A PREDICTED, OPTIMAL BENCH HEIGHT FOR INDIVIDUALIZED PLYOMETRIC TRAINING

A Thesis

by

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ABSTRACT

A PREDICTED, OPTIMAL BENCH HEIGHT FOR INDIVIDUALIZED PLYOMETRIC TRAINING. (May 1985)

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Plyometrics is a relatively new conditioning concept in this country, however, it has already proven to be a superior training method for the development of power. Plyometrics is designed to decrease the amortization phase of counter movement patterns, a process which involves quickly switching from overcoming work to imparting the necessary amount of acceleration in the required direction. A plyometric exercise or depth jump is a training drill performed by stepping down from a pre-determined height and immediately executing a maximal vertical rebound jump.

In this study the subjects were instructed to step down from a series of six different depth jump heights (10, 14, 18, 22, 26, and 30 inches). Vertical jump measurements were taken in centimeters and anaerobic leg power was determined by the Lewis Formula. The highest vertical jump obtained may indicate the optimum height to begin training. By subjecting measures of static strength measure, dynamic strength measures and vertical jump converted to power, a regression equation may be developed to determine the optimum bench height for a particular strength and/or initial power level. A second purpose of this study was to determine the relationship between depth jump heights and respective amortization times. The amortization time was calculated from the time the subject was in contact with a switchmat, following a depth jump, until he rebounded from the mat to execute a vertical jump.

The subjects tested were divided into three groups: (a) untrained; (b) intermediate (aerobic/anaerobically trained), (c) anaerobic. An individual group analysis, as well as a combined group analysis was performed in order to generate equations for each group and the group as a whole. An equation for the anaerobic group was formulated, however, due to a R^2 value of 16.82 and only 6.13 percent of total variance accounted for the equation was found unacceptable. A prediction equation for the remaining groups could not be formulated because no variables were retained in the model. A further analysis revealed that the principle components needed for the stepwise regression analysis were inter-correlated resulting in contamination among the variables. Linearity could not be established on the sample subject pool, which indicates the model may be curvi-linear. In addition, no clear cut relationship could be established between amortization time and depth jump height in the present model.

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Finally, the author would like to express his appreciation to the athletes and students who contributed their time for the completion of this study.

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CHAPTER 1

Introduction

New methods and techniques are constantly sought by athletes and coaches to try to bridge the gap between strength and power. Plyometrics, a relatively new conditioning concept in this country, may offer a possible solution to this problem.

Plyometric training is designed to decrease the amortization phase of counter movement patterns, a process which involves quickly switching from overcoming work to imparting the necessary amount of acceleration in the required direction (Verhoshanski, 1966).

The two major effects of plyometrics are the storage of elastic energy and the stretch reflex mechanism. These properties are developed through jump training and plyometric drills to help improve athletic performance. The scientific basis for plyometrics is based on the principle that the faster the muscle is forced to lengthen the greater the tension it exerts. Therefore, plyometrics can be defined as an eccentric contraction followed immediately by a concentric contraction.

Plyometrics, also known as depth jumping, is traditionally performed by stepping down from a height and immediately executing a vertical rebound jump. This type of training develops strength, quicker reactions, and agility (Mann, 1981). Chu (1983) depicts plyometrics as drills or exercises that link sheer strength and speed to produce an explosive-reactive type of movement known as "power".

O'Bryant suggests (Coaches Roundtable, 1984) before beginning plyometric drills a strength base may be a necessary prerequisite (Mann, 1981). According to Henson (1980) many injuries have resulted from adding plyometric drills to existing weight training programs, subsequently, causing injury to the knee and extensor muscle groups. Intensity and lack of recovery time was indicated as the cause of the injuries. O'Bryant suggests (Coaches Roundtable, 1984) starting jump training between the hypertrophy phase and the strength-power phase and beginning plyometric drills between the strength-power phase and the power phase when employing a periodization weight training program. According to Mann (1981) the advantage that plyometrics has, that is unattainable through weight training, is the ballistic or explosive movement from the muscle in its stretched condition. The author also states that plyometric drills are not a substitute for weight training, as weight training develops muscle size, tendons, and ligaments.

A weight training program which strengthens the extensor muscle groups of the lower extremities should help prevent injuries and establish a strength base prior to plyometric training. Such lifts may include parallel squats, leg curls, calf rises, leg press, and leg extensions. Russian sport scientists suggest not to do plyometrics until parallel squats can be performed with two times the body weight (Coaches Roundtable, 1984). Weight training should be followed by jump training, bounding or leaving off one or both feet from the floor. O'Bryant has suggested (Coaches Roundtable, 1984) this type of training will also help develop strength and power through increased excitability of the neuromuscular system.

Jump training can be performed by rebounding vertically or horizontally from the floor. Plyometrics, are however, performed by stepping down from a height and immediately executing a vertical rebound jump. Some suggest jump training should begin with double leg work and progress to single leg work.

Plyometric drills should begin at a low level with single depth jumps. Training may progress with an increase in height and multiple depth jumps. Polhemus (1981) found substantial gains in the vertical jump, standing long jump, and 40 yard dash when utilizing plyometrics, with ankle and vest weights, at a depth of 18 inches, in conjunction with weight training. Scoles (1978) used a height of .75 meters when investigating the effects of depth jumping on the vertical jump and long jump. Verkhoshanski (1973) has stated that the effective improvement of reactive ability can only be achieved from a pre-determined height. Heights of 2 feet 5 and ½ inches and 3 feet and 7 and ¼ inches were recommended for training. Other heights have been suggested as the optimal elevation for maximum rebound results, however, no systematical approach to determine bench height has yet been devised. Plyometric drills may increase the excitability of the nervous system, increase jump strength, develop power, and improve the reflex speed of the muscles.

There are several reasons why plyometrics may result in an injury to the athlete. If the knee and extensor muscle groups are not conditioned adequately before beginning plyometric training the stress may be too great for the muscles to handle, therefore, a strength base may be a necessary prerequisite. Secondly, because most athletes are training from the same heights, due to the varying degrees of strength, a high bench height may be too stressful for the less conditioned athletes. And thirdly, the intensity and recovery time may not be adequate when integrating plyometrics with existing training programs.

The ability to determine the optimum bench height to train for a particular strength level may be essential to obtain the desired training effect and high level of performance in athletic events. Therefore, this variable may be the single most important determinant in establishing a scientifically sound approach to planning and implementing an individualized plyometric training program.

Statement of the Problem

A large number of injuries that occur from plyometric training may result when athletes with different strength levels and experiences are instructed to jump from the same height. The ability to determine the optimum bench height from which to train for a particular strength level is essential to develop the neuromuscular system to its greatest potential while maintaining an adequate margin of safety. To obtain the desired training effect and optimum performance this problem should be recognized and resolved.

Purpose of the Study

The primary purpose of this study was to determine the optimum bench height to train from when performing plyometric drills. A second purpose was to determine the relationship between depth jump heights and amortization time.

Hypothesis

The hypothesis of this study was that the highest vertical jump obtained from a series of six different depth jump heights can indicate the optimum height to begin training. By employing static strength measures, dynamic strength measures, and vertical jump converted to power, a regression equation will be developed to determine the optimum bench height for a particular strength and/or initial power level.

Null Hypothesis

The null hypothesis was that the maximum height obtained from a series of depth jumps will not be an indicator for the optimal bench height to train plyometrically. In addition, static strength, dynamic strength and vertical jump distance converted to power cannot be used to develop a formula to predict the optimum bench height to train for effective individualized plyometric conditioning.

Delimitations

A sample of 100 male subjects were obtained from volunteers of the intercollegiate football, baseball, track and field, and soccer teams at Appalachian State University. The intercollegiate athletes were well conditioned and participating in a weight training program. Thirty additional subjects were obtained from activity courses at ASU. These subjects did not engage in any other training except for the activity course being taken.

Limitations

The author assumed that each subject put forth a maximum effort during the depth jumping drills, static strength, dynamic strength, and vertical jump measures.

Definition of Terms

Eccentric Contraction: When external resistance overcomes the active muscle and the muscle lengthens while developing tension.

Concentric Contraction: Muscle shortens as it develops tension and overcomes the resistance.

Plyometrics: Training drills performed by stepping down from a height and immediately executing a vertical rebound jump. Plyometrics utilize eccentric contractions followed immediately by concentric contractions.

Jump Training: Training drills performed by rebounding or leaving off one or both feet vertically or horizontally from the floor.

Counter Movement: Rebound jumping pattern using force of gravity and acceleration to store elastic energy during amortization phase of muscle contraction.

Periodization: A progressive weight training program that consists of four phases: (a) Hypertrophy, high volume-low intensity, (b) Basic Strength, moderate volume-high intensity, (c) Strength-Power, low volume-very low intensity, (d) Active rest, very low volume-very low intensity (O'Bryant, 1982).

Amortization Time: Amortization time is calculated from the time the jumper contacts the landing surface, followed by the depth jump, until he rebounds from the landing surface to execute a rebound vertical jump.

CHAPTER 2

Review of Literature

Physiological Concept

The physiological concept of plyometric training involves the storage of elastic energy and the stretch reflex mechanism. The sarcomere, the site of muscle contraction, contains both series and parallel elastic components. The parallel elastic components are located between the actin and myosin filaments (Rasch and Burke, 1974). The series elastic components are located at the end of the sarcomere at the "Z" disc (Rasch and Burke, 1974). The series elastic components are thought to help act against injury and bare the resting tension of the muscle, as well as store elastic energy in the muscle. While executing a depth jump, as the individual makes contact with the landing surface, the downward movement pre-stretches the quadriceps. It appears that during eccentric contraction of the muscles, mechanical energy is stored by the series elastic components and is made available during the concentric contraction followed immediately from the stretch of the eccentric phase. The kinetic energy released helps in a synergetic fashion along with the chemically produced concentric contraction.

There are two types of receptors located in the muscles and tendons: (a) muscle spindles, which detect changes in length of the muscles and rate of change in length of muscle fibers and

(b) golgi tendon organs, which detect tension applied to the muscles during eccentric and concentric contraction. The activation of these receptors elicits a proprioceptive response, that almost instantaneously causes a shortening of the muscle to resist the stretch. The muscle spindles in the intrafusal fibers lie parallel with the skeletal muscle fibers (extrafusal fibers). The skeletal muscle fibers are innervated by alpha type motorneurons and intrafusal fibers are innervated by gamma type motorneurons. It is the central portion of the intrafusal fibers that contains the propriceptors, the muscle spindles (Guyton, 1981). The central portion is thought to contain few if any actin and myosin filaments and, therefore, does not contract when the ends do (Guyton, 1981). The contractile tissue at the ends of the intrafusal fibers are excited by the gamma motor nerve fibers. The receptor area contains either an elastic nuclear bag, where a large number of nuclei have congregated, or nuclear chain, which is about half the diameter and length of the nuclear bag, and has nuclei that are spread out in a chain fashion through the receptor area (Guyton, 1981). Stretching the whole muscle or when the gamma fibers are activated the ends of the intrafusal fibers contract and stretch the receptor portion. The primary endings, type (Ia) fibers, transmit sensory signals to the spinal cord at the velocity of 100 meters per second (Guyton, 1981). The secondary fibers innervate the receptor region of each side of the primary endings. The primary coil has a low threshold level and, therefore, is activated with very minute stretching. The secondary fibers have a higher threshold level than the primary endings and, therefore, by the time the secondary endings are activated the primary endings have already been activated. The function of the muscle spindle reflex is to inhibit the antagonist and when stimulated it will cause the contracting of the agonist to become more powerful.

