training program consists of a 13 week double periodization model.
4. The plyometric and jump training program consists of a eight-week training period.
5. Two training groups will train three days a week.
6. Each subject will be pre and post tested in the six following tests: (a) 1 RM parallel squat; (b) 1 RM bench press; (c) modified Wingate Cycle Ergometer Test, for anaerobic capacity; (d) Vertical Jump Test (using the Lewis Formula for a power

index); (e) field hockey drive velocity and accuracy test; and (f) the 16 yard dash.

Limitations

1. Two training sessions during the 13 week protocol had to be cancelled due to unsafe weather conditions (i.e., snow).
2. The loss of 15 subjects due to (a) a car accident; (b) illness; (c) lack of participation.

Significance of the Study

Plyometric training has primarily been a protocol used to enhance athletes in the area of track and field. A limited few have utilized plyometric training which combines sheer strength and speed of movement to produce "power". The general accepted type of plyometric training deals with jump and depth jump training. Very little has been done to creatively use plyometrics with the upper body. The specificity of depth jump training in sports should transfer into plyometrics for the upper torso.

This investigation was designed to verify the effects of an upper and lower body plyometric program upon selected strength, power and field hockey performance parameters. Group A was trained in a double periodization weight training program for 13 weeks, while group B trained in an identical double periodization program plus a program in upper and lower plyometrics. The application of the findings to the sport of field hockey will assist in the correct use of plyometrics for several sport specific performance skills.

CHAPTER 2

Methodology

The primary purpose of this study was to determine the effects of an upper and lower body plyometric program upon selected field hockey performance tasks. A second purpose was to determine increased strength, power, and anaerobic capacities due to the plyometric training program. Groups A and B participated in a 13 week weight training program, while in addition group B performed upper and lower body plyometrics for eight weeks of the total training period.

Subjects

The 48 subjects utilized in the study included the women's field hockey team and other female volunteer students from Appalachian State University. Volunteers were obtained from previous weight training activity classes, and other interested students. From a randomized process, two unbiased, equally skilled groups were formed. Group A (n=24), weight trained with a 13 week double periodization program. Group B (n=24) was trained in an identical periodization program and a progressive plyometrics program for eight of the 13 weeks of the total training time. During an orientation session, consent forms were signed and obtained from the subjects. The participants were

asked not to participate in any other form of training during the experiment. Anthropometric measures including age, height, weight and percent body fat were collected on all subjects.

Anthropometric measures of subjects who completed the study (group A, n=16; group B, n=17) are found in Table 1.

Materials

Various equipment was used in the training and testing procedures in this study. The equipment used was a coupling of commercial and individually fabricated items specifically designed for this study.

In the periodization training, the Appalachian State University Varsity Weight Training Room, supplied with the appropriate free weights and leg machines were utilized. In addition to the weight room, the plyometric training took place in the Appalachian State University Women's Locker Room, and the Human Performance Laboratory. For the upper body plyometric exercises, specially designed apparatus included the use of a pulley device with adjustable weights, with a hockey stick attached to it. Two upper body plyometric stations were organized and used (refer to Appendix A).

To aid in the jump training progression, raised platforms were used. Three of the platforms had dimensions of 46 cm high x 61 cm wide x 45 cm long. Two other platforms had smaller dimensions of 36 cm high x 61 cm wide x 45 cm long, and 30 cm high x 61 cm wide x 45 cm long, respectively. In addition to the raised platforms, five, dense, synthetic foamed mats each 1.5 cm thick, were utilized in plyometrics (refer to Appendix B).

Table 1
Anthropometric Measures by Group

GROUP	Age (yrs.)	Std. Dev.	Height (cm)	Std. Dev.	Weight (kg)	Std. Dev.	Body Fat (%)	Std. Dev.
A (n=16)	20.6	±4.09	165.50	±4.80	61.75	±7.48	18.62	±1.86
B (n=17)	20.3	±2.87	164.00	±8.90	58.36	±8.02	17.01	±2.38

The Appalachian State University Varsity Weight Training Room and appropriate free weight equipment including the squat and bench press racks and supine benches were used to test for a one repetition maximum (1 RM) of the parallel squat and supine bench press, respectively.

The modified Wingate Cycle Ergometer Test (WCE), a test for anaerobic capacity, used a monark cycle ergometer equipped with a microswitch revolution counter interfaced with a PET 4032 microcomputer which uses specially designed software (Nicklin, 1983) (refer to Appendix C). A printer interfaced to the system allowed for swift hard copy documentation and data retrieval. The twenty second length of the test was kept by the use of a battery powered Cronus-Single Event stopwatch.

The Vertical Jump Test incorporated the use of a container of powdered chalk and a centimeter scaled jump board. The scaled jump board was mounted to a wall in the Appalachian State University Kinesiology/Biomechanics Laboratory. The conversion of the collected data into power utilized the following Lewis Power Index formula: $\text{Power Index (kg-m/sec)} = \sqrt{\text{vertical jump (m)} \times \text{body weight (kg)}} \times \sqrt{4.9}$ (Fox & Mathews, 1981). To acquire the weight of the subjects for this calculation, calibrated Health-O-Meter bar balance medical scales were used. The measured body weights were estimated and recorded to the nearest half pound. The Health-O-Meter bar balance was used in collecting the weight and height data for anthropometric measures during the first meeting. In addition to these measurements, the estimation of percent body fat from skinfolds employed a Lange skinfold caliper. Estimation

figures for each subject were calculated by using the method of Sloan, Burt & Blyth (1962) for females.

One stopwatch and a flat hard surface were desired when evaluating the 16 yard dash. Due to the weather factor, it was decided that both the pre and post 16 yard dash would occur indoors. A hallway was measured and marked off for the test. Tape was placed on the wall to mark the start and finish line for the test. The same start and finish lines were used in the pre and post test of the 16 yard dash. A Cronus-Single Event stopwatch was used to collect the data for the 16 yard dash. The stopwatch measured the data to 1/100 of a second and was energized by three 1.5 volt batteries.

The velocity and accuracy of the field hockey drive incorporated a fabricated runway (refer to Appendix D). The containment walls were 192 cm long and 48 cm wide. Two FPT 100 photo transistor cells, placed 61 cm apart, embedded within the containment walls, were interfaced into a PET 4032 microcomputer with appropriate specially designed software, and a printer (Rafert and Nicklin, 1984). Two DC powered flashlights provided the light source. The runway had a synthetic turf type playing surface and a specially constructed device to catch the ball as it left the runway when driven. Finally, additional equipment used included a polyurethane hockey ball and several individually selected mulberry wood hockey sticks, ranging in length from 34 to 36 inches.

Procedure

The researcher met with the subjects and provided information and expectations of the study which included: the 90% participation policy, the training protocol and the testing procedures. Subjects were requested to read the instruction and consent sheets and after questions were answered a signed consent form was collected from all participants (refer to Appendix E). Anthropometric measures were obtained. Participants were scheduled for training sessions and pre-testing time and dates. Copies of training and testing schedules were made available to each individual.

During each test, the subject was given instructions, and adequate time for warm-up and practice, to assure accurate test scores. Each test was administered before the training program began. Post tests were administered at the termination of the 13 week training protocol.

Power was determined by using the Vertical Jump Test (Johnson & Nelson, 1979; Fox & Mathews, 1981) and the Lewis Formula: Power Index (kg-m/sec) = $\sqrt{\text{vertical jump (m)} \times \text{Body weight (kg)} \times \sqrt{4.9}}$ (Fox & Mathews, 1981). The weighing of the subject before performing the vertical jumps on the Health-O-Meter bar balance medical scale, which included full jumping attire was taken and later used in the calculation of power. The measurement of weight was taken after the subject warmed-up, but before the actual vertical jump testing. A baseline value for the vertical jump was obtained for each individual by a standing vertical reach to the board which included the extension of a self selected dominant

hand, and reaching as high as possible on the board. The reading was recorded as the initial reading. A practice jump was then taken by the subject. The subject then proceeded to take three testing trail vertical jumps. The measurements were read off of the scaled jumping board to the lower half centimeter indicated by the chalk marks showing the contact of the subject's finger tips. Control for knee flexion was not imposed and use of the arms were encouraged. All jump scores were recorded, however, only the best score was used in the subsequent power calculation. A power value was generated by using the Lewis Power Index.

