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A comparison of three training programs for increasing vertical jump

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**A comparison of three training programs for increasing vertical
jump**

Oberg, Terri Lynn, M.A.

San Jose State University, 1993

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A COMPARISON OF THREE TRAINING
PROGRAMS FOR
INCREASING VERTICAL JUMP

A Thesis
Presented to
The Faculty of the Department of Human Performance
San Jose State University

In Partial Fulfillment
of the Requirements for the Degree
Master of Arts

by
Terri Lynn Oberg
December, 1993

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APPROVED FOR THE DEPARTMENT OF HUMAN PERFORMANCE

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APPROVED FOR THE UNIVERSITY

ABSTRACT

A COMPARISON OF THREE TRAINING PROGRAMS FOR INCREASING VERTICAL JUMP

by Terri Lynn Oberg

The purpose of this study was to compare three training methods for improving vertical jump heights. Forty-eight female physical education students trained three times a week for eight weeks. The training methods used were: (a) Universal leg press machine, using three sets of 10, 8, 6 repetitions at 60%, 70%, and 80% of 1RM respectively; (b) CMC Shuttle 2000, performing three sets of ten repetitions utilizing an explosive/quick two foot bounding method, and three sets of ten repetitions of one foot take-off on each leg; or (c) jump training only. All three groups performed jump training exercises which consisted of five successful jumps or 10 attempts, whichever came first, using the standing and the 2-step approach technique. Pre and post tests of vertical jump height were separated by eight weeks of training.

The results indicated that all training methods improved vertical jump heights, but there was no significant difference in mean jump heights ($p < .05$) between the three training groups. Thus, the Shuttle 2000 is as effective as other training methods, and might be used with athletes to decrease jarring and the stress on the lower body during training.

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Sincere love and thanks is extended to Les for believing in me and encouraging me to finish.

To my mom who has always been there for me and taught me that all my hopes and dreams can come true.

DEDICATION

This thesis is dedicated to my dad, who is “The wind beneath my wings.” You left when I was in the middle of my program, but I struggled through it, wondering if I could do it. Wish you were here to share, though I know in my heart you added a push to help me finish. I love you very much, and miss you dearly.

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CHAPTER 1

Introduction

In all levels of play, from high school to international, competitors are looking for improvement that will give them the edge, that slight advantage that results in victory (Garl, Rink, & Bomba, 1988). In many sports skills which involve explosive leg power, such as the volleyball spike, and basketball lay-up, strength development routines are utilized as part of the normal training regimen (Cresswell, Engel, & Nicol, 1987). In basketball, it is crucially important to develop a solid strength and conditioning program that develops the power areas (for example, speed and quickness, dynamic power, and absolute strength) that are necessary for success (Vermeil, 1987a). Semenick and Adams (1987) found that in jumping for a basketball rebound, "the human body is a projectile, the center of gravity of which is governed by the same laws that govern the motion of the basketball itself. The height of the jump will be determined by the vertical velocity of the body's center of gravity at the time of takeoff" (p.5).

Specificity in exercise refers to creating training demands to develop those particular aspects of neuromuscular performance most needed for a given task (Kroll, 1984). The principle of specificity of training indicates that, to be most efficient, training must be specific to your sport or activity because the body will adapt to the specific stress to which it is exposed (Wilmore, 1979). Chu (1986) agrees that the specificity in training is a necessary component for teaching the neuromuscular apparatus to respond more quickly and forcefully. Semenick and Adams (1987) believe that the single best method for an athlete to improve his or her vertical jump is to practice maximum vertical jumping. Some researchers reported that additional sports-specific training techniques,

including weight training, improve vertical jumping ability (Blattner & Noble, 1979; Chu, 1986; Clutch, Wilton, McGown, & Bryce, 1983). Previously held beliefs that basketball players jeopardized their ability to shoot the ball well by undertaking weight/strengthening exercise have been disproven (Garl, Rink, & Bomba, 1988). Vermeil (1987) has seen several basketball athletes improve their acceleration, lateral speed, rebounding and ability to block shots, as a result of strength training.

Thus, while the specificity of training has been proven, and some research suggests jump training is the best type of exercise to increase vertical jump, other researchers suggest other methods may also be effective.