Stretching puts pressure on the muscle spindles and when the muscle contracts, as it shortens, it takes pressure off the muscle spindles and puts pressure on the golgi tendons organs (Rasch and Burke, 1974). The golgi tendons lie in series with the muscle fibers and are located between the contractile components and the connective tissue. The receptors are sensitive to stretch and tension. The receptors have a high threshold level. When activated the receptors facilitate the antagonist muscles to take the pressure off of the joints and tissues (Rasch and Burke, 1974). The receptors also stimulate inhibition of the agonist muscle (Rasch and Burke, 1974).

The stretch reflex reaction time is extremely important in power related sports, such as in jumping, throwing and sprinting. Plyometric exercises and bounding drills may increase the sensory signals of the muscle spindles to the CNS with consequent increases in alpha motorneuron excitation of the skeletal muscle fibers. This may help condition the muscles to react more quickly and forcefully when put into a stretched position.

Strength Training

Previous research has indicated that performing three sets of six repetitions three times per week produces maximum strength gains (Berger, 1962; Clarke, 1973; O'Shea, 1966). Other methods, such as pyramiding and performing various sets to exhaustion have been used to produce strength gains.

In order to obtain a scientifically sound approach to training certain basic principles must be followed: intensity, frequency, duration, rate of progression and, most importantly, specificity (Edington and Edgerton, 1976; Tschiene, 1979). These four components may help prevent injury and overtraining. Most recently, a concept known as periodization (Matveyev, 1972; Tschiene, 1979) has shown to produce superior strength-power gains when compared to the above traditional methods (Stone, O'Bryant, and Garhammer, 1981). Periodization consists of four phases: (a) Hypertrophy, high volume-low intensity, (b) Basic Strength, moderate volume-high intensity, (c) Strength-Power, low volume-high intensity, (d) Active Rest, very low volume-very low intensity. O'Bryant suggests (Coaches Roundtable, 1984), when utilizing periodization, starting jump training between the hypertrophy phase and the basic strength phase and beginning plyometric drills between the basic strength and strength-power phase. By integrating the above components and through variation in intensity and volume, the concept of periodization helps produce optimal athletic performance, as well as reduce injury and prevent the possibility of overtraining.

Relationship of Dynamic and Static Strength to Anaerobic Leg Power

Instantaneous power is defined as the ability to apply maximum muscular force in the shortest possible time. Power differs from strength in that strength is measured by the muscular force exerted without reference to the rate at which the work is being done. The most common measure of power has been the vertical jump converted to power (Lewis formula) (Mathews and Fox, 1976). Therefore, the legs have predominately been used as an indicator of muscular potential and power (Clarke, 1974; Costill, 1974). Power has shown to be dependent upon the strength and velocity of the limb (Genuario and Dolgener, 1980).

Strength can be measured in two ways: (a) dynamic (isotonic) strength is where muscular tension produces work over a range of motion, and (b) static (isometric) strength is where muscular force is exerted without movement in the joints. Some investigators have found dynamic strength to be significantly related to leg power (Berger and Henderson, 1966; McClement, 1966). Berger and Harris (1966), O'Shea (1966), Wilmore (1979), and Withers (1970) have indicated the 1RM squat as the preferred measure of dynamic strength. Static strength has been found to be significantly related to leg power (Berger and Henderson, 1966; Considine and Sullivan, 1973). Other researchers have found significant low to moderate correlations between isometric and isotonic strength and power as measured by a vertical or board jump (Bangerter, 1968; Berger and Henderson, 1966; Considine, 1963; Eckert, 1974, McClement, 1966; Smith, 1961b).

Body Composition

Body composition is the relationship of body fat and fat-free weight (lean body weight) to the total weight of the body. Body fat can be estimated from skinfolds (Durnin, 1974; Sloan and Weir, 1970) or by hydrostatic weighing (Brozek, Grande, Anderson and

Keys 1963; Katch, Michael and Horvath, 1967; Wilmore and Behnke, 1967). Strauss (1979) found that low body fat is advantageous for most athletes. Cureton, Hensley, and Tiburzi (1979) found a negative relationship between optimum athletic performance and body fat. Body composition can be affected by the training frequency, intensity and duration of exercise (Mathews and Fox, 1976; Wilmore, 1975).

Plyometrics (Depth Jumps) vs. Jump Training

There is no clear distinction made in the literature between plyometrics and jump training, therefore, a more distinct separation may be warranted. As defined earlier, plyometric drills (depth jumps) are performed by stepping down from a pre-determined height, one foot leading, and landing on the contact surface with both feet, and immediately executing a maximal rebound vertical jump. Jump training, however, is performed by bounding vertically or horizontally from the floor. This writer would like to suggest, even though there are innumerable combinations employing both plyometric and jump training drills, any exercise incorporating a depth jump should be considered a plyometric drill. In addition, some have suggested that progression should begin with jump training first and then proceed to plyometric training (Mann, 1981; Wilt, 1975; Coaches Roundtable, 1984), as plyometrics creates the greatest excitability of the neuromuscular system. This writer would also like to emphasize that combinations of plyometrics and jump training may be required to produce a desired training effect, following a normal rate of progression. The possibilities for such combination drills are only limited by the individual's own creativity and imagination. It is this writer's intention to distinguish between plyometrics and jump training in the literature review.

Chu (1984) defines plyometrics as an exercise which uses force of gravity to store energy in the muscular framework of the body. Chu indicates two major components of the landing and take-off phase in depth jump drills, (a) a short or brief support time (amortization phase) on the landing surface is desired, and (b) the amount of elastic energy stored and strength-power possessed by the athlete. The support time begins from the time contact is made with the floor until the body leaves the landing surface. Chu has indicated that the shorter the amortization phase, the greater the athlete's neuromuscular reaction to the ground contact stimulus. The elastic strength the athlete possesses provides the explosive force to rebound from a surface. Chu emphasizes that the time spent in contact with the landing surface may be looked at as the neuromuscular reactivity of the athlete. Therefore, first and foremost, the amortization phase must be developed. Chu illustrated an angle box that could be used in plyometric drills to simulate landing on irregular surfaces. This type of drill imposes stress, and therefore, strength and power development which may prepare the athlete for similar stress that might occur on the playing surface. Chu does not distinguish plyometrics from jump training, but does categorize the different drills by type and specific effect desired. Chu refers to plyometric drills as "In-depth Jumps" or Box Drills" and depicts several depth jumping drills involving double and single leg work with or without multiple depth jumps. The jump training exercises were categorized under specific effects desired and several examples of each were given.

Chu (1983) described plyometric drills as exercises aimed at linking sheer strength and speed to produce an explosive-reaction type of movement often referred to as "power". Plyometrics was also defined as an exercise that involves a rapid stretching of the muscle or muscles when undergoing eccentric stress followed by a rapid concentric contraction producing a forceful movement over a short period of time. Chu indicated that since plyometric exercises are to develop the neuromuscular system, the overload principle must be applied in order to reach optimum levels of performance. Chu also noted the importance of specificity of training and concluded that the movement patterns of the desired activity should be made as close as possible when performing plyometric exercises. The two jump training exercises mentioned emphasized the importance of vertical and horizontal forces of movement in athletic events. These exercises were indicated to help improve the running stride length and frequency. Importance was also placed on the development of power from lateral movement.

Miller (1981) has cited the following studies in order to make available and relate the more important aspects of depth jumping. Depth jumping was described by Miller as an exercise which involves stepping down from a height and immediately performing a rebound vertical jump. Miller has indicated that the concepts of specificity and overload must also be applied to the development of maximum strength and elastic energy. Marey and Demeny (1885) considered the possibility of the storage of elastic energy in the muscles, and stated that when two jumps in succession are performed, the second jump is always higher than the first because of the mechanical energy stored during the falling phase of the jump. Lenz and Losch (1979) were indicated to have recommended the use of depth jumps for young throwers, and Tschiene (1973) noted that "...they (depth jumps) lend themselves to the development of specific leg activity, especially the right leg in shot putting." Verkhoshanski (1967), Virgas, (1977), Kreer (1977), Uzlov (1979) and Muthiah (1980) have advocated depth jumping as a training aid for jumpers. Verkhoshanski (1967) and Virgas (1977) were indicated to have recommended depth jumps from heights between 75 cm and 100 cm, and Uzlov and Kreer stated the maximum height to be 90 cm. Other authors have also recommended the following heights to train from when performing plyometric drills: Asumssen and Bonde-Peterson (1974) found a height of 40 cm produced the best results for rebound jumping; Kstschajov, Gomberaze and Revson (1976) constructed a special apparatus to perform depth jumps from, and found a height of 80 cm produced the best results; Komi and Bosco (1978) found an optimum height for males to be 62 cm and 50 cm for females; Dursenev and Raevsky (1978) found when jumping down from heights of 200 cm and 320 cm without rebound jumping produced optimal results, however, the researchers were forced to admit that athletes jumping from these heights did so "...without desire and sometimes under pressure from the instructor!". There are several practical aspects, as described by Miller, that should be consulted before beginning a plyometric training program: (a) to avoid undue discomfort, a padded surface, such as a gymnastic mat, should be used; and (b) hands should be kept on the hips throughout the exercise, as upward movement of the arms leads to a transfer of momentum from the arms to the whole body, consequently making the rebound jump easier. Due to the neurophysiological after-effects it has been suggested by Van Zely (1977) that a maximum of two sessions per week should be performed and that unconditioned individuals should start on a progressive basis. This author would like to note that there is disagreement with (b) above, because by keeping the hands on the hips throughout the exercise, specificity may be omitted and the author feels that the benefits gained from the specificity of training outweigh the minimum conditioning effect that may be lost performing the drill.

Mann (1981) suggests that a weight training program should precede bounding drills to develop strength and safeguard against injury. For bounding and depth jump workouts, one session per week is recommended for beginners and two sessions per week for intermediates, with running and relaxation exercises between sets. This author would like to note that there is some disagreement with running being performed between bounding and depth jump drills, as the running may be too stressful during the recovery. There was no distinction made between bounding and depth jump drills given.

Polhemus (1981) conducted a study to determine the effects of plyometric drills on the functional strength of 103 college football players. The athletes were divided into three groups:

group 1--conventional weight training; group 2--same as group 1 plus plyometric drills; group 3--same as group 2 with the addition of ankle and vest weights to the plyometric exercises. Groups 1 and 2 began the plyometric drills after completing the weight training program. Drill 1 consisted of running in place with two and one-half pound ankle weights secured to each ankle. In drill 2 the subjects jumped down from a bench height of 18 inches, while facing the bench so to explode back up onto the bench in a successive fashion. After six weeks of training, group 3 showed substantial gains over the other two groups in all three areas, 3.2 inch increase in vertical jump, 7.91 inch increase in the standing long jump, and .19 second increase in the forty yard dash. There was no distinction made between plyometrics and jumping drills.