The modified Wingate Cycle Ergometer (WCE) had a demonstrated high correlation as an anaerobic capacity test (Christian, 1983; Inbar, 1982; and Green, McConnell, Harris & Christian, 1984). The WCE was modified in the following manner: prior to testing, all load settings were set by a testing assistant at the appropriate load setting at (Kiloponds x kg of body weight). For all female subjects the formula used was (0.075 x kg of body weight). The subject mounted the cycle. The optimum height of the seat was attained by adjusting the seat until a slight bend 5-10 degrees in the knee joint was observed as the ball of the foot of the slightly bent leg and other leg were on the appropriate pedals (Christian & Johnson, 1981). Each subject had a pedal starting position which positioned the left foot right below the switch timer on the bike. The subject was told by the tester to remain seated throughout the 20 second test, and instructed to pedal in an "all-out" effort. On the "ready" command the two testers and subject got prepared for the test. On the "go" command the

subject began to pedal with maximum acceleration and velocity from a loaded still start, while staying seated. Simultaneously, the computer was started with the "go" command given the subject. The predetermined set load was adjusted if needed, within the first 1.5 seconds of the test, by an assistant. The test had a duration of 20 seconds. Recordings of an anaerobic peak power, time to peak power (seconds), and power versus time plots were generated, for this test of anaerobic capacity (refer to Appendix F).

This study included two power tests, one which tested for instantaneous power (vertical jump converted into a power index), and the other which tested for anaerobic capacity over a period of time (20 second modified cycle ergometer test). Due to the different power aspects assessed by these two tests both were utilized.

Many football teams, according to McArdle, Katch & Katch (1981) and Appalachian State University Strength Coach (Sigmon, personal communication, May 20, 1985), often used the 40 yard dash as a criterion to evaluate a player's speed. Although there are many types of "speed" that need to be evaluated, these test scores may provide some information for the evaluation of a player, even though it has yet to be established that 40 yard speed is related to overall football ability for players at similar positions. A run test of shorter duration (up to 20 yards) may turn out to be an equally or more suitable running performance. The 16 yard dash is a sport specific test relating to the defensive rush from a penalty corner in field hockey. The subject when tested in the 16 yard dash started behind the starting line with a self-selected

lead foot close to but not on or over the line. All of the subject's body must stay behind the line. The subject was given time to stretch and warm-up. The tester gave directions to the subject indicating how far the subject needed to run, rest intervals, number of trials, and the commands which were used to initiate the test. The tester asked if there were any questions, then moved to the finish line where a synchronized, verbal cue of "on your marks, get set, go" was provided from the tester. The tester simultaneously upon the "go" command lowered the starting arm. When the starting arm reached the bottom on the swing the clock was started. As the subject's body crossed completely over the 16 yard finish line the stopwatch was stopped. All scores of three trials were recorded, however, only the best score was utilized in the data analysis. Adequate rest between trials was assured.

The velocity and accuracy of the field hockey drive was determined by the velocity runway testing device. The photo-cell runway had an established reliability of .998 with a validity of .999, however, due to its mechanical set-up a $\pm 4\%$ error was accepted (refer to Appendix G) (Lowe, 1984). Each subject had a ten minute warm-up which included trial drives down the runway to get comfortable with the testing apparatus. The subject was then tested until ten "accurate" trials had been recorded. Trials which lifted and did not break both light beams were counted as inaccurate trials. A trial taken which hit the runway containing walls, was also ruled as an inaccurate trial. All other trials were counted as "accurate" trials. Before each trial, the subject

ran a "stick run" through the beams to assure the proper working of the phototransistors and computer. The tester then reset the program and gave a positive verbal communication when it was satisfactory for the subject to take another trial. The velocity was determined through a software program specifically designed for the use of the phototransistors (Rafert and Nicklin, 1984). The data points generated by this program were then placed in another program for rapid calculations of the data into miles per hour (refer to Appendix H) (Lowe, 1984). This computation was performed to yield immediate feedback to the subject. When data were analyzed a conversion back into meters per second was generated. The data collected in the test yielded information on the average velocity of the ten accurate trials and the number of total trials required to generate such trials.

A relationship has been established between dynamic leg strength and leg power (Berger and Henderson, 1966). Measures for dynamic leg and hip strength were determined by a 1 RM squat. A 1 RM parallel squat has been the preferred measure for dynamic leg and hip strength (O'Bryant, 1982; O'Shea, 1966; Stone & O'Bryant, 1984). Each subject was given instructions and a demonstration on the proper technique for performance of the parallel squat. The subject was instructed to achieve a position during the test where the top of the thighs were parallel to the floor on the down phase of the move before coming up with the weight. This position had to be reached for the trial to count as a successful attempt.

Similarly, arm and shoulder strength was measured from a 1 RM supine bench press which was executed by taking the bar down

slowing and slightly touching the chest, then pressing the bar up until the arms were fully extended. Instructions and demonstration on proper technique for performance of the supine bench press were given before the test.

In order to allow a maximum effort and stabilize the neuromuscular system each subject performed warm-up stretches. Then the subject continued to warm up by performing one set of five repetitions with a light amount of weight (40-60% of perceived maximum). After approximately a one minute rest period and light stretching, a set of three repetitions was lifted with a heavier amount of weight (60-80% of perceived maximum). After another minute of rest and light stretching the subject performed 3-4, one repetition maximums. Each one repetition attempt was spread out by a 30-60 second rest interval with the next repetition being attempted with increasingly heavier weights. If the 1 RM was not achieved by this point additional lifts were attempted with additional rest periods (refer to Appendix I) (Stone and O'Bryant, 1984).

To provide adequate rest for subjects, two tests were administered on the same day. They were balanced with each other so the first test did not have a depreciable effect upon the other, as established upon previous data on the recovery of the energy systems used (Fox, 1979; Fox & Mathews, 1981; McArdle et al., 1981). Each day of testing was followed by a day of rest before testing occurred again. The testing schedule is shown in detail in Table 2.

Table 2
Testing Schedule

Day	Group Tested*	Test Administered
Wednesday	1 and 2	16 yard dash % body fat
Thursday	1	Vertical jump Cycle 20 sec.
Friday	2	Vertical jump Cycle 20 sec.
Saturday	1	F.H. Drive speed/accuracy
Sunday	2	F.H. Drive speed/accuracy
Monday	1 and 2	make-ups F.H. Drive
Tuesday	1	1 RM Squats 1 RM Bench
Wednesday	2	1 RM Squats 1 RM Bench
Thursday	1	Periodization starts
Friday	2	Periodization starts

*Group 1 was made up of groups A and B, subjects which trained on T/Th/Sun, Group 2 was made up of groups A and B, subjects which trained on M/W/F.

Various traditional forms of weight training exist (O'Bryant, 1982). In this study a documented weight training program designed to maximize performance after thirteen weeks was chosen (Stone et al., 1981; O'Bryant, 1982). Major, secondary and associative lifts were included in the three day a week double periodization program. The double periodization protocol for Groups A and B are shown in Table 3, and indicates the introduction of the progressive plyometric protocol. Group B started plyometric training after three weeks of periodization. The three weeks of double periodization developed the base strength needed before engagement into the plyometric protocol was initiated (Hinkel, 1984; O'Bryant, 1984).

The group trained eight weeks, three times a week, following weight training. A progression of simple to complex drills were used. The plyometric protocols for Group B are shown in Table 4. The upper and lower body plyometric programs were progressive. The lower body plyometrics progressed from jump training, box jumping, to depth jumping. The upper body plyometrics progressed with a biomechanical sport specific drill using the hockey stick secured to the wall with cables and weights. The first phase used the motion of the field hockey drive with little resistance, then weights were added to the pulley system as needed in addition to increasing sets during the program's progression.

Data Analysis

All data collected from Groups A and B in the pre and post test were analyzed by an Analysis of Variance (ANOVA). The null hypothesis was tested at a level of significance using an alpha

Table 3

Periodization Weight Training Protocol

Activity	3 weeks	2 weeks	1 week	1 week	3 weeks	2 weeks	1 week	Post-test
Major lifts (sets x reps)	5 x 10	1 x 10* 3 x 05 1 x 10**	1 x 10* 3 x 02 1 x 10***	Active Rest	3 x 10	1 x 10* 3 x 05 1 x 10**	1 x 10* 3 x 02 1 x 10***	
Supplemental lifts (#1)	3 x 10	3 x 10	3 x 10	Rest	3 x 10, increasing weight			
Supplemental lifts (#2)	2 x 10	2 x 10	2 x 10	Rest	2 x 10, increasing weight			
Sit-ups	3 x 10	3 x 20	3 x 20	Rest	3 x 20, increasing weight			
Wrist Rolls	1 up/dn	2 up/dn	2 up/dn	Rest	2 up/dn, increasing weight			
Hip Rotations	2 x 08	2 x 10	2 x 10	Rest	2 x 10	2 x 15	2 x 20	
Super women/ hyper-extensions	2 x 10 sec.	2 x 10 sec.	2 x 10 sec.	Rest	1 x 10	1 x 10		

Jump training begins
(no weights)

Jump training
(with weights)
Upper Plyo. (no wt.)