Statement of the Problem

The purpose of this study was to compare the effectiveness of three types of training (i.e., CMC Shuttle 2000 training, weight training, and jump training) in increasing vertical jump heights for college female physical education students.

Need for Study

Various studies have been conducted in increasing jumping ability with plyometric training (Bielik, 1986; Clutch et al., 1983; Fukashiro & Komi, 1987), isokinetic training (Blattner & Noble, 1979), and isotonic training (Clutch, et al., 1983). There is a need for a study to evaluate the training effects of a relatively new apparatus (the CMC Shuttle 2000), which utilizes the principle of concentric and eccentric muscle contraction without the gravitational forces, in improving vertical jumping ability. Currently, there is no published literature which utilizes the Shuttle 2000 as a strength training apparatus.

Hypothesis

There will be no significant difference in mean vertical jump heights among physical education students as a function of training protocol (progressive resistance weight, Shuttle 2000, or jump training).

Delimitations

This study was delimited to female community college physical education students who had not engaged in weight training during the past year. All subjects were volunteers.

Limitations

The subjects were asked to make no changes in their regular diet or activity habits; however, there was no control over diet or activities outside of school. The results may have been affected by the individual differences in the initial level of training. The training period lasted only eight weeks.

Assumption

It was assumed that each subject gave their best effort during the exercise training and testing.

Definitions of Terms

CMC Shuttle 2000 - is a "Cardio-Muscular Conditioning" Shuttle which provides both eccentric and concentric resistance without detrimental impact or gravitational stress (Interview with Bonnie Buzzardy, 1990, President of Leading Technologies Inc.).

Concentric Contraction - is described by Knuttgen (1986) as a movement in which the ends of the muscles are drawn closer together.

Eccentric Contraction - is "movement in which the ends of the active muscles are separated by the external resistance" (p. 433). In terms of work, negative work is performed (Astrand & Rodahl, 1986).

Isokinetic Exercise - is a weight training system that involves a muscular contraction at a constant velocity. As the muscle length changes, the resistance alters in a manner which is directly proportional to the force exerted by the muscle (Astrand & Rodahl, 1986).

Power - is the product of force and velocity. Applied to muscular performance, it is the work output of muscles at specific speeds of contraction (Hislop & Perrine, 1967).

Progressive Resistance Exercises (PRE) - progressive resistance exercises are weight training exercise techniques based on an individual's maximal load (Delorme & Watkins, 1948).

Strength - is the capacity to exert force against a resistance (Nunn & Mahew, 1988).

Chapter 2

Literature Review

Previous research regarding to the different methods used for improving vertical jump and the various training methods utilized is reviewed in this chapter. In order to examine such studies, the review of literature has been divided into five sections: (a) neuromuscular mechanisms of the vertical jump; (b) training for the vertical jump; (c) CMC Shuttle 2000; (d) training components for basketball; and (e) relative stresses on the lower extremity.

Neuromuscular Mechanisms of the Vertical Jump

Efforts to understand the mechanical basis of skilled motor performance have led researchers to question the role of individual body segments (Miller, 1980). Whenever a motor task is to be executed, the central nervous system sends impulses to a number of muscles (Astrand & Rodahl, 1986). The muscular forces developed in response to these impulses interact with the mechanical demands of the tasks, and movement results (Bobbert, & Van Ingen Schenau, 1988).

A general type of muscle activity is described as dynamic in nature but the specific type of contraction can be identified as being either concentric or eccentric (Knuttgen, 1986). Astrand and Rodahl (1986) found that "if an activated muscle is stretched, part of the added energy is degenerated into heat, but another part can be absorbed by the series of elastic elements of the muscle" (p.434). This stored energy can be made available during the contraction. Cavagna, Dusman, and Margaria (1968) explained movement as the utilization of this "stretch-shortening cycle," which means that an eccentric contraction precedes the concentric contraction. This implies that "during the

stretching of an active muscle, potential elastic energy is stored in it, and this elastic energy can be utilized during the following concentric work" (Cavagna, et al., 1968, p.21). Bosco, Viitasalo, Komi, and Lugtanen (1982) summarized the use of elastic recoil as a "shortening contraction taking place in the muscle in the short time before the tension has disappeared completely the high tension in the previously stretched muscle will act as an elastic recoil whose force can be added to the force developed in the following shortening contraction" (p.563). The results of their study showed that the restitution of elastic energy plays an important role in regulating the mechanical efficiency of work.