One basic principle that must be observed to maximize the benefits of bounding and depth jumping is the implementation of a vigorous weight training program (Mann, 1981). Mann, also stated, that the weight training program should precede the bounding program to ascertain an adequate strength level to help prevent injury. Illustrations, depicted by stick figure drawings, included several bounding techniques, such as hopping vertically in place, skipping down a runway, alternating foot patterns, etc. In addition, several illustrations of plyometric drills were given, which included jumping down from a box to the ground and back to the top of the box. These exercises were performed single and double legged from boxes of different heights. Other plyometric exercises were illustrated. No distinction was made between plyometric drills and bounding drills. The author did, however, indicate a rate of progression in the drawings.

Humphrey (1980) emphasized the importance of weight training in strength development and in establishing a good strength base before beginning plyometric drills. Humphrey further states, that jump training and plyometrics may be a good way to add variety to a weight training program.

Henson (1980) stated that stress placed on the muscles by performing plyometric drills is far greater than those which occur in the more common slow concentric contractions such as heavy squats. The author also states that a large number of injuries that occur from depth jumps are a result of adding the drills to existing weight training programs, causing too much stress to the knee and extensor muscle groups as a result of the intensity and lack of recovery time. The author has also recognized the importance of too high bench heights for the less conditioned athlete. While the heights reported by the Russian sport scientists may be acceptable for the highly trained athlete, these heights may produce too much stress for the average or unconditioned individual. The author has reported using 20 inch boxes without any increase in muscle or joint injuries. As well as could be interpreted from the literature and illustrations, jump training preceded plyometric drills, however, no sequence of progression was indicated and no clear distinction was made between plyometrics and jump training.

Polhemus, Osina, Burkhardt and Patterson (1980) conducted a study to determine the effects of weight training, and weight training and plyometric training with ankle and vest weight drills on the performance of twenty-seven male track and field athletes in the vertical jump, standing long jump, and forty yard dash. Two drills were chosen for the test group. Drill 1 consisted of running in place with a two and one-half pound ankle weight secured to each ankle. After the fourth and fifth week the subjects discontinued drill 1 and started drill 2. In drill 2 the subjects performed a depth jump from a bench (the height was not indicated) wearing a weighted vest ten to twelve percent of body weight. The depth jumps were performed, while facing the bench, so that an immediate rebound back onto the bench could be performed in succession. The test group improved significantly over the control group in all areas with a three inch increase in vertical jump, a seven and one-fourth inch increase in the standing long jump,and a .33 second increase in the forty yard dash reported.

Scoles (1978) conducted a study to determine the effects of depth jumping on the vertical jump and standing long jump of college age males. Twenty-six subjects completed the program and were tested both pre and post. The subjects were divided into three groups; group 1--depth jumps, group 2--flexibility, and group 3--control. Groups 1 and 2 trained for eight weeks and the control group remained inactive. Group 1 jumped from a height of .75 meters two times per week, twenty jumps per training session. In group 1 (depth jump group) there was an increase of two centimeters per subject in the vertical jump (4.3% increase) and an increase of eight centimeters in the standing long jump (2.9% increase). Though not statistically significant, the tests did indicate greater improvement for group 1 than the other groups. Scoles indicated that the small number of subjects in each group and the inability to control the outside activity of the subjects may have imposed limitations on the study.

Polhemus and Burkhardt (1980) conducted a six week study to determine the effects of three different training regimen on performance of collegiate football players in physical strength gains in the bench press, half squat, power clean, and military press. Group 1 used a conventional weight training program and no plyometrics. Group 2 used conventional weight training plus plyometric drills without added weight. Group 3 used conventional weight training plus plyometric drills with ankle and vest weights. Plyometric drills were done after the weight program was concluded. Three drills were performed in the study. Drill 1 consisted of running in place with a 2 and ½ pound weight secured to each ankle. Group 3 performed drill 1 with weight while group 2 performed the drill, but did not use weights. Drill 2 was performed by jumping down from a bench height of 18 inches to the ground, while facing the bench, and exploding back up onto the bench in succession. Group 3 completed the drill with weighted vests and group 2 performed the drill without weighted vests. Drill 3 consisted of bounding three consective times across the floor. Group 3 performed the bounding drills with weighted vests and group 2 without weighted vests. Group 3 showed the greatest improvement in all four lifts (bench press, half squats, power clean, and military press). The author concluded that the effects of plyometric drills with ankle and vest weights greatly enhanced the strength gains from the weight training program.

Costello (1978) stated that the key to success in coaching is being able to simplify a particular event by breaking it down through a series of drills. The author depicts plyometric drills as a variety of bounding, leaping, and running exercises. Costello noted that of all the athletes he worked with, the short sprint runners exhibited the best results from the jumping drills. Depth jumps were not mentioned and all examples given consisted of jump training drills from the ground.

Wilt (1975) suggested that training should be geared to include plyometric drills in order for the muscles to develop more tension and the ability to contract more forcefully. The following considerations have been suggested in the literature when designing plyometric exercises: (a) maximum tension develops when the muscle is stretched quickly; (b) the faster a muscle is forced to lengthen the greater the tension the muscle exerts; (c) the rate of stretch is more important than the magnitude of stretch and (d) utilize the overload principle. Wilt cited various depth jumping drills for track and field events which involved bounds and hops, various numbers of sets and repetitions, double and single leg work, as well as various depth jump heights for throwers and jumpers. Depth jumps were included as an individual plyometric drill and no sequence of progression was mentioned. No distinction was made between jump training and plyometrics.

Werschoshanskij and Semjonow (1973) noted the importance of long leaps, leaps from one leg onto the other over stretches of fifty to two-hundred meters, in order to increase the work efficiency of the driving leg and result in development of starting strength in sprinters.

Verkhoshanski (1973) suggests it is best to jump straight down from a height of 2 feet 5 and ½ inches and 3 feet 7 and ¼ inches for the development of reactive abilities. Investigations by Verkhoshanski have shown that the effected improvement of reactive ability of the neuromuscular system can only be achieved from a pre-determined height. Verkhoshanski further cites, between series of depth jumps, running and relaxation exercises can be done.

Verkhoshanski (1966) stated that plyometric training is designed to decrease the amortization phase, a process which involves quickly switching from overcoming work to imparting the necessary amount of acceleration in the required direction. Verkhoshanski also indicated that the basis for depth jumping involves the following concept: as strength is developed through weight training, the development of speed is being decreased at the same time and frequently the speed of switching the muscles from yielding work to overcoming work. Therefore, it is desirable for the development of reactive ability of the neuromuscular system to have strength training conditioning for dynamic strength development corresponding to the amortization phase in depth jumps, and at the same time does not slow down the switching of the muscles to overcoming work. This author is not in full agreement with the concept that as strength is developed through weight training, the development of speed is being decreased; as weight training can develop power by increasing the velocity of the repetitions resulting in an increase in power.

O'Bryant recommended (Coaches Roundtable, 1984) when starting a jump training program that the athlete start with double leg work and progress to single leg work.

Empirical data suggest not to begin plyometric drills until parallel squats can be performed with two times the body weight (Coaches Roundtable, 1984). Russian coaches do not extend plyometric drills to individuals who have not yet reached this strength level.

Zanon (1977) stated that "...the stronger the athlete is relatively, the greater the need of optimum elevated heights of fall."

Summary

To prevent overtraining and injury it is essential to incorporate the following components in a training program; frequency, intensity, duration, and rate of progression. Basic strength development may be the first consideration when planning and implementing a training program. Exercises used to produce a desired training effect should be made to simulate the particular athletic event. When employing plyometrics and jump training, a strength base must be set first, followed by jump training then plyometric training. Periodization is the weight training model recommended for strength-power development, as this model has been shown to be superior to traditional methods and incorporates variation in intensity and volume. After a basic strength level has been reached, a progressive jump training program should be employed. Jump training can begin with jumping over a relatively low object, such as a mat. Five to six mats should be the maximum used at the beginning. Beginning with double leg work, the horizontal distance and vertical height should be increased on a progressive basis. Starting back with the original sequence single leg work can be performed in the same progressive manner.

Leg trauma may be experienced by the heavier athletes as a result of the tremendous forces created by the body as contact is made with the landing surface. Jump training with dumbbells from the floor may be a suggested alternative for the heavier athletes. There are four basic techniques that can be used: (a) rebound dumbbell jumps; (b) rebound release dumbbell jumps (jump and drop dumbbells); (c) static dumbbell jumps (start with thighs held parallel to the floor); (d) static release dumbbell jumps (thighs parallel to the floor, hold, jump and drop dumbbells). These techniques should help lessen the trauma and further injury. Jump training should always be done on a padded surface with properly supportive footwear. After having gone through a series of this type of training the athlete may then use plyometrics to a better advantage.

Without adequate preparatory conditioning plyometric training may create a potential for injury to the hips, knees and ankles resulting in muscle sprain or shin splints. Therefore, the following basic principles that should be utilized when performing plyometric drills include: (a) development of a good strength base before beginning an extensive training regimen; (b) alternate days of training (never perform drills two days in succession); (c) double leg work first then single leg work; (d) progressive resistance should be employed, but it should be emphasized that speed may be more improtant than the resistance; (e) the intensity, volume, and frequency depends on the strength level and experience of the athlete; (f) the volume of depth jumps should not be too great; (g) in order to develop the neuromuscular system each jump should be performed to a maximum; (h) between sets the athlete should perform some stretching and flexibility exercises, or relaxation techniques; (i) allow ten to fifteen minutes of rest between sets of exercises; (j) never exceed six to ten sets of eight to ten repetitions; and (k) depth jumps should be discontinued twelve to fifteen days before competition.

CHAPTER 3

Research Procedures

Overview

Previous research indicates that plyometrics may increase the excitability of the nervous system, develop power, and improve the reflex speed of the muscles. It has been suggested that these parameters can only be effectively achieved from a pre-determined height while performing plyometric drills. Various depth jump heights have been reported to produce significant gains in strength and power, however no systematic approach to determine the optimal bench height has yet been devised. The primary purpose of this study was to determine the optimum bench height to train from when performing plyometric drills. A second purpose was to determine the relationship between depth jump heights and respective amortization times.

Selection of Subjects

A sample of 100 male subjects were obtained from volunteers of the intercollegiate football, baseball, track and field, and soccer teams at Appalachian State University. The intercollegiate athletes are well conditioned and participating in a weight training program. Thirty additional volunteers were obtained from activity courses at Appalachian State University. These subjects were not engaged in any other training except the activity course being taken. Table 1 contains biographical data on the subjects in the study.

The subjects were divided into three groups; (1) untrained group (G1) which consisted of 30 unconditioned students obtained from physical education activity courses, (2) intermediate group (G2) which consisted of 30 moderately aerobic/anaerobically trained varsity athletes, and (3) anaerobic group (G3) which consisted of 70 highly anaerobically trained intercollegiate football players.

Testing Equipment

A stainless steel adjustable bench was used to accurately obtain depth jump heights. The bench was extremely stable and was supported by a base 16 inches wide and 36 inches long. The upper platform is adjustable in 1 inch increments from 10 through 30 inches in height.