Plyometric training begins
Upper Plyo. (w/wt.)

Major lifts:
Parallel squats (Sun/Th)
Bench Press (Sun/Th)
Mid-thigh pulls (Tues)

Supplemental lifts #1
French curls/Dumbbells (Th)
Pullovers (Tues)

Supplemental lifts #2
Leg curls (Sun/Th)
Bicep curls (Sun/Th)
Groins-hold 5 sec. (Tues)

*warm-up light load
**follow-up set with 70% original max.
***follow-up set with 75% original max.

Table 4
Plyometric Training Protocol

	WEIGHT TRAINING (sets x reps)	JUMPING (sets x reps)	STICK PLYO. (sets x reps)
Week One:	3 x 5	6 x 10 6 x 8	none
Week Two:	3 x 5	same as above plus 2½ lbs. wt.	none
Week Three:	3 x 2	3 x 10 3 x 8 (5 lb. wt)	3 x 10
Week Four:	Active Rest		
Week Five:	3 x 10	3 x 10 3 x 10	4 x 10
Week Six:	3 x 10	3 x 10 3 x 8	4 x 10
Week Seven:	3 x 10	3 x 10	4 x 10
Week Eight:	3 x 5	3 x 12 (5 lb. wt. each hand)	4 x 10+wt.
Week Nine:	3 x 5	same as above	same as above
Week Ten:	3 x 2	4 x 10	4 x 10

- Week One: 6 x 10 Jumping up in the air in place
6 x 8 Jumping across the floor as far out as possible
- Week Two: 6 x 10 With 2½ lb. weight jumping in air
6 x 8 With 2½ lb. weight jumping across the floor
- Week Three: 3 x 10 With 5 lb. weight jumping in the air
6 x 8 With 5 lb. weight jumping across the floor
- Week Four: Active Rest Break
- Week Five: 3 x 10 Jump onto the top of 36 cm box (step down to get off)
3 x 10 Jump over boxes (select 46 cm or 36 cm box)
- Week Six: 3 x 10 Jump over box
3 x 8 Step off of box rebound up into the air
- Week Seven: 3 x 10 Off of box bound onto another box
- Week Eight: 3 x 10 Bounding onto and off of box runway (six boxes on runway)
- Week Nine: 3 x 12 Jump up onto box, step off rebound off (5 lb. wt. each hand)
- Week Ten: 4 x 10 Jumping sideways as fast as possible onto top of box and off,
back on it again
- Stick plyometric drill: In week three started with 3 x 10, the rest of the time increased to 4 x 10 and added resistance as needed.

level of $p \leq .05$. The pre and post test results were organized in a 2 x 2 factorial, repeated measures ANOVA design (ASU Computer User's Guide, 1982).

CHAPTER 3

Results

An Analysis of Variance (ANOVA) 2 x 2 factorial design with repeated measures, was used to analyze all data in this study. The findings of this study were supportive of the null hypothesis, as stated previously in all test variables tested. The results of the ANOVA on the pre test data showed no significant differences between groups A and B for any of the variables.

The illustrated gains of the 1 RM in the parallel squat and supine bench press are shown in Figures 1 and 2. A significant difference was found for both groups A and B when analyzing the pre and post data. However, no significant interaction between the treatment groups was indicated. The null hypothesis was not rejected at an alpha level of $p \leq .05$.

The 16 yard dash showed significant differences in both A and B groups when analyzing the pre and post results. The null hypothesis was not rejected due to the nonsignificance of interaction between groups A and B (refer to Figure 3).

Collected power index values showed no significant gains between the groups. A significant difference was observed between the pre and post scores of subject in groups A and B. The null hypothesis was not rejected at the $p \leq .05$ level of significance. The illustrated gains can be seen in Figure 4.

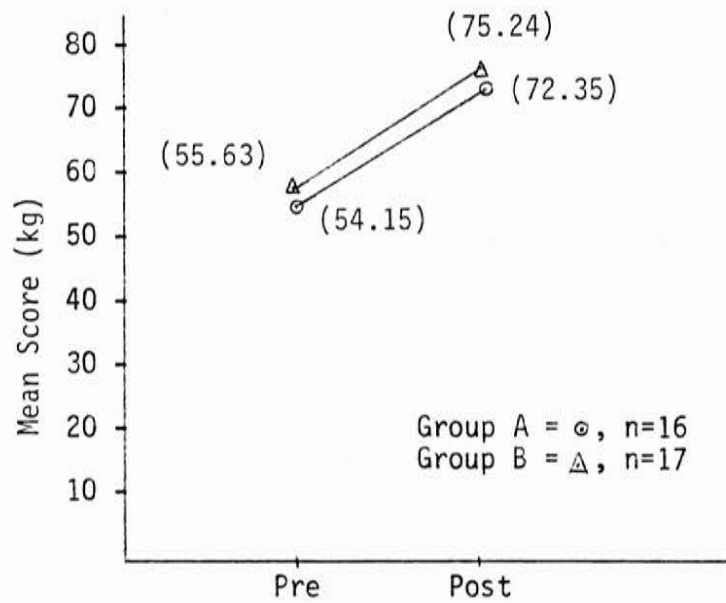


Figure 1. Parallel Squat (kg improvement)

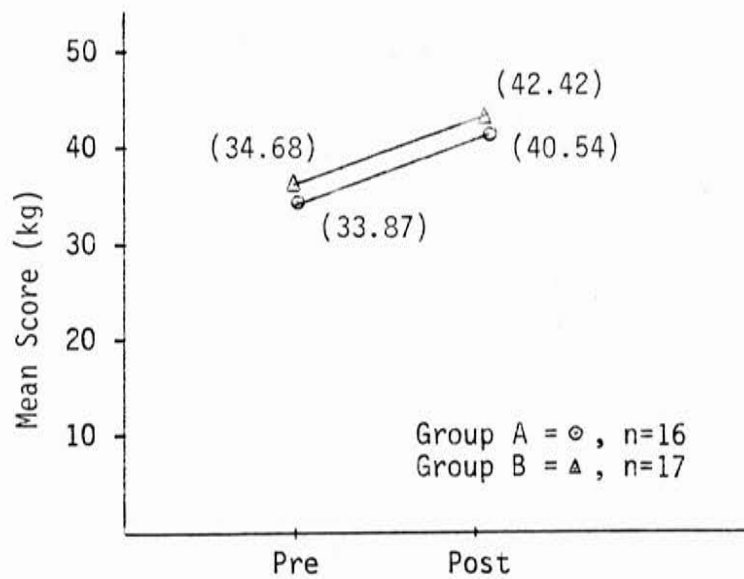


Figure 2. Supine bench press (kg improvement)

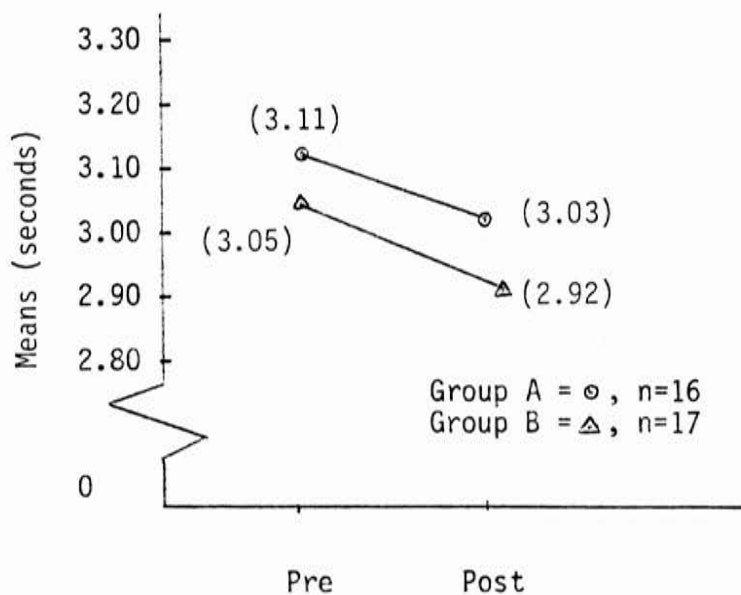


Figure 3. 16 yard dash (seconds improvement)