A Health-O-Meter bar balance medical scale was used to measure body weight to the nearest one-half pound. Other equipment includes a parallel squat rack and a 7 foot olympic bar with various weights to test for dynamic strength. A leg dynamometer was used to test for static strength as described by Matthew (1973). A standard goniometer was needed to determine the angle for isometric knee extension (Skhar MFG Co.). A smooth vertical surface marked off in centimeters, 200 cm above the standing surface was needed to test for vertical jump height. Harpenden skin fold calipers were used to assess percent fat. The following sites were used: tricep, pectoralis, and abdominal (Brozek and Keys, 1951).

A switchmat interfaced with a Commodore Model 4032 microcomputer was utilized to record the amortization time of the different depth jumps. Access to the user port of the

Table 1

Mean Height, Weight, % Fat, and Age of the Three Groups Tested

Group	N	Height (ft) ±SD	Weight (lbs) ±SD	% Fat (mm) ±SD	Age Years ±SD
Unconditioned	30	5.58	168.8	9.7	20.1
		±0.227	32.3	3.9	1.42
Intermediate	30	5.95	178.3	7.7	19.6
		±0.217	18.1	3.72	1.16
Anaerobic	70	6.04	207.1	9.6	19.0
		±0.207	28.4	3.9	0.884

microcomputer was accomplished with a customized 22 pin circuit board through an analog to digital converter. Amortization time was calculated by the computer from the time the subject contacted the switchmat, following a depth jump, until he rebounded from the mat to execute a vertical jump. The relationship between the contact time on the mat in seconds and the vertical jump converted to power was analyzed statistically by the Pearson Product Moment Method of Correlation.

Testing Procedure

Anaerobic Leg Power. Power was determined by using the Sargent Chalk Jump Test for vertical jump (VJ) (Johnson and Nelson, 1979) and the Lewis Formula: $\sqrt{4.9}$ x BWT(kg) x $\sqrt{\text{VJ(m)}}$ (Mathews and Fox, 1976). A rebound and static vertical jump was performed. The starting position for the static vertical jump began with the legs held parallel to the floor. The subjects were instructed to hold this position for approximately three seconds, and without any hip flexion execute a vertical jump. All VJ measurements were taken in centimeters and body weight in pounds and later converted to meters and kilograms for subsequent calculations. The standing vertical reach of the subject was measured for each individual who, standing to one side with the dominant hand, reached as high as possible keeping both heels on the floor. To make the jumps as sport specific as possible, unrestricted use of the arms was permitted. Knee flexion was not controlled. The subjects were given one practice and three trial jumps. The best of the three jumps was recorded. The rebound vertical jumps were performed immediately before the first three depth jumps and the static vertical jumps were performed immediately before the second three depth jumps on an alternate day.

Depth Jumps. Depth jumps were performed from six different heights; 10 inches, 14 inches, 18 inches, 22 inches, 26 inches and 30 inches. The subjects were given a brief explanation and demonstration of how to perform the jumps. The jumps were executed by standing on the adjustable bench with the ball of the foot pivoting on the edge of the platform. The subject then stepped off the bench, one foot leading, onto a switchmat positioned twelve inches in front of the bench, landed on both feet and immediately executed a maximal rebound vertical jump. Three attempts were made from each height and the average of the three jumps was recorded. Performance of the heights were counter balanced to help avoid any learning effect and negate fatigue that may result from the repetitive jumping. Three depth jumps from three depth jump heights were performed on one day, following a day of recovery, three depth jumps from three different depth jump heights were performed.

Static Strength. Studies have shown static strength to be significantly related to leg power (Berger and Henderson, 1966; Considine and Sullivan, 1973). The leg dynamometer was used to determine leg power as described by Matthew (1973). Angle of knee flexion was determined with a standard goniometer adjusted to 120 degrees (Clarke, 1950). Each subject executed two maximal efforts on the leg dynamometer and the best score was recorded. The leg dynometer was performed after all jumping preceding the first depth jump drill, or during weighing and body fat assessment on a day that depth jumps were not being performed.

Dynamic Strength. Studies have found dynamic strength to be related to leg power (Berger and Henderson, 1966; McClements, 1966). Measures for dynamic leg and hip strength were determined by a 1RM squat where the bottom of the thighs were parallel with the floor. A 1RM squat has been the preferred measure for dynamic leg and hip strength (Berger and Harris, 1966; O'Shea, 1966; Wilmore, 1977-79; Withers, 1970). Each subject was given instructions and a demonstration on the proper execution of a 1RM parallel squat. In order to illicit a maximum effort and stabilize the neuromuscular system each subject warmed up by performing one set of five to eight repetitions with a light weight followed by two to three sets of one repetition with increasing heavier weights prior to the 1RM attempt. Rest intervals between lifts varied according to each subjects perceived readiness before attempting a heavier lift or 1RM. The 1RM parallel squat was executed after all the depth jump drills were completed or before beginning the depth jump drills.

Statistical Procedures

Each subject was tested by rebound and static vertical jumps (converted to power), 1RM parallel squat (dynamic strength), leg dynamometer (static strength), and six different depth jump heights. The data gathered from the depth jumps, dynamic strength measure, static strength measure, and vertical jumps converted to power were statistically analyzed by a stepwise regression statistical procedure. This analysis was used to statistically determine which independent variables were strong predictors in determining the optimal bench height to train from related to strength and/or initial power level via the formation of a regression equation. Pearson r correlation was utilized to determine the relationship between the different depth jump heights and the amortization time. The alpha level for both statistical procedures was preset at 0.05.

CHAPTER 4

Presentation and Analysis of Data

A forward stepwise regression analysis was used to formulate an equation to determine the optimum bench height for a particular strength and/or initial power level. With an established alpha level of $p \leq 0.05$ no variables were retained in the model for the combined (Gen), untrained (G1), and intermediate group (G2). An equation for the anaerobic group (G3) was formulated. For each group the following 17 independent variables were regressed on the mean optimum bench height (MEOBHO; BWT (total body weight), % Fat (percent body fat), RVJ (rebound vertical jump), SVJ (static vertical jump), SQT (1RM parallel squat), LEGDYN (leg dynamometer), RPI (rebound power index), SPI (static power index), LBW (lean body weight), RDS (relative dynamic strength or SQT/BWT), RSS (relative static strength or LEGDYN/BWT), RDS (relative dynamic strength or LBW-LEGDYN/LBW), RSPIL (relative static power index or LBW-SPI/LBW). RELRPI (relative rebound power index or RPI/BWT), and RELSPI (relative static power index or SPI/BWT).

SPI and SQT were the only variables retained in the model for the formation of the prediction equation in (G1). The regression equation was:

$$Y = 50.29 - 49(RPI/LBW) + 6.8(SQT/BWT)$$

However, only 6.13 percent of the total variation was accounted for with an R^2 of 16.82 thus rendering the equation unacceptable.

A factor analysis was used to determine the principle components needed for the stepwise regression analysis. However, due to the inter-correlations and contamination among variables, the factor analysis revealed that any further attempt would be of no statistical value. Among the variables measured on the present subject pool, linearity, could not be established, which indicated a contradictory model than previously speculated in the literature review.

Correlations Among Variables

Correlations were used to determine the relationship between the independent variables and the optimum bench height and amortization time. At an alpha level of $P \leq 0.05$, a correlation of $r=.174$ was needed to be statistically significant. The degree of strength among the variables can be determined from the correlation matrix in Table 2. Correlation matrices for (Gen), (G1) and (G2) are in Appendix A.

Cumulative Proportion of Total Variance

The variance explained by each factor is the eigenvalue for that factor. Total variance is defined as the sum of the diagonal elements of the correlation matrix. The explained variance is in Table 3. The variance explained for the (Gen), (G1), and (G2) are in Appendix B.

Rotated Factor Loadings (Patterns)

The VP for each factor is the sum of the squares of the elements of the column of the factor pattern matrix corresponding to that factor. When the rotation is orthogonal, the VP is the

Table 2

Correlation Matrix for the Anaerobic Group

		BWT 1	%FAT 2	RVJ 3	SVJ 4	SQT 5	LEGDYN 6	MEOBH 7	MEAT 8	RPI 9	SPI 10	MAXAT 11	MAXOBH 12
BWT	1	1.000											
%FAT	2	0.560	1.000										
RVJ	3	-0.134	-0.582	1.000									
SVJ	4	-0.183	-0.568	0.932	1.000								
SQT	5	0.446	-0.070	0.377	0.358	1.000							
LEGDYN	6	0.306	-0.094	0.295	0.266	0.375	1.000						
MEOBH	7	-0.200	-0.134	-0.170	-0.159	0.022	-0.132	1.000					
MEAT	8	0.348	0.304	-0.194	-0.183	0.115	0.085	0.082	1.000				
RPI	9	0.874	0.245	0.338	0.272	0.603	0.432	-0.275	0.230	1.000			
SPI	10	0.872	0.256	0.316	0.314	0.600	0.423	-0.279	0.234	0.983	1.000		
MAXAT	11	0.350	0.287	-0.004	-0.026	0.131	0.315	-0.108	0.650	0.374	0.317	1.000	
MAXOBH	12	-0.262	-0.259	-0.007	-0.024	-0.033	-0.125	0.586	0.051	-0.255	-0.268	-0.004	1.000
LBW	14	0.945	0.263	0.037	-0.003	0.547	0.391	-0.169	0.283	0.919	0.911	0.293	-0.198
RDS	15	-0.356	-0.510	0.525	0.534	0.669	0.125	0.179	-0.156	-0.092	-0.091	-0.147	0.173
RSS	16	-0.391	-0.456	0.396	0.391	0.040	0.751	0.004	-0.166	-0.184	-0.189	0.061	0.056
RDSL	17	-0.240	-0.281	0.412	0.426	0.725	0.105	0.162	-0.092	-0.037	-0.033	-0.087	0.117
RSSL	18	-0.296	-0.261	0.288	0.288	0.020	0.791	-0.030	-0.108	-0.147	-0.149	0.136	-0.002
RSPIL	19	0.214	0.064	0.695	0.777	0.373	0.252	-0.306	0.005	0.533	0.592	0.185	-0.236
RRPIL	20	0.238	0.045	0.782	0.707	0.403	0.286	-0.313	-0.010	0.606	0.584	0.207	-0.212
RELRPI	21	-0.160	-0.586	0.997	0.928	0.370	0.290	-0.165	-0.200	0.335	0.310	-0.010	-0.006

LBW	14	1.000							
RDS	15	-0.219	1.000						
RSS	16	-0.281	0.357	1.000					
RDSL	17	-0.172	0.968	0.260	1.000				
RSSL	18	-0.246	0.261	0.978	0.208	1.000			
RSPIL	19	0.211	0.243	0.120	0.284	0.141	1.000		
RRPIL	20	0.247	0.248	0.133	0.284	0.148	0.902	1.000	
RELRPI	21	0.032	0.523	0.395	0.409	0.286	0.690	0.782	1.000

$P \leq 0.05$ .174
$P \leq 0.01$ .288

OBH - Optimum Bench Height
AT - Amortization Time
MEOBH - Mean Optimum Bench Height
MEAT - Mean Amortization Time

Guide for Interpretation of Correlation Coefficients

(Johnson and Nelson, 1979)

r = .00 (no relationship)
r = ± .01 to ± .02 (low relationship)
r = ± .02 to ± .50 (slight to fair relationship)
r = ± .50 to ± .70 (substantial relationship)
r = ± .70 to ± .99 (high relationship)
r = ± 1.00 (perfect relationship)

Table 3

Cumulative Proportion of Total Variance for the Anaerobic Group

Factor	Variance Explained	Cumulative Proportion of Total Variance
1	6.387893	0.304185
2	5.300721	0.559934
3	2.298979	0.669409
4	2.082209	0.768562
5	1.533920	0.841606
6	1.323664	0.904637
7	0.774382	0.941513
8	0.459445	0.963391
9	0.295825	0.977478
10	0.256444	0.989690
11	0.191664	0.998816
12	0.007386	0.999168
13	0.006751	0.999490
14	0.003602	0.999661
15	0.003307	0.999819
16	0.001675	0.999898
17	0.000919	0.999942
18	0.000597	0.999971
19	0.000325	0.999986
20	0.000202	0.999996
21	0.000092	1.000000

variance explained by the factor. An asterisk (*) will denote the clean load patterns which can be found in Table 4. The Rotated factor loadings for the (Gen), (G1), and (G2) are in Appendix C.