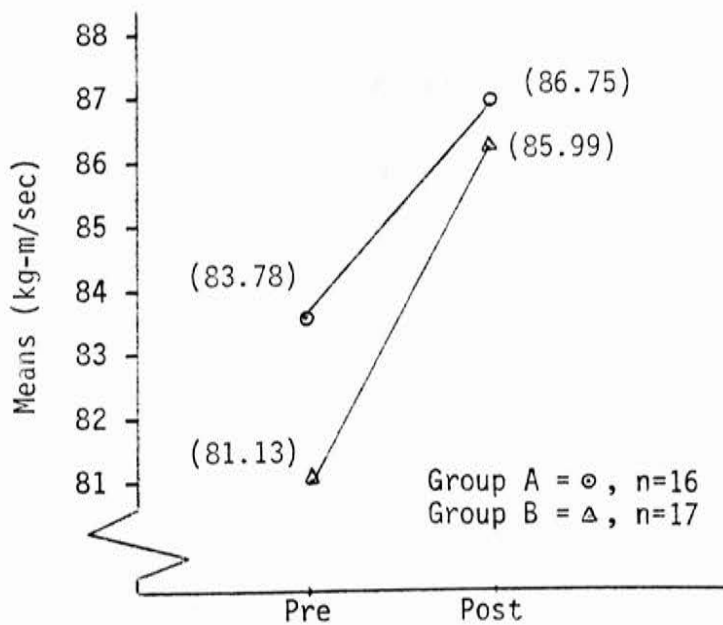
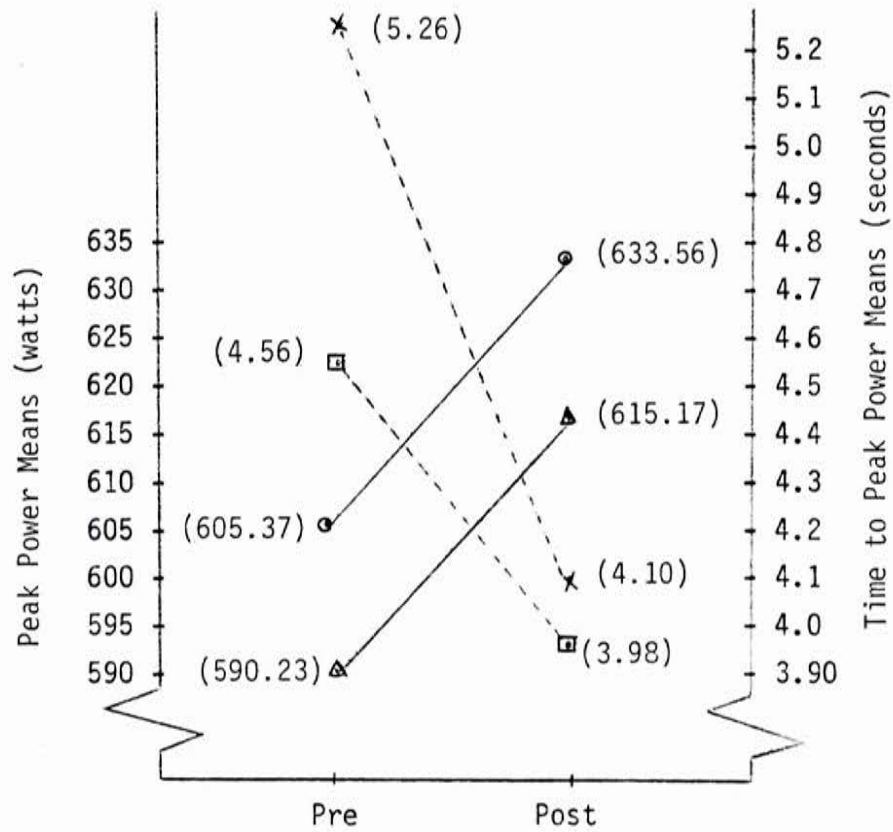


Figure 4. Power index (kg-m/sec)

The peak power data collected in the anaerobic capacity cycle test showed significant gains in both treatment groups, but did not support one treatment over the other for possible significant gains. The null hypothesis was not rejected at the $p \leq .05$ alpha level of significance. The data collected in this test also yielded values of "time to peak power". Significant gains were found between pre and post scores in group A and B. The null hypothesis was accepted at the $p \leq .05$ level due to a nonsignificant interaction between the treatment groups. Figure 5 shows both the peak power and time to peak power data results.

The speed of the field hockey drive was the only test which showed no significant increase in either group A or group B, between pre and post testing. However, the accuracy test did show significant gains in both groups. Again, no significant interaction between treatments was indicated. The null hypothesis was not rejected at the $p \leq .05$ level of significance. Figure 6 shows the resulting values and relationships between groups A and B.

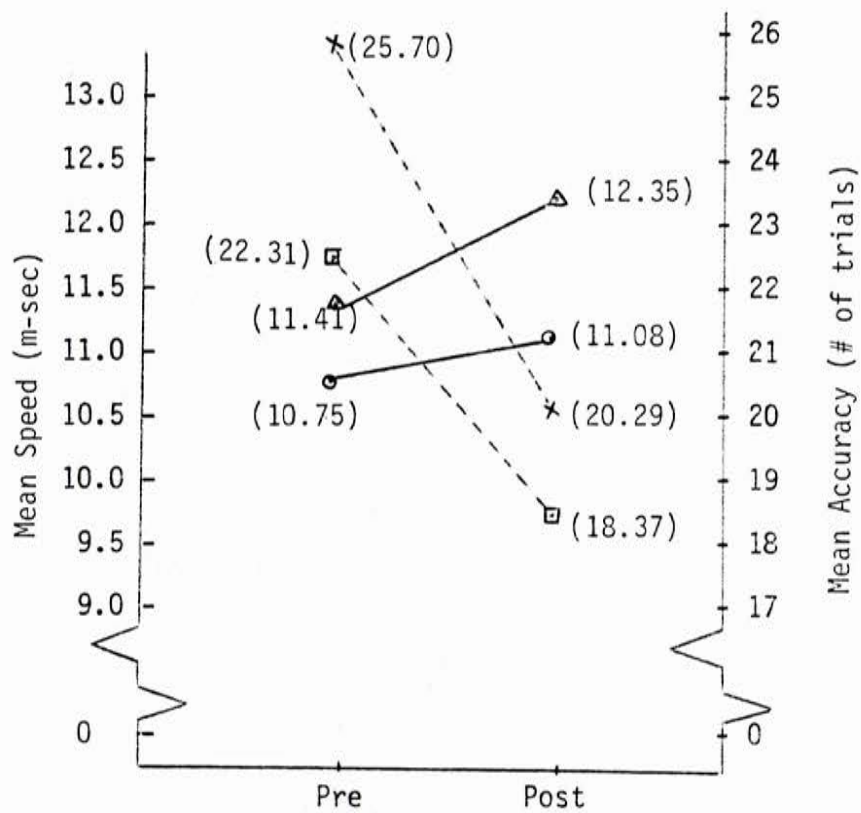
Refer to Appendices J and K for ANOVA tables.



peak power: Group A = ○, n=16
 Group B = △, n=17

peak time: Group A = □, n=16
 Group B = ×, n=17

Figure 5. Peak power and time to peak power (watts and seconds improvement)



Group A = ●, speed, n=16
 Group B = ▲, speed, n=17

Group A = ◻, accuracy, n=16
 Group B = ×, accuracy, n=17

Figure 6. Field hockey drive, speed and accuracy

CHAPTER 4

Discussion

The ability to join power and speed to produce an explosive movement has been considered a major factor in the enhancement of an athlete's performance (Bosco & Komi, 1980; Chu, 1984; Komi & Bosco, 1978; Polhemus & Burkhardt, 1980; Verhoshanskiy, 1966). Of the 48 subjects who initially started the program, 33 completed all pre and post testing and participated within the 90% attendance policy set for the training protocol. In this study, the group who trained with periodization and plyometrics (Group B, n=17) was unable to produce significantly greater scores on the eight variables analyzed, when compared to the group who trained only by periodization (Group A, n=16). While both groups showed significant gains from pre to post testing in all areas except the 16 yard dash and the speed of the hockey ball during the field hockey drive, no significant interaction occurred between treatments. Due to previous supporting data, gains observed in groups A and B were attributed to the periodization protocol (O'Bryant, 1982; Stone & O'Bryant, 1984).