ANOVA Comparison Among Variables

ANOVA was used to determine if a significant difference exists between SQT, LBW, BWT, and LEGDYN among the good and poor jumpers. ANOVA table for SQT, LBW, BWT, and LEGDYN are in Appendix F.

ANOVA was used to determine if a significant difference exists between RVJ, SVJ, RPI, and SPI among the good and poor jumpers. Table for RVJ, SVJ, RPI, and SPI are in Appendix E.

ANOVA was used to determine if a significant difference exists between MAXOBH among good and poor jumpers. ANOVA table for MAXOBH can be seen in Appendix G.

Means and Standard Deviations for Each Group

Basic statistics for (G1), (G2), (G3), and (Gen) are in Appendix D.

Table 4

Rotated Factor Loadings (Patterns) for the Anaerobic Group

		Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6
BWT	1	-0.138	0.904*	-0.011	-0.031	0.288	-0.230
%FAT	2	-0.431	0.200	-0.282	-0.057	0.508	-0.499
RVJ	3	0.939*	0.067	0.193	0.164	-0.147	0.062
SVJ	4	0.925*	0.020	0.174	0.186	-0.133	0.034
SQT	5	0.209	0.568	0.067	0.784	0.040	0.043
LEGDYN	6	0.119	0.397	0.888*	0.086	0.137	-0.081
MEOBH	7	-0.219	-0.099	-0.052	0.173	0.047	0.072
MEAT	8	-0.103	0.194	-0.059	-0.036	0.801*	0.181
RPI	9	0.324	0.896*	-0.014	0.042	0.194	-0.188
SPI	10	0.330	0.885*	-0.025	0.048	0.201	-0.208
MAXAT	11	0.072	0.169	0.190	-0.068	0.855*	-0.005
MAXOBH	12	-0.010	-0.167	-0.037	0.047	0.114	0.822*
LBW	14	-0.009	0.976*	-0.020	-0.012	0.135	-0.066
RDS	15	0.347	-0.166	0.146	0.852*	-0.175	0.213
RSS	16	0.221	-0.245	0.931*	0.095	-0.069	0.061
RDSL	17	0.257	-0.130	0.074	0.936*	-0.056	0.093
RSSL	18	0.135	0.223	0.946*	0.083	0.045	-0.052
RSPIL	19	0.805*	0.192	-0.007	0.159	0.217	-0.341
RRPIL	20	0.828*	0.236	0.017	0.149	0.202	-0.308
RELRPI	21	0.939*	0.062	0.919	0.160	-0.152	0.064
	VP	4.752	4.696	2.839	2.632	2.096	1.983

CHAPTER 5

Summary, Findings, Discussion, Conclusions and Recommendations

Summary

The purpose of this study was to formulate a prediction equation to determine the optimum bench height for individualized plyometric conditioning. One hundred thirty male subjects from Appalachian State University, Boone, North Carolina participated in the study. The subjects were divided into three groups. The untrained group (G1) consisted of 30 unconditioned subjects who were obtained from activity courses at ASU and not involved in a rigorous training regime. The intermediate group (G2) consisted of 30 moderately aerobic/anaerobically trained varsity soccer, basketball, baseball, track, and wrestling athletes. Due to the level of training and conditioning at the time of testing these athletes were placed in an intermediate grouping. The anaerobic group (G3) consisted of 70 highly anaerobically trained intercollegiate football players.

Each subject performed a 1RM parallel squat, a static hip and knee test using a leg dynamometer, a rebound and static vertical jump, and body weight was taken and body composition was determined by skin fold calipers. Anaerobic leg power was determined by using the Lewis Power Index. In addition, each subject performed depth jumps from six different depth jump heights (10, 14, 18, 22, 26, and 30 inches) and the respective amortization time was recorded.

In addition, to the individual group analysis, all three groups were combined (Gen) in order to generate a general equation for determining optimum bench height (OBH). Therefore, the four predication equations include athletes who are well trained anaerobically, athletes who are well trained in sports that require a high percentage of both anaerobic and anaerobic conditioning, such as middle distance runners, and unconditioned individuals or untrained athletes.

Findings

The findings of this study to formulate a predication equation to determine optimum bench height for individualized plyometric conditioning were as follows:

1. The prediction of $Y = 50.29 - 49(RPI/LBW) + 6.8(SQT/BWT)$ for (G3) was not acceptable for predicting OBH. Only 6.13 percent of the total variance was accounted for and a R-SQ of 16.82 allows for error 82.12 percent of the time.

2. A prediction equation for (Gen), (G1), and (G2) could not be formulated because no variables were retained in the models at the established alpha of $P \leq .05$.

3. A factor analysis revealed that the principle components needed for the stepwise regression analysis were inter-correlated resulting in contamination among the variables.

4. Linearity could not be established on the sample subject pool, which indicates the model may be curvi-linear.

5. Substantial relationship exists between RPI and SQT in (G3). High relationship exists between RPI and BWT, SQT in (Gen).

Substantial relationship exists between RPI and RVJ, LEGDYN, in (Gen).

6. Substantial relationship exists between SPI and SQT in (G3). High relationship exists between SPI and SQT, LEGDYN in (G1). High relationship exists between SPI and SQT in (Gen).

7. Substantial relationship exists between LBW and SQT, RPI, SPI in (G3). High relationship exists between LBW and RPI, SPI, in (G2). High relationship between LBW and SQT, SPI, in (G1). Substantial relationship exists between LBW and LEGDYN in (G1). High relationship exists between LBW and SQT, RPI, SPI in (Gen).

8. Substantial relationship exists between RDS and % Fat, RVJ, SVJ, in (G3). Substantial relationship exists between RDS and RVJ, SVJ, in (Gen.)

9. High relationship exists between SQT and BWT in (G1). Substantial relationship exists between SQT and BWT, RVJ, SVJ, in (Gen).

10. Substantial relationship exists between RDS and % Fat, LEGDYN in (G1). High relationship exists between RDS and SQT in (G1).

11. High relationship exists between RSPIL and BWT, SQT, in (G1). Substantial relationship exists between RSPIL and BWT, SQT, LBW in (Gen).

12. Substantial relationship exists between LEGDYN and BWT in (Gen).

13. Substantial relationship exists between RRPIL and SQT, BWT, LBW, in (Gen).

14. Substantial relationship exists between RELSPI and SQT in (Gen).

15. Substantial relationship exists between RELRPI and SQT in (Gen).

16. Poor jumpers performed better than the good jumpers at higher bench heights.

Discussion

In the present study analysis of data indicated that there was not a linear relationship among the variables measured on the present subject pool. The hypothesis that the highest vertical jump obtained from a series of six different depth jump heights could be used to determine from static strength measures, dynamic strength measures, vertical jump converted to power, percent body fat, and/or a ratio of the variables to formulate a prediction equation to determine optimum bench height when performing plyometric drills was rejected. The non-linearity among the variables in the present subject pool indicated a model contradictory to the literature review, however, moderate to high correlations exist among some variables and suggest some of the components in the model may be important determinants in establishing optimum bench height.

The two variables retained in the regression equation for (G3) were significant at the $P \leq 0.01$ level. A correlation of $r = 0.919$ exists between RPI and LBW. The velocity of limb movement may be enhanced by increasing the force at which a muscle contracts. Therefore, the speed of movement may be accomplished by general strengthening of the appropriate muscles. With an increase in maximum strength through resistive training, power output and general performance may also increase. Vertical jump converted to power by the Lewis Formula has shown a significant increase in power and limb velocity accompanying an increase in strength in the leg and hip extensor muscles. This is in agreement with Mann (1981), Humphrey (1980), empircal data reported by Miller (1981), and O'Bryant's summation (Coaches Roundtable, 1984) that a strength base may be a necessary prerequisite for plyometric conditioning. A similar correlation of r = .919 exists between SPI and LBW and is in agreement with the above findings. The relationship between RPI/SPI and LBW further suggests that an athlete with a greater muscle mass has a greater potential for power. This result agrees with the findings of Cureton, Hensley, and Tiburzi (1979). Therefore, in athletes in equal body weight, but different amounts of active tissue, a measure for force producing potential may be expressed as strength normalized for differences in lean body mass. Consequently, it was not surprising in (G3) to see a substantial relationship of r = 0.547 between LBW and SQT. There are similar correlations between LBW and RVJ (r = 0.525) and SVJ (r = 0.603) and SPI (r = 0.600) further suggesting that a strength base should be achieved for beginning plyometric drills. These findings are in agreement with Berger and Henderson (1966) and McClement (1966) that dynamic strength is significantly related to leg power and Berger and Henderson (1966) and Considine and Sullivan (1973) that static strength is related to leg power.

In order to establish some common trends among the good and poor jumpers the following questions were asked: (a) Do the better jumpers have more LBW, BWT, higher SQT and LEGDYN?; (b) What relationship exists between RVJ, SVJ, RPI, and SPI among the good and poor jumpers? and (c) At what MAXOBH do the better jumpers tend to perform? One standard deviation above and below the mean for RVJ was used to qualify a good and poor jumper. The mean and standard deviation were obtained from the (Gen) factor analysis: mean RVJ was 61.3cm with a standard deviation of ±9.85cm. Therefore, the better jumpers performed RVJ of 71.5cm or higher and the poor jumpers performed RVJ of 51.5cm or lower.

Analysis of Variance was used to determine if a significant difference exists between SQT, LBW, BWT, and LEGDYN among the good and poor jumpers. The better jumpers had greater measures for each variable and was statistically significance at P 0.05 level. When comparing RVJ, SVJ, RPI and SPI among the good and poor jumpers a statistical difference was also found at the P 0.05 level. Conversely, the poor jumpers performed better than the good jumpers at higher bench heights. O'Bryant suggests (Coaches Roundtable, 1984) due to the good jumpers being heavier it may be harder for them to decelerate from the higher bench heights. Joint trauma and undue stress placed upon the connective tissue during deceleration of plyometric drills may be experienced by heavier jumpers, therefore the heavier jumper may want to avoid high bench heights. Jump training with dumbbells from the floor may be an effective alternative for the heavier jumper. Suggested drills include: (a) dumbbell jumps using counter movement; (b) dumbbell jumps using static starts; (c) dumbbell jumps using counter movement and dropping weight as the floor is cleared; (d) dumbbell jumps using static starts and dropping weight as the floor is cleared; and (e) squat jumps with weights. As stated by O'Bryant (Coaches Roundtable, 1984) these weight drills incorporate speed work with less emphasis on deceleration and more emphasis on acceleration of jumping mechanics (Coaches Roundtable, 1984).