The subjects in group B gained strength at approximately the same rate as those in group A. Therefore, gains in the 1 RM parallel squats and supine bench press were similar for both groups. The lower body plyometric training protocol incorporated

similar movement patterns as performed in the parallel squat. After eight weeks of jump training and plyometrics, which were incorporated into the 13 week weight training program, no significant gains occurred between group treatments.

Similar results in the power index of groups A and B indicated no significant difference between treatments. Both groups did accomplish significant gains from pre to post testing. These gains were a combination of greater height reached in the vertical jump due to increased strength, and an increase in lean body weight. Both of these changes readily occur by one going through a periodization weight training program, caused by performing the hypertrophy phase of periodization followed by strength phases. Due to increases in the jumping height and increase of the subject's body weight the resulting power index increased. A study by Komi and Bosco (1978) found similar results in female subjects when looking for stretch reflex mechanisms involved in plyometric drills from different heights and positions. The results indicated that females use a greater percentage of absorbed energy (stretch phase) in the reflex mechanism as compared to male counterparts. In contrast to expected results however, the males were able to improve performance from much higher drops indicating that their stretch loads were higher. The hypothesis in the study addressed the finding of different performance results between the males and females in the area of the utilizing potential elastic energy as being due to sex differences in body dimensions.

The 16 yard dash as a specific performance task in the sport of field hockey, showed significant gains from pre to post scores of both groups A and B. The plyometric training failed to elicit a statistically significant gain in such an explosive accelerated run. However, the periodization, upper and lower plyometric programs did not incorporate any similar movement patterns to running. No practice of the 16 yard dash was incorporated into the training protocol. The explosive power from the legs produced by the quadriceps and hamstrings for the acceleration phase of the dash was not enhanced by the plyometric training protocol. Perhaps the percent of fast to slow twitch muscles in the subjects of the study should have been taken into account. Not all subjects in the study had previous training in anaerobic activity prior to their participation in the 13 week program.

Though the plyometric drills did not simulate any aspect of the riding the bicycle it was postulated such drills would enhance the thigh and hamstring muscles which would assist in the generation of a higher power variable output, reached in a shorter amount of time, during the 20 second anaerobic capacity test. Pre and post anthropometric readings of most subjects in the study indicated increases in body weight (n=31 out of 33) and decreases in percent body fat (n=33 out of 33). These changes were attributed to the already supportive data surrounding the periodization resistive training program. Due to the changes in body weight the workload resistance was increased from the pre to post testing in all cases except two. The changing of the workload caused the training effect to overcome added resistance

while also striving to produce a greater peak power variable, which was accomplished by subjects in both groups A and B. A significant change in time to the peak power variable was also seen by both groups.

The final test in the study was incorporated to test gains of the upper plyometric drills. The field hockey drive included accuracy and speed variables. The speed of the field hockey drive indicated nonsignificant gains by groups A and B. After testing was completed the test was ruled too stringent due to the inability of the equipment to test the speed of a trial if the ball lifted off the ground by the diameter of the hockey ball (7.5 cm). Due to the restrictions of the test the subject became frustrated with the results and began hitting the ball lightly to simply record an accurate trial and finish the test. The situation of the frustrated subject occurred several times throughout the testing procedure and occurred with field hockey players as well as with non-field hockey players. The test was ruled too strict due to the premise of the field hockey game. When in a game situation, the ball on a stationary drive is allowed to raise to the height of the player's knees before being interpreted as uncontrolled.

Both groups improved in the accuracy variable by lowering significantly the number of total trials taken to yield ten accurate trials. No significant increases were found however in the speed variable of the hockey drive due to the upper plyometric drill which biomechanically and mechanically simulated the field hockey drive with the exception of striking the ball. The

speculation was made that the test being too rigid affected the results of this test. The field hockey drive was not practiced by either group during the training protocol of 13 weeks.

Due to the specificity of the plyometric drills of the upper and lower body, speculation was for primary gains to have resulted in the power index and in the speed of the field hockey drive. Secondary significant gains were speculated in the areas of strength, anaerobic capacity and field hockey performance tasks. The findings of this study are similar to findings by Bosco et al. (1983) and Steben and Steben (1981) which found that gains were less and sometimes nonsignificant in females training with plyometrics when compared to other protocols. The findings of Komi and Bosco (1978) which indicated observed sex differences in utilizing potential elastic energy may be due to the difference in body dimensions may support the inability of this study to produce significant differences between groups A and B. Another possible factor influencing the results was the females' smaller muscle mass which might have prevented a statistical significant gain to occur between the groups. A third area to consider is the muscle fiber type of the subjects involved in the study. The female with the higher percentage of fast twitch muscle could have had a tendency to gain more in the anaerobic type of training performed in this study.

The periodization/plyometric protocol session required 1 1/2 to 2 hours to perform, with proper rest breaks for recovery of the anaerobic energy system, while lifting the 3 sets x 10 repetitions phase of the weight training program. On the average, the workout

sessions ran 1 3/4 hours when proper rest intervals were observed by subjects. An increase in sets and repetitions of the plyometric drills may be desired to cause the sought increases. The ability to balance the duration, frequency and intensity of the plyometric program in conjunction with the periodization program as one increases the variables should take top priority as two plyometric programs are administered instead of the more traditional program of only jump plyometrics.

The results of this study may have been different had the female subjects all been athletes who played field hockey, with previous anaerobic training, and a muscle fiber type which favors a high percentage of fast twitch muscle.

Summary and Conclusions

Training on the upper and lower plyometrics program in conjunction with a periodization weight training program produced nonsignificant differences on all test variables in this study when compared to female subjects who trained only with the weight training protocol. Similar results have been found in previous studies. The present lack of knowledge in the area of optimum bench height, optimum intensity and duration of plyometrics as it applies to female athletes is a door which appears to be unopened by researchers. Consequently, increased scientific research is needed to open the door to these variables. When the variables can be used maximally, then functional plyometric programs for female athletes may be generated to enhance the female athletic performance significantly. The doors have been opened to the male athlete but not yet to the female athlete due to a difference in

body dimensions and muscle mass. With this in mind, it is concluded from this study that plyometrics theoretically should enhance both female and male athletic performances. However, due to several unsolved variables, a plyometric program for female athletes has not been developed which produces a significantly enhanced performance over other generally accepted training techniques. More specifically, this study failed to generate an upper and lower plyometric program which may have produced significant gains in strength, power, and selected field hockey performance parameters. The gains observed from pre to post testing in groups A and B were attributed to the periodization weight training program which as been shown to improve significant increases in the parameters of strength and power.