The analysis of data in this study suggests that total body weight may be an important determinant for individualized plyometric conditioning. The heavier jumper may want to avoid high bench heights to prevent potential injury. The poor jumpers, which are lighter and possess less strength than the good jumpers, may also want to avoid high bench heights even though they are able to decelerate and overcome work quicker because they may not have an adequate strength base to prevent injury at the higher bench heights. Therefore, a strength base should be considered a necessary prerequisite for plyometric conditioning. Stronger muscles protect the joints they cross, reducing the potential for injury. Furthermore, since strength training increases the skeletal muscle force output as well as increases the strength of the tendons and ligaments, a superior resistive training program such as periodization (O'Bryant, 1982) is recommended to increase the strength of the extensor muscles and joints of the knee and hip before beginning plyometric training.

Stated earlier a secondary purpose was to establish a relationship between amortization time and depth jump height. No clear cut relationship was obtained in this model, therefore, the hypothesis was also rejected. A future recommendation would be to separate the reactive switch and active take-off phases of total amortization time. This relationship may be important in establishing optimum bench height for individualized plyometric conditioning. Garhammer and Gregor (1979) found good jumpers (74 cm) to have a greater total amortization time than poor jumpers (43 cm) and greater force and velocity during the active take-off phase when using Kistler force plates to analyze vertical force-time data obtained from 4 Olympic weight lifters and 9 athletes executing standing vertical jumps. This type of analysis may help establish why the poor jumpers (51.5 cm) performed better from higher bench heights than the good jumpers (71.5 cm) in the present study.

Conclusions

Within the limits of this study and among the variables measured on the subject pool tested, the following conclusions were:

1. An acceptable prediction equation for determining OBH could not be established with the present model using a linear analysis.
2. No relationship could be established between amortization time and depth jump height with the present model.
3. Due to substantial high correlations among the independent variables some may be important considerations for plyometric conditioning.

Recommendations

Due to the relationship of the variables to the simple sampling population the model may be curvi-linear. Thus a non-linear regression analysis may be appropriate for a model of this type. In addition, to establish a relationship between amortization time and depth jump height, obtaining knee velocity and range of flexion during the eccentric and concentric phase of the depth jump should separate the reactive switch and active take-off phases of total amortization time. This relationship may be an important determinant for predicting optimal bench height.

REFERENCES

Bangerter, B. L. (1968). Contributive componetns in the vertical jump. Research Quarterly, 39, 432-436.

Berger, R. A. (1962). Effects of varied weight training programs on strength. Research Quarterly, 33(2), 168-81.

Berger, R. A. & Harris, M. W. (1966). Effect of various reptetive rates in weight trianing on improvement in strength and endurance. Journal of Association for Physical and Mental Rehabilitation, 20, 205.

Berger, R. A. & Henderson, J. E. (1966). Relationship of power to static and dynamic strength. Research Quarterly, 37, 9-13.

Brozek, J. and Keys, A. (1951). The evaluation of leanness, fatness in man; norms and interrelationships. British Journal of Nutrition, 5, 194-206.

Chu, D. (1984). Plyometric exercises. NSCA Journal, 5, 56-59, 61-63.

Chu, D. (1983). Plyometrics: The link between strength and speed. NSCA Journal, 5, 20-21.

Clarke, D. H. (1973). Adaptations in strength and muscular endurance resulting from exercise. Exercise and Sport Sciences Reviews, 1, 73-102.

Clarke, H. H. (1978). Muscular power of the legs. Physical Fitness Research Digest, (8, Serial No. 2).

Clarke, H. H., E. C. Elkins, G. M. Martin and K. G. Walkim. (1950). Application of muscular power to movement of the joint. Arch. Phys. Med. Rehabil. 31:81-89.

Coaches Roundtable. (1984). Improving jumping ability. NCSA Journal, 6, 10-20.

Considine, W. J. & Sullivan. (1973). Relationship of selected tests of leg strength and leg power on college men. Research Quarterly, 44, 404-416.

Costello, F. (1978). Drills, weight training, flexibility, and plyometrics--for sprinters and hurdlers. Track & Field Quarterly, 60-61.

Costill, D. (1974). Championship material. Runner's World, 9, 26-27.

Eckert, H. M. (1964). Linear relationships of isometric strength to propulsive force, angular velocity, and angular acceleration in the standing broad jump. Research Quarterly, 35, 298-306.

Edington, N. & Edgerton, V. R. (1976). The Biology of Physical Activity. Boston: Houghton Mifflin Co.

Garhammer, J., Gregor, R. J. (1979). Force plate evaluations of weightlifting and vertical jumping (abstract). Medicine and Science in Sports 11(1):106.

Genuario, S. E. & Dolgener, F. A. (1980). The relationship of isokinetic torque at two speeds to the vertical jump. Research Quarterly, 51, 593-598.

Guyton, A. C. (1981). Textbook of Medical Physiology (6th ed.) Philadelphia: W. B. Sanders.

Henson, P. L. (1980, Winter). Depth jumping with box drills. Track & Field Quarterly Review, 80, 56-57.

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

Johnson, B. L. & Nelson, J. K. (1979). Practical Measurments for Evaluation in Physical Education (3rd ed.). Minnesota: Burgess Publishing Company.

Mann, R. (1981). A plyometric progression to meet the athlete's needs. Women Scene, 6, 51-52, 55.

Mann, R. (1981, Winter). Ploymetrics. Track & Field Quarterly Review, 81, 55-57.

Mathews, D. K. (1973). Measurements in Physical Education. (4th ed.). Philadelphia: W. B. Sanders.

Mathews, D. K. & Fox, E. L. (1976). The Physiological Basis of Physical Education and Athletes (2nd ed.). Philadelphia: W. B. Saunders.

Matveyev, L. P. (1972). Periodisienang dos sportlichen training (translated into German by P. Tschience with a chapter by A. Kruger). Berlin, Beles and Wernitz.

McClements, L. E. (1966). Power relative to strength of legs and thigh muscles. Research Quarterly, 37, 71-78.

Miller, B. P. & Power, S. (1981, Winter). Developing power in athletics through the process of depth jumping. Track & Field Quarterly Review, 81, 52-54.

O'Bryant, H. S. Periodization: A Hypothetical Model for Strength and Power, Doctorial Dissertation, School of Health, Physical Education, Recreation and Dance, Louisiana State University, 1982.

O'Shea, P. (1966). Effects of selected weight training programs on the development of strength and muscle hypertrophy. Research Quarterly, 37, 95-102.

Polhemus, R. (1981, November). Ploymetric training for the improvement of athletic ability. Scholastic Coach, 51, 68-69.

Polhemus, R. & Burkhardt, E. (1980). The effects of plyometric training drills on the physical strength gains of collegiate football players. NSCA Journal, 2, 14-17.

Polhemus, R., Osina, M., Burkhardt, E., & Patterson, M. (1980, February). The effect of plyometric training with ankle and vest weights on onventinal weight training programs for men. Texas Coach, 80, 16-17.

Rasch, P. J., Burke, R. K. (1974). Kinesiology and Applied Anatomy (5th ed.). Philadelphia: Lea and Febiger.

Scoles, G. (1978). Depth jumping: Does it really work? The Atheletic Journal, 48-50.

Skhar, J. MFG Co. Long Island City, N.Y.

Smith, L. E. (1961). Relationship between explosive leg strength and performance in vertical jump. Research Quarterly, 32, 405-408.

Stone, M. H., O'Bryant, H., & Garhammer, J. (1981). A hypothetical model for strength training. Journal of Sports Medicine and Physical Fitness, 21, 342-351.

Tschiene, P. (1979, July). The distinction of training structure in different stages of athlete's preparation. Paper presented at the "International Congress of Sports Sciences." Edmonton, Alberta: Canada, 25-29.

Verkhoshanski, J. (1973). Depth jumping in the training of jumpers. Track Technique, 51, 1618-19.

Verkhoshanski, J. (1966). Perspectives in the improvement of speed-strength preparation of jumpers. Track and Field, 9, 11-12, 28-34.

Werschoshanskij, J. & Semjonow, W. (1973). Strength training for sprinters. _Athletic Coach_, 5-9.

Wilmore, J. H. (1977). _Athletic Training and Physical Fitness: Physiological Principles and Practices of the Conditioning Process_. Boston: Allyn and Bacon, Inc.

Wilmore, J. H. & Bergfeld, J. A. (1979). A comparison of sports: Physiological and medical aspects. In R. H. Strauss (ed.)., _Sports Medicine and Physiology_. W. B. Saunders Company.

Wilt, F. (1975). Plyometrics: What it is--How it works. _The Athletic Journal_, _76_, 89-90.

Withers, R. T. (1970). Effect of varied weight-training loads on the strength of university freshmen. _Research Quarterly_, _41_, 110.

Zanon, S. (1977). _Athletic Coach_, _11_, 14-20.

APPENDIX A

Correlation Matrices for Prediction Variables

Table 5

Correlation Matrix for the General Group

		BWT 1	%FAT 2	RVJ 3	SVJ 4	SQT 5	LEDYN 6	MEOBH 7	MEAT 8	RPI 9	SPI 10	MAXAT 11	MAXOBH 12
BWT	1	1.000											
%FAT	2	0.574	1.000										
RVJ	3	0.246	-0.272	1.000									
SVJ	4	0.228	-0.282	0.935	1.000								
SQT	5	0.665	0.212	0.548	0.546	1.000							
LEGDYN	6	0.535	0.143	0.372	0.339	0.619	1.000						
MEOBH	7	-0.116	-0.132	-0.081	-0.063	0.031	-0.005	1.000					
MEAT	8	0.303	0.211	0.024	0.033	0.173	0.102	0.003	1.000				
RPI	9	0.922	0.357	0.597	0.555	0.785	0.588	-0.131	0.262	1.000			
SPI	10	0.905	0.329	0.595	0.607	0.784	0.575	-0.119	0.063	0.984	1.000		
MAXAT	11	0.343	0.202	0.191	0.214	0.256	0.196	-0.145	0.655	0.355	0.361	1.000	
MAXOBH	12	-0.059	-0.097	0.033	0.025	0.063	0.015	0.555	0.042	-0.042	-0.035	0.040	1.000
LBW	14	0.954	0.305	0.386	0.368	0.728	0.575	-0.081	0.272	0.942	0.932	0.325	-0.025
RDS	15	0.024	-0.022	0.516	0.542	0.733	0.354	0.142	-0.047	0.220	0.238	0.050	0.145
RSS	16	-0.083	-0.226	0.248	0.231	0.231	0.789	0.082	-0.107	0.028	0.028	-0.046	0.067
RDSL	17	0.183	0.000	0.446	0.463	0.808	0.398	0.110	0.006	0.320	0.331	0.101	0.119
RSSL	18	0.035	-0.013	0.192	0.172	0.278	0.840	0.055	-0.067	0.101	0.095	-0.003	0.045
RSPIL	19	0.539	0.254	0.762	0.829	0.640	0.410	-0.116	0.153	0.742	0.799	0.317	-0.018
RRPIL	20	0.589	0.339	0.807	0.741	0.659	0.447	-0.154	0.150	0.802	0.784	0.304	-0.037
RELSPI	21	0.225	-0.294	0.914	0.983	0.527	0.334	-0.046	0.037	0.546	0.614	0.210	0.035
RELRPI	22	0.246	-0.277	0.906	0.932	0.544	0.370	-0.074	0.023	0.599	0.595	0.188	0.027