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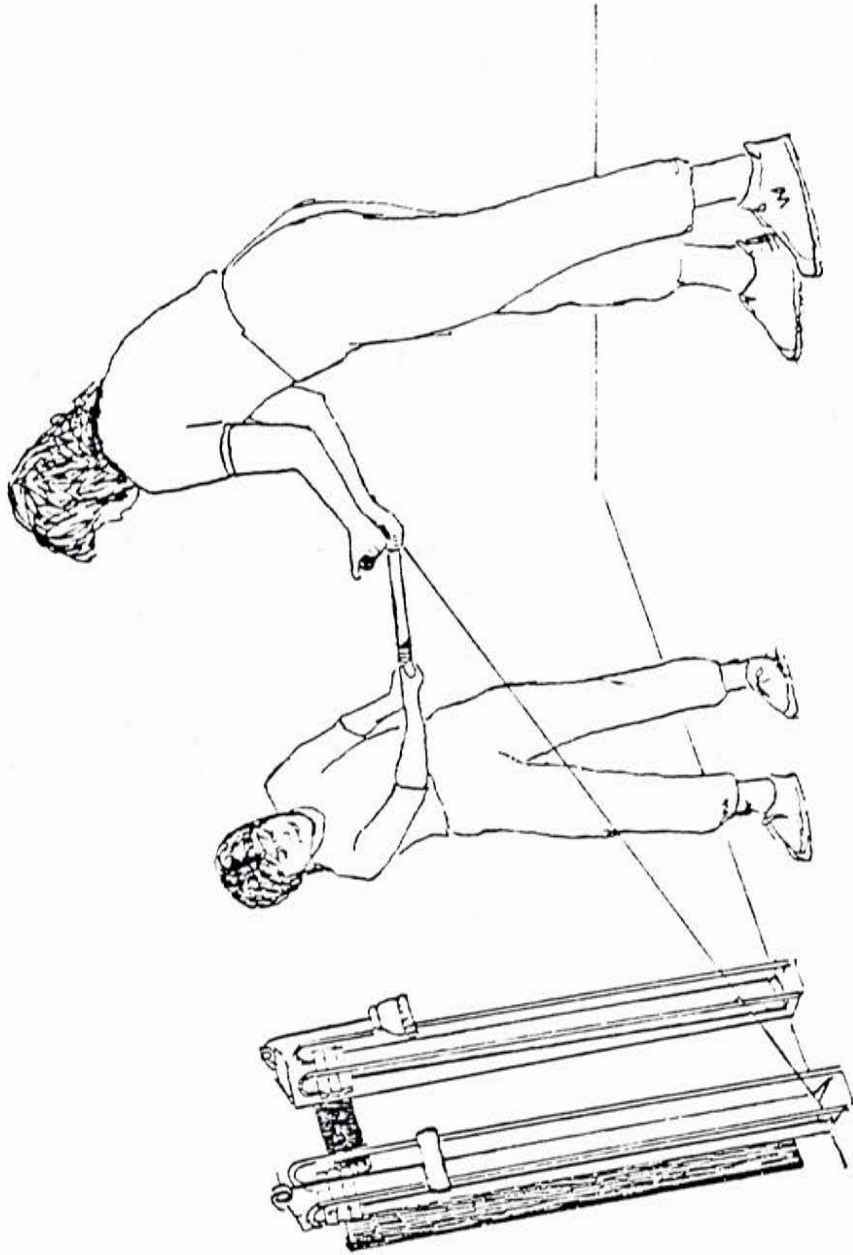
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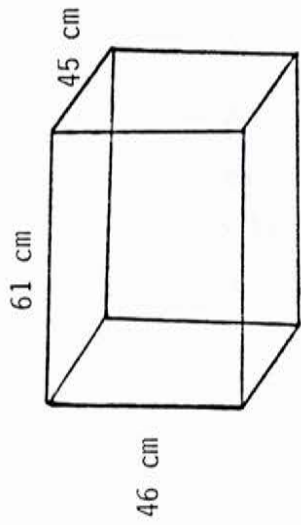
APPENDIX A

Upper Body Plyometric Station



APPENDIX B

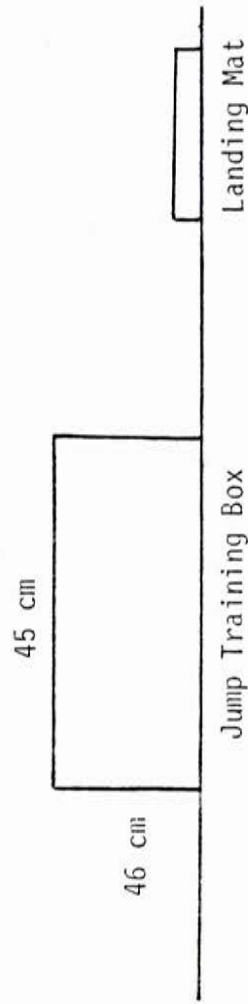
Lower Body Plyometric Station



Jump Training Box

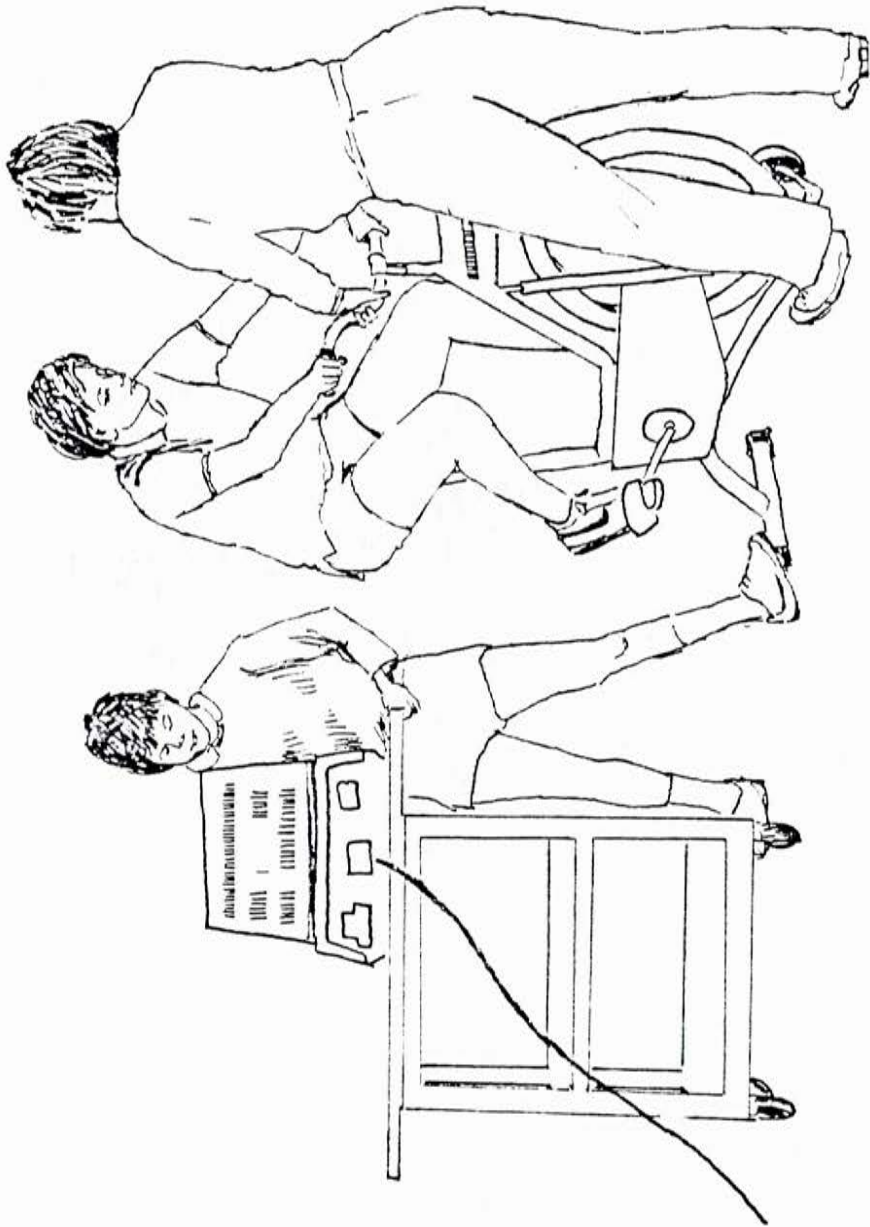
Dimensions: 46 x 61 x 45
(cm)
36 x 61 x 45
30.5 x 60 x 45