		LBW 14	RDS 15	RSS 16	RDSL 17	RSSL 18	RSPIL 19	RRPIL 20	RELSPI 21	RELRPI 22
LBW	14	1.000								
RDS	15	0.114	1.000							
RSS	16	-0.010	0.403	1.000						
RDSL	17	0.196	0.959	0.344	1.000					
RSSL	18	0.050	0.359	0.976	0.361	1.000				
RSPIL	19	0.533	0.392	0.102	0.473	0.159	1.000			
RRPIL	20	0.563	0.361	0.102	0.464	0.176	0.908	1.000		
RELSPI	21	0.368	0.520	0.228	0.444	0.168	0.847	0.721	1.000	
RELRPI	22	0.389	0.510	0.246	0.438	0.189	0.763	0.809	0.916	1.000

Table 6

Correlation Matrix for the Intermediate Group

		%FAT 1	RVJ 2	SVJ 3	SQT 4	LEGDYN 5	MEOBH 6	MEAT 7	RPI 8	MAXAT 9
%FAT	1	1.000								
RVJ	2	0.063	1.000							
SVJ	3	-0.149	0.036	1.000						
SQU	4	-0.195	0.135	0.019	1.000					
LEGDYN	5	0.122	0.222	-0.155	0.086	1.000				
MEOBH	6	0.318	-0.049	0.102	-0.129	-0.127	1.000			
MEAT	7	0.349	0.045	0.116	-0.237	-0.262	0.094	1.000		
RPI	8	0.101	0.275	-0.376	-0.099	0.210	-0.218	-0.003	1.000	
MAXAT	9	0.353	0.033	0.060	-0.208	-0.267	0.111	0.987	-0.008	1.000
MAXOBH	10	-0.149	-0.052	-0.065	0.163	0.068	-0.222	-0.030	0.126	-0.090

Table 7

Correlation Matrix for the Unconditioned Group

		BWT 1	%FAT 2	RVJ 3	SVJ 4	SQT 5	LEGDYN 6	MEOBH 7	MEAT 8	SPI 9	MAXAT 10	MAXOBH 11	LBW 12	RDS 13
BWT	1	1.000												
%FAT	2	0.817	1.000											
RVJ	3	0.120	-0.062	1.000										
SVJ	4	0.106	-0.022	0.842	1.000									
SQT	5	0.819	0.741	0.154	0.842	1.000								
LEGDYN	6	0.576	0.458	0.138	0.072	0.753	1.000							
MEOBH	7	-0.022	-0.067	0.031	0.041	0.038	0.106	1.000						
MEAT	8	0.044	-0.006	0.195	0.169	-0.112	-0.325	-0.242	1.000					
SPI	9	0.887	0.630	0.458	0.511	0.774	0.534	0.056	0.092	1.000				
MAXAT	10	0.149	0.145	0.224	0.299	0.104	-0.234	-0.366	0.639	0.200	1.000			
MAXOBH	11	0.120	0.088	0.116	0.136	0.110	-0.037	0.531	-0.118	0.215	0.084	1.000		
LBW	12	0.955	0.613	0.186	0.177	0.734	0.552	0.008	0.057	0.888	0.139	0.127	1.000	
RDS	13	0.123	0.199	0.113	0.229	0.658	0.528	0.038	-0.266	0.190	0.041	0.061	0.059	1.000
RSS	14	-0.011	-0.039	0.100	0.048	0.334	0.802	0.138	-0.468	0.026	0.422	-0.125	0.003	0.577
RDSL	15	0.421	0.555	0.080	0.168	0.851	0.632	0.021	-0.223	0.411	0.082	0.082	0.285	0.923
RSSL	16	0.199	0.219	0.092	0.031	0.519	0.905	0.127	-0.448	0.193	-0.368	-0.098	0.159	0.611
RSPIL	17	0.518	0.434	0.695	0.804	0.679	0.360	0.097	0.102	0.823	0.257	0.254	0.479	0.316

		RSS 14	RDSL 15	RSSL 16	RSPIL 17
RSS	14	1.000			
RSDL	15	0.477	1.000		
RSSL	16	0.965	0.608	1.000	
RSPIL	17	0.077	0.447	0.197	1.000

APPENDIX B

Cumulative Proportion of Total Variance

Table 8

Cumulative Proportion of Total Variance for the Unconditioned Group

Factor	Variance Explained	Cumulative Proportion of Total Variance
1	6.376755	0.375103
2	3.519625	0.582140
3	2.216985	0.712551
4	1.716444	0.813518
5	1.255555	0.887374
6	0.654938	0.925900
7	0.456994	0.952782
8	0.362345	0.974097
9	0.203407	0.986062
10	0.177477	0.996502
11	0.045021	0.999150
12	0.010872	0.999789
13	0.002074	0.999911
14	0.000802	0.999958
15	0.000302	0.999976
16	0.000273	0.999992
17	0.000130	1.000000

Table 9

Cumulative Proportion of Total Variance for the General Group

Factor	Variance Explained	Cumulative Proportion of Total Variance
1	9.216703	0.418941
2	3.658911	0.585255
3	2.446278	0.696450
4	1.669592	0.772340
5	1.436515	0.837636
6	1.346246	0.898829
7	0.833765	0.936728
8	0.457527	0.957524
9	0.357157	0.973759
10	0.296606	0.987241
11	0.233725	0.997865
12	0.023650	0.998940
14	0.004616	0.999656
15	0.004042	0.999749
16	0.002746	0.999874
17	0.001272	0.999932
18	0.000578	0.999958
19	0.000483	0.999980
20	0.000206	0.999989
21	0.000184	0.999998
22	0.000054	1.000000

Table 10

Cumulative Proportion of Total Variance for the Intermediate Group

Factor	Variance Explained	Cumulative Proportion of Total Variance
1	2.484273	0.248427
2	1.724120	0.420839
3	1.324770	0.553316
4	1.149896	0.668306
5	0.911394	0.759445
6	0.788350	0.838280
7	0.708492	0.909130
8	0.466371	0.955767
9	0.434047	0.999171
10	0.008287	1.000000

APPENDIX C

Rotated Factor Loading (Patterns)

Table 11

Rotated Factor Loadings (Patterns) for the Unconditioned Group

		Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
BWT	1	0.992*	-0.002	0.073	0.065	0.007
%FAT	2	0.831*	-0.090	0.287	0.159	0.018
RVJ	3	0.052	-0.007	-0.007	0.938*	-0.001
SVJ	4	0.034	-0.104	0.109	0.952*	0.062
SQT	5	0.769	0.145	0.588	0.121	0.031
LEGDYN	6	0.544	0.663	0.410	0.128	-0.119
MEOBH	7	-0.024	0.311	-0.070	0.052	0.814*
MEAT	8	0.046	-0.689*	-0.121	0.212	-0.283
SPI	9	0.859*	-0.009	0.081	0.476	0.094
MAXAT	10	0.108	-0.800*	0.250	0.237	-0.177
MAXOBH	11	0.098	-0.143	0.089	0.098	0.875*
LBW	12	0.937*	0.040	-0.051	0.159	0.007
RDS	13	0.037	0.216	0.937*	0.133	0.036
RSS	14	-0.050	0.833*	0.446	0.132	-0.142
RDSL	15	0.355	0.156	0.903*	0.060	0.041
RSSL	16	0.165	0.788	0.509	0.098	-0.131
RSPIL	17	0.477	-0.063	0.240	0.761	0.161
	VP	4.590	3.102	2.922	2.839	1.633

Table 12

Rotated Factor Loadings (Patterns) for the General Group

		Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6
BWT	1	0.056	0.971*	0.025	0.065	0.171	-0.060
%FAT	2	-0.452	0.593	-0.121	0.242	0.196	-0.254
RVJ	3	0.943*	0.186	0.119	0.135	0.017	-0.007
SVJ	4	0.950*	0.155	0.090	0.171	0.043	-0.002
SQT	5	0.350	0.625	0.192	0.616	0.072	0.085
LEGDYN	6	0.170	0.492	0.835*	0.132	0.072	0.005
MEOBH	7	-0.087	-0.046	0.027	0.089	-0.074	0.863*
MEAT	8	-0.020	0.168	0.036	-0.027	0.886*	0.067
RPI	9	0.420	0.875*	0.067	0.100	0.146	-0.055
SPI	10	0.457	0.853*	0.056	0.106	0.154	-0.043
MAXAT	11	0.154	0.181	0.011	0.027	0.881*	-0.054
MAXOBH	12	0.020	-0.024	0.007	0.064	0.088	0.850*
LBW	14	0.229	0.914*	0.078	-0.008	0.125	0.030
RDS	15	0.423	-0.044	0.244	0.806*	-0.051	0.165
RSS	16	0.148	-0.112	0.970*	0.199	-0.058	0.050
RDSL	17	0.300	0.121	0.211	0.898*	-0.003	0.095
RSSL	18	0.052	0.011	0.970*	0.171	-0.018	-0.006
RSPIL	19	-.0704	0.483	0.019	0.271	0.150	-0.123
RRPIL	20	0.651	0.544	0.039	0.271	0.131	-0.164
RELSPI	21	0.948*	0.157	0.088	0.142	0.043	0.016
RELRPI	22	0.945*	0.188	0.117	0.127	0.014	-0.006
	VP	5.651	5.472	2.799	2.442	1.768	1.643

Table 13

Rotated Factor Loadings (Patterns) for the Intermediate Group

		Factor 1	Factor 2	Factor 3	Factor 4
%FAT	1	0.375	-0.369	0.583*	0.130
RVJ	2	0.115	-0.010	0.017	0.869*
SVJ	3	0.114	0.787*	0.063	0.122
SQT	4	-0.251	0.340	-0.341	0.403
LEGDYN	5	-0.337	-0.365	0.072	0.531*
MEOBH	6	0.037	0.158	0.752*	-0.103
MEAT	7	0.981*	0.034	0.055	-0.026
RPI	8	0.076	-0.721*	-0.220	0.300
MAXAT	9	0.969*	0.019	0.086	-0.033
MAXOBH	10	0.020	-0.121	-0.665*	-0.042
	VP	2.253	1.565	1.532	1.334