Landing Mat: 1.5 cm thick foam



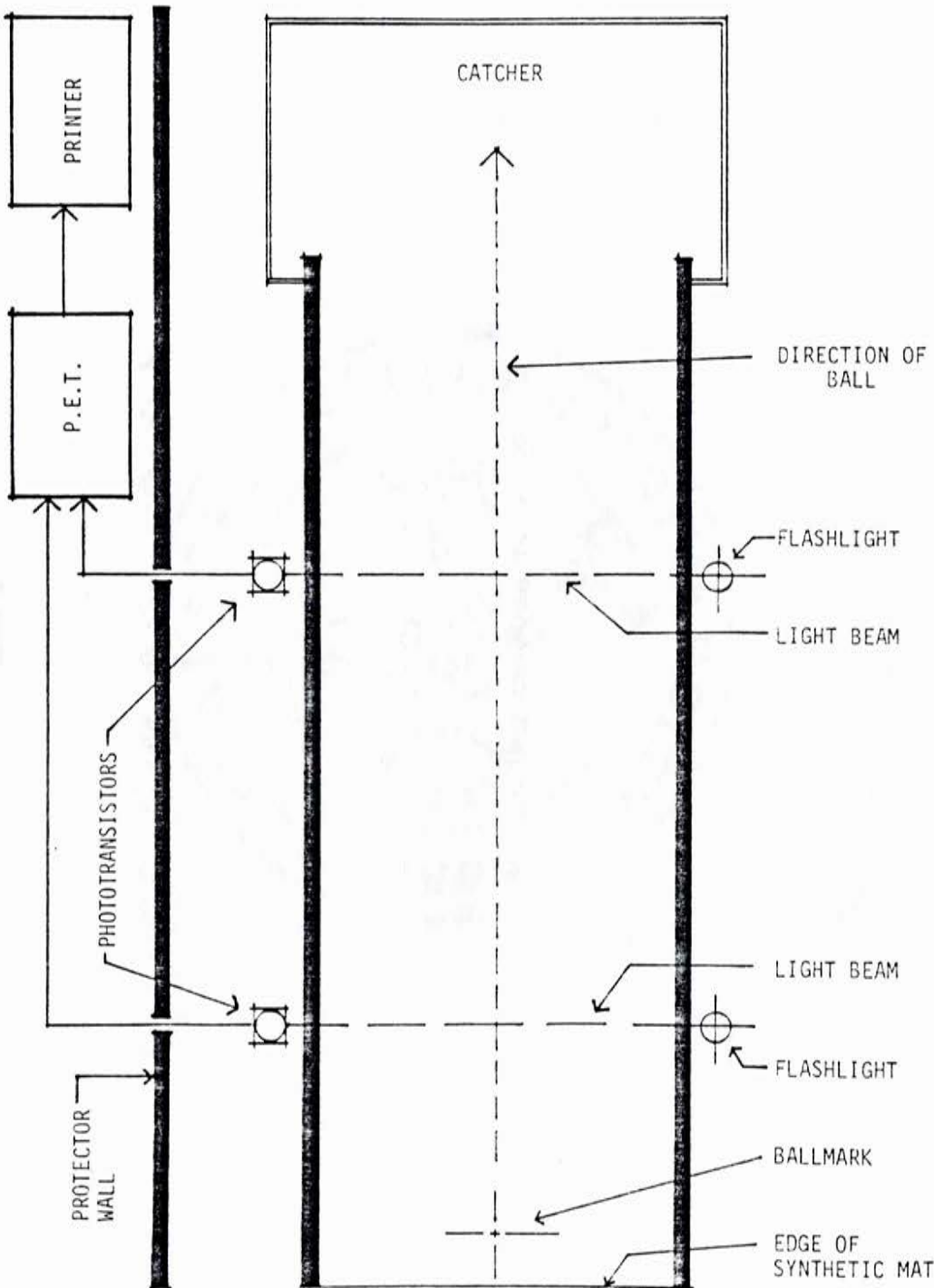
TRAINING STATION

APPENDIX C
Anaerobic Capacity Test Station



APPENDIX D

Field Hockey Drive Test Station



APPENDIX E
Consent Form

General Information and Consent Form

Description of Test

Vertical Jump: Stand with favored side to the wall, bend knees, while keeping feet flat on the floor (you may not step into the jump), using your arms, jump as high off the floor as possible. Reaching with your hands and with your favored hand touch the board with your fingertips. First: Get weighed. Second: Reach as high as possible on the board with feet flat on the floor for an initial reading. Third: Take a practice jump. Fourth: Take three test trial jumps with chalk on your fingertips.

20 sec. Bike Test: First: Sit on the bike. Second: Get off of the bike while the seat is being adjusted and the proper work load is set. Third: Get back on the bike. Fourth: On the command "ready", get ready. Fifth: On the command "go", ride hard, pumping the pedals as hard as possible, while staying seated, throughout the whole test, for 20 seconds. Sixth: On the "stop" cue you may slow your pace. Seventh: Ride slowly at a low resistance to cool-down.

Velocity and Accuracy Test: First: Select an appropriate sized hockey stick (tester will assist you in proper selection. Second: Take ten minutes to stretch, warm-up and practice trials down the runway. Place the field hockey ball on the mark on the runway as instructed after each trial. Third: Take a "stick run" when instructed before each trial. Fourth: When o.k. is given hit the ball down the runway. Fifth: Take as many trials as needed to record 10 "good" trials.

Strength Measures: To acquire the 1 RM on the squats and bench press the following will be used:

- First: Stretch out
- Second: 5 lifts, light load (1 x 5)
- Third: 3 lifts, medium load (1 x 3)
- Fourth: 1 lift, added weight (1 x 1)
- Fifth: 1 lift, added weight (1 x 1)
- Sixth: Should have or be close to 1 RM on the 3rd 1 x 1
- Seventh: Continue until you reach 1 RM

16 Yard Dash: First: Stretch out. Second: Listen to instructions about starting commands, and information on the starting and finishing lines. Third: Run dash three times for a time, with rest intervals inbetween.

Consent Form

I (name of subject), _____, voluntarily agree to participate in this study. I understand that the training sessions will run 13 weeks, with three workouts a week. I also agree to take the six pre and post test as was described to me. I accept full responsibility for any injury or illness which could result from this participation after having received proper instruction from the director of the study. I will be present at each testing session barring injury or illness. I understand and will abide by the 90% attendance policy for the training program.

Signature of subject participating

Date

APPENDIX F

Anaerobic Capacity Test Sample Data Sheet

PG

TIMER CYCLE TIME= 8.3199033E-03 SEC

NUMBER OF SWITCH CYCLES= 34

FORCE(KILOPONDS)= 4.64

TIMER CYCLES

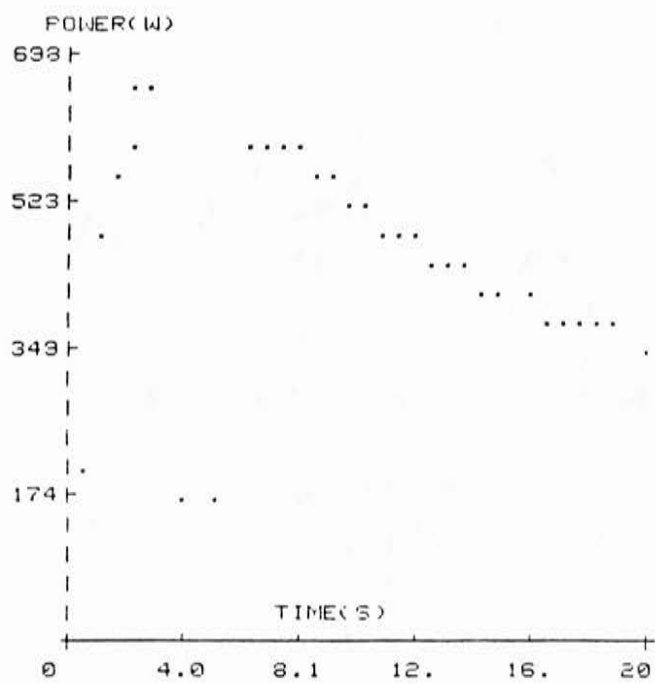
39 105 62 55 50 47 47 46 140 192 51 50 51 52 52 54 55 55 57
 58 61 62 64 66 66 67 69 71 73 75 78 79 80 83 84

PG

TIMER CYCLE TIME= 8.3199033E-03 SEC

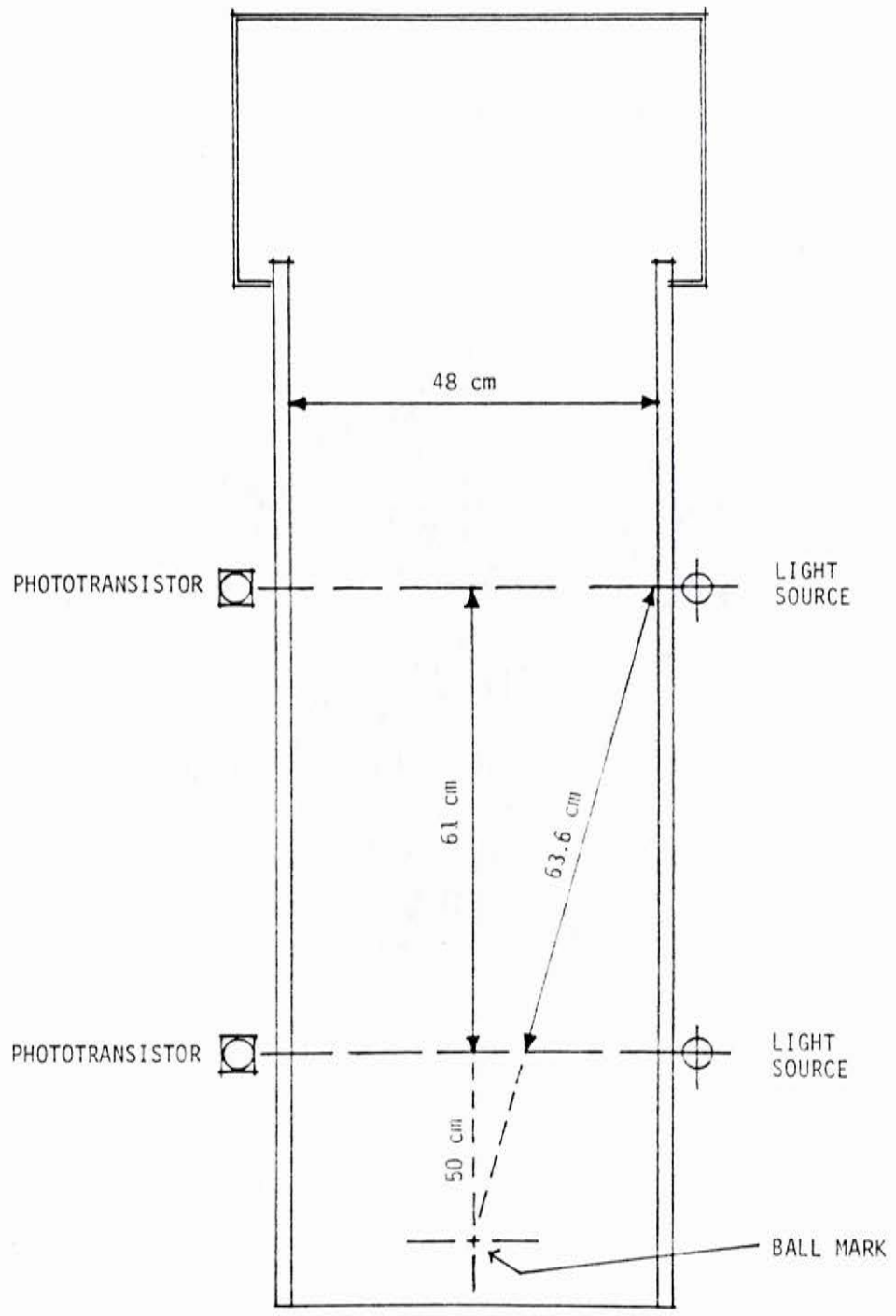
NUMBER OF SWITCH CYCLES= 34

TIME(S)	POWER(W)	LOGPOWER
.59	228	5.42
1.45	529	6.27
1.94	597	6.39
2.37	657	6.48
2.78	638	6.54
3.17	698	6.54
4.14	176	5.17
5.71	171	5.14
6.72	644	6.46
7.14	657	6.48
7.56	644	6.46
7.99	631	6.44
8.42	631	6.44
8.86	608	6.4
9.32	597	6.39
9.78	597	6.39
10.24	576	6.35
10.72	566	6.33
11.21	538	6.29
11.73	529	6.27
12.25	513	6.24
12.79	497	6.2
13.34	497	6.2
13.89	490	6.19
14.46	476	6.16
15.04	462	6.13
15.64	450	6.1
16.26	438	6.03
16.89	421	6.04
17.55	416	6.02
18.21	410	6.01
18.89	395	5.99
19.58	391	5.96
20.29	382	5.94



APPENDIX G

Field Hockey Drive Test Error Diagram



APPENDIX H

Field Hockey Drive Test Computation Program

VELOCITY CALCULATIONS

1. $\frac{(\text{distance covered between beams}) \times (\text{time clock used})}{\text{address difference from computer data}}$
2. $\frac{(\text{figure from above calculation, meters/second}) \times (60 \text{ mph})}{28.8 \text{ meters/second}}$
3. Equation number two gives results of velocity in miles per hour (mph)

Example:

Step 1. $\frac{.61 \text{ m} \times 2880}{13290 - 12288} = 1.75 \text{ meters/second}$

Step 2. $\frac{1.75 \times 60}{26.8 \text{ m/s}} = 3.925 \text{ mph}$

Step 3. 3.925 mph

APPENDIX I

1 Repetition Maximum Procedure

1 REP MAX-POST MEASUREMENTS

Reminders:

1. Stretch out properly before attempting a max.
2. Parallel squat requires you to position the top of the thighs horizontal to the floor.
3. Supine bench press requires you to take the bar down slowly to your chest, lightly touch your chest and fully extend your arms. Avoid arching your back during the lift and keep your feet on the floor.
4. Max attempt requires light warmup and three max attempts, with the last attempt your maximal lift. Add on weight accordingly so that the last lift is a max attempt and you don't under- or over-shoot your true max.

Parallel squat

Light warmup: 1x5 _____ lbs.

1x3 _____ lbs.

Max attempt: 1st _____ lbs.

2nd _____ lbs.

*3rd _____ lbs.

+4th _____ lbs.

+5th _____ lbs.

*parallel squat max: _____ lbs.

Supine bench

Light warmup: 1x5 _____ lbs.

1x3 _____ lbs.

Max attempt: 1st _____ lbs.

2nd _____ lbs.

*3rd _____ lbs.

+4th _____ lbs.

+5th _____ lbs.

*supine bench max: _____ lbs.

+ use only if needed

APPENDIX J

ANOVA Table

<u>TEST</u>	<u>SOURCE</u>	<u>SUMS OF SQUARES</u>	<u>DEGREES OF FREEDOM</u>	<u>MEAN SQUARES</u>	<u>F</u>
1 RM Squat (kg)	TRT	5894.170	1	28552.228	124.69
	TG	8.135	1	43.147	0.19
	Error	1465.548	31	228.985	
1 RM Bench (kg)	TRT	854.590	1	854.590	103.99
	TG	4.768	1	4.768	0.58
	Error	254.760	31	8.21	
16 Yard Dash (seconds)	TRT	0.178	1	0.178	30.93
	TG	0.007	1	0.007	1.31
	Error	0.178	31	0.0057	
Power Index (kg-m/s)	TRT	252.522	1	252.522	27.44
	TG	14.62	1	14.62	1.59
	Error	285.30	31	9.20	
Accuracy F.H. Drive (# of trials)	TRT	360.23	1	360.23	8.54
	TG	8.95	1	8.95	0.21
	Error	1307.52	31	42.17	
Speed F.H. Drive (m/sec)	TRT	6.56	1	6.56	3.43
	TG	1.48	1	1.48	0.78
	Error	59.29	31	1.91	
Peak Power Variable (watts)	TRT	11632.76	1	11632.76	4.20
	TG	43.43	1	43.43	0.02
	Error	8571.68	31	2766.82	
Time to Peak Power Variable	TRT	12.50	1	12.50	11.99
	TG	1.37	1	1.37	1.32
	Error	32.33	31	1.04	

APPENDIX K
Mean and Standard Deviation Table

<u>TEST</u>	<u>GROUP</u>	<u>PRE-MEAN</u>	<u>ST. DEV. (\pm)</u>	<u>POST MEAN</u>	<u>ST. DEV. (\pm)</u>
1 RM Squat (kg)	A	54.147	18.292	72.353	21.023
	B	55.631	14.613	75.243	12.376
1 RM Bench (kg)	A	33.877	7.474	40.540	8.837
	B	34.686	8.836	42.424	7.554
16 Yard Dash (seconds)	A	3.116	0.254	3.033	0.233
	B	3.053	0.135	2.928	0.158
Power Index (kg-m/s)	A	83.786	13.136	86.758	11.947
	B	81.137	12.798	85.992	12.587
Accuracy F.H. Drive (# of trials)	A	22.312	8.829	18.375	11.262
	B	25.708	6.927	20.294	7.800
Speed F.H. Drive (m/sec)	A	10.75	4.36	11.08	3.70
	B	11.41	3.26	12.35	2.05
Peak Power Variable (watts)	A	605.375	105.40	633.562	92.377
	B	590.239	132.54	615.176	112.099
Time to Peak Power Variable (seconds)	A	4.563	1.026	3.981	1.220
	B	5.268	1.523	4.108	0.596

VITA

Cathy Lee Lowe was born in Arlington, Virginia on January 13, 1956. She attended elementary schools in the Herndon/Chantilly area of Fairfax County and graduated from Herndon High School in June 1974. The following August she entered Longwood College, and in May 1978, received a Bachelor of Science degree in Health, and Physical Education. In the fall of 1978 she was employed by and taught elementary physical education for Rappahannock County Schools until June 1980. In the fall of 1980 until June 1983 she taught elementary physical education and coached on the high school level for Stafford County Public Schools.

In August 1983 she entered Appalachian State University and began work towards a Master of Arts degree in Exercise Science. Miss Lowe will be employed by Appalachian State University in the Department of Health Education, Physical Education and Leisure Studies, after graduation, which is scheduled for August 1985.

Miss Lowe's address is Route 6 Box 297, Boone, North Carolina. She has a single marital status.

Her parents are Mr. and Mrs. Thomas Haywood Lowe of Chantilly, Virginia.