APPENDIX D

Means and Standard Deviations for Each Group

Table 14

Mean and Standard Deviation for the General Group

Variable	Mean	Standard Deviation
1 BWT	191.63538	32.14853
2 %FAT	9.16923	4.33047
3 RVJ	61.34231	9.85005
4 SVJ	54.90000	9.32890
5 SQT	296.34615	70.38870
6 LEGDYN	1123.15385	292.72742
7 MEOBH	17.13846	6.24035
8 MEAT	0.35165	0.08224
9 RPI	150.78692	30.11577
10 SPI	142.45153	29.05314
11 MAXAT	0.34253	0.10544
12 MAXOBH	17.07692	5.92540
14 LBW	173.27071	25.10358
15 RDS	1.54532	0.27283
16 RSS	5.87928	1.32511
17 RDSL	1.70214	0.29042
18 RSSL	6.47188	1.41202
19 RSPIL	0.81652	0.07323
20 RRPIL	0.86456	0.07019
21 RELSPI	0.74085	0.06669
22 RELRPI	0.78426	0.06296

Table 15

Mean and Standard Deviation for the Anaerobic Group

Variable	Mean	Standard Deviation
1 BWT	207.13000	28.44253
2 %FAT	9.57571	3.90003
3 RVJ	66.32143	9.23409
4 SVJ	59.38571	8.55806
5 SQT	336.64286	55.81232
6 LEGDYN	1244.57143	236.18763
7 MEOBH	17.37143	6.62488
8 MEAT	0.37064	0.08102
9 RPI	168.71000	23.97618
10 SPI	159.74142	22.66514
11 MAXAT	0.36947	0.09395
12 MAXOBH	17.82857	6.36788
14 LBW	186.68373	21.85766
15 RDS	1.63815	0.26694
16 RSS	6.07163	1.19119
17 RDSL	1.80849	0.26266
18 RSSL	6.70114	1.21049
19 RSPIL	0.85442	0.05174
20 RRPIL	0.90225	0.05168
21 RELRPI	0.81576	0.05760

Table 16

Mean and Standard Deviation for the Intermediate Group

Variable	Mean	Standard Deviation
1 %FAT	17.82333	1.80606
2 RVJ	7.38667	17.23360
3 SVJ	52.12333	33.14152
4 SQT	119.43333	173.29120
5 LEGDYN	2034.16667	2704.80546
6 MEOBH	9.86667	2.88556
7 MEAT	0.29157	0.01125
8 RPI	478.30661	295.18858
9 MAXAT	0.29360	0.01191
10 MAXOBH	18.40000	25.03184

Table 17

Mean and Standard Deviation for the Unconditioned Group

Variable	Mean	Standard Deviation
1 BWT	168.81667	32.31032
2 %FAT	9.72667	5.50892
3 RVJ	53.10000	5.62997
4 SVJ	46.39000	6.59552
5 SQT	231.16667	60.62439
6 LEGDYN	940.06667	300.57209
7 MEOBH	16.93333	5.03048
8 MEAT	0.34257	0.08023
9 SPI	114.58666	24.93063
10 MAXAT	0.30903	0.13764
11 MAXOBH	16.93333	5.13899
12 LBW	150.99142	21.03674
13 RDS	1.36456	0.21038
14 RSS	5.57135	1.39003
15 RDSL	1.52052	0.27284
16 RSSL	6.19213	1.58204
17 RSPIL	0.75380	0.07908

APPENDIX E

ANOVA for RVJ, SVJ, RPI and SPI

Table 18

ANOVA of RVJ and SVJ Among Good and Poor Jumpers

```
Analysis of Variance for RVJ

DUE TO         DF         SS        MS=SS/DF       F-RATIO
FACTOR          1       8740.3       8740.3         563.39
ERROR          37        574.0         15.5
TOTAL          38       9314.4

LEVEL           N         MEAN        ST. DEV.
Good           22        77.45          4.26
Poor           17        47.26          3.46

POOLED ST. DEV. =  3.94

INDIVIDUAL 95 PERCENT C.I. FOR LEVEL MEANS
(BASED ON POOLED STANDARD DEVIATION)
      +---------+---------+---------+--------+--------+--------+
Good                                             I*I*I
Poor           I*I*I
      +---------+---------+---------+--------+--------+--------+
     40.0     48.0      56.0      64.0     72.0     80.0     88.0
```

```
Analysis of Variance for SVJ

DUE TO         DF         SS        MS=SS/DF       F-RATIO
FACTOR          1       7044.9       7044.9         260.23
ERROR          37       1001.6         27.1
TOTAL          38       8046.5

LEVEL           N         MEAN        ST. DEV.
Good           22        68.89          5.53
Poor           17        41.78          4.73

POOLED ST. DEV. =  5.20

INDIVIDUAL 95 PERCENT C.I. FOR LEVEL MEANS
(BASED ON POOLED STANDARD DEVIATION)
      +---------+---------+---------+--------+--------+--------+
Good                                             I**I***I
Poor        I***I**I
      +---------+---------+---------+--------+--------+--------+
     35.0     44.0      49.0      56.0     63.0     70.0     77.0
```

Table 19

ANOVA of SPI and RPI Among Good and Poor Jumpers

```
Analysis of Variance for RPI

DUE TO          DF          SS        MS=SS/DF       F-RATIO
FACTOR           1      29493.         29493.         53.09
ERROR           37      20556.          556.
TOTAL           38      50049.

LEVEL            N        MEAN         ST. DEV.
Good            22       176.1          20.2
Poor            17       120.7          27.4

POOLED ST. DEV. =   23.6

INDIVIDUAL 95 PERCENT C.I. FOR LEVEL MEANS
(BASED ON POOLED STANDARD DEVIATION)
      +---------+---------+---------+--------+--------+--------+
Good                                        I*****I******I
Poor      I******I*******I
      +---------+---------+---------+--------+--------+--------+
     105.      120.      135.      150.     165.     180.     195.
```

```
Analysis of Variance for SPI

DUE TO          DF          SS        MS=SS/DF       F-RATIO
FACTOR           1      28042.         28042.         55.20
ERROR           37      18795.         508.
TOTAL           38      46837.

LEVEL            N        MEAN         ST. DEV.
Good            22       166.2         18.5
Poor            17       112.1         26.9

POOLED ST. DEV. =   22.5

INDIVIDUAL 95 PERCENT C.I. FOR LEVEL MEANS
(BASED ON POOLED STANDARD DEVIATION)
      +---------+---------+---------+--------+--------+--------+
Good                                      I*****I******I
Poor    I******I******I
      +---------+---------+---------+--------+--------+--------+
     100.      115.      130.      145.     160.     175.     190.
```

APPENDIX F

ANOVA for SQT, LBW, BWT and LEGDYN

Table 20

ANOVA of BWT and LBW Among Good and Poor Jumpers

```
Analysis of Variance for BWT

DUE TO          DF        SS        MS=SS/DF        F-RATIO
FACTOR           1      5808.        5808.           6.42
ERROR           37     33497.         905.
TOTAL           38     39305.

LEVEL            N       MEAN        ST. DEV.
Good            22      199.3          22.8
Poor            17      174.7          37.5

POOLED ST. DEV. =  30.1

INDIVIDUAL 95 PERCENT C.I. FOR LEVEL MEANS
(BASED ON POOLED STANDARD DEVIATION)
      +---------+---------+---------+--------+--------+--------+
Good                          I************I************I
Poor  I**************I**************I
      +---------+---------+---------+--------+--------+--------+
     160.      170.      180.      190.     200.     210.     220.
```

```
Analysis of Variance for LBW

DUE TO          DF        SS        MS=SS/DF        F-RATIO
FACTOR           1      8416.        8416.          14.42
ERROR           37     21601.         584.
TOTAL           38     30017.

LEVEL            N       MEAN        ST. DEV.
Good            22      186.0          19.1
Poor            17      156.4          29.5

POOLED ST. DEV. =  24.2

INDIVIDUAL 95 PERCENT C.I. FOR LEVEL MEANS
(BASED ON POOLED STANDARD DEVIATION)
      +---------+---------+---------+--------+--------+--------+
Good                                 I*********I**********I
Poor       I**********I**********I
      +---------+---------+---------+--------+--------+--------+
     140.      150.      160.      170.     180.     190.     200.
```

Table 21

ANOVA of SQT and LEGDYN Among Good and Poor Jumpers

```
Analysis of Variance for SQT

DUE TO          DF         SS        MS=SS/DF       F-RATIO
FACTOR           1      146303.       146303.        36.29
ERROR           37      149171.         4032.
TOTAL           38      295474.

LEVEL            N         MEAN        ST. DEV.
Good            22        362.0          53.9
Poor            17        238.5          74.2

POOLED ST. DEV. =   63.5

INDIVIDUAL 95 PERCENT C.I. FOR LEVEL MEANS
(BASED ON POOLED STANDARD DEVIATION)
      +---------+---------+---------+--------+--------+--------+
Good                                    I*****I*****I
Poor    I*******I******I
      +---------+---------+---------+--------+--------+--------+
     200.      240.      280.      320.     360.     400.     440.
```

```
Analysis of Variance for LEGDYN

DUE TO          DF         SS        MS=SS/DF       F-RATIO
FACTOR           1     1218947.      1218947.        11.23
ERROR           37     4017479.       108581.
TOTAL           38     5236426.

LEVEL            N         MEAN        ST. DEV.
Good            22        1137.        306.
Poor            17         980.        308.

POOLED ST. DEV. =   330.

INDIVIDUAL 95 PERCENT C.I. FOR LEVEL MEANS
(BASED ON POOLED STANDARD DEVIATION)
      +---------+---------+---------+--------+--------+--------+
Good                           I*********I**********I
Poor   I**********I**********I
      +---------+---------+---------+--------+--------+--------+
     800.      950.      1100.     1250.    1400.    1550.    1700.
```

APPENDIX G

ANOVA for MAXOBH Among Good and Poor Jumpers

Table 22

ANOVA of MAXOBH Among Good and Poor Jumpers

```
Analysis of Variance for MAXOBH

DUE TO          DF         SS         MS=SS/DF          F-RATIO
FACTOR           1         28.4        28.4.             0.67
ERROR           37       1569.9        42.4
TOTAL           38       1598.4

LEVEL            N         MEAN         ST. DEV.
Good            22         17.45          6.68
Poor            17         19.18          6.29

POOLED ST. DEV. =   6.51

INDIVIDUAL 95 PERCENT C.I. FOR LEVEL MEANS
(BASED ON POOLED STANDARD DEVIATION)
     +---------+---------+---------+--------+--------+--------+
Good  I******************I****************I
Poor           I********************I*******************I
     +---------+---------+---------+--------+--------+--------+
    14.5      16.0      17.5      19.0     20.5     22.0     23.5
```

VITA

Donald Thirrel Evitt was born in Newton, North Carolina, on November 30, 1951. He received an Associate in Science degree from Western Piedmont Community College in Morganton, North Carolina in 1974. The following September he entered the University of North Carolina at Charlotte, and in May 1980, he received a Bachelor of Science degree in Biology.

The author served on active duty and in the active reserves with the United States Army Special Forces from September 1972 to the present. He is a member of the National Strength and Conditioning Association, Southeast Chapter of the American College of Sports Medicine, Professional Association of Diving Instructors, and the U.S. Army Reserves.

In 1982 he entered Appalachian State University and began work toward a Master's degree. This degree was awarded in May 1985 in the field of Exercise Science. While at Appalachian State University, he was an assistant strength coach and director of the Adult Fitness Program.