Thomas (1988) concluded that the greater amount of work done after pre-stretching was accounted for by a combination of the utilization of stored elastic energy and the force developed by the contractile component of the muscle itself.

Asmussen and Bonde-Petersen (1974a) noted similar findings when they studied subjects who performed maximal vertical jumps from three positions: (a) semi-squatting position; (b) after a natural counter movement from a standing position; and (c) in continuation of jumps down from various heights (.233 m, .404 m, .690 m). Their results showed that the height of the jump becomes increasingly greater when a counter-movement or a jump down from a height precedes the actual jump at .233 m and .404 m. These results showed that mechanical energy may be temporarily stored in the series elastic components of active muscles for re-use in a following contraction in the vertical jump. Asmussen and Bonde-Petersen (1974b) conducted a second study in which they looked at human muscles during exercise. The subjects were tested on the treadmill against varying horizontal impeding forces, and the results showed that during running 35-53% of the energy absorbed during the

negative phase was re-used.

In a study conducted by Thy, Faraggiana, and Margaria (1972) subjects who performed plyometric exercises (using concentric/eccentric contraction) accelerated faster, did more work in less time, generated more power and were more efficient than when they performed non-plyometric exercises. The differences were interpreted as evidence that elastic potential energy stored in the muscles stretched during the negative work phase of the exercise is utilized for the performance of positive work. A critical mechanism accounting for much of the improvement associated with plyometric training is the utilization of stored elastic energy (Thomas, 1983).

Studies done by Thy et al. (1972), Cavagna et al. (1968), and Asmussen and Bonde-Petersen, (1974a) strongly emphasize the role of muscle elasticity in the economy of muscular exercise as running and jumping.

Clutch et al. (1983) also believe that a rapid lengthening of a muscle just prior to a contraction will result in a much stronger contraction. Researchers believe that the added contractile strength is due to a stretching of muscle spindles involving a "myotatic reflex" (Chu, 1983; Clutch, et al., 1983; Thomas, 1988) which results in an increased frequency of motor unit discharge, stimulation of other receptors, and an increased number of activated motor units.

Muscle spindles located within the muscle react to sudden stretch by sending signals to the spinal cord, resulting in muscular contraction to resist the sudden stretch (Thomas, 1988). This stretch reflex is the body's involuntary defense mechanism to protect the muscle from the sudden, forceful stretch. An example of the stretch reflex would be the knee jerk. The spindle receptors are sensory in nature and are sensitive not only to the amount of stretching they undergo, but also the rate of stretching (Chu, 1983).

Training for the Vertical Jump

Basketball is a game of speed - forward, backward, lateral, and vertical. The successful athlete must have ability to change direction, stop and go, and to jump at the quickest impulse. It is important to train the leg muscles to react and respond with power at any time. Chu (1983) suggests absolute height and vertical velocity as important traits which require the keenest of neuromuscular reaction and movement time in basketball. He reports elastic strength as the trait most important to jumping and the ability to improve an absolute value through training and technique improvement has to range in the areas of 8-10% for vertical heights.

Steben and Steben (1981) studied track and field athletes and the stretch-shortening cycle in muscles and its effect on jumping. Their purpose was to ascertain whether specific plyometric drills can facilitate improvement in field event performances by young subjects as contrasted with classmates in physical education classes. Group 1 trained with depth jump exercise, specifically recommended for improvement in the vertical jump. The subjects trained 20 minutes a day, five days a week. Results showed the increases in strength recorded isometrically were not accompanied by increases in jumping performances. "This further verifies the contention that strength training would involve a degree of neuromuscular specificity to be effective" (p. 227). It is also important to remember that plyometric training places a high demand on the neuromuscular system (Chu, 1986).

In deciding the height to be used, Bobbert, Huijing, and Schenau (1987b) examined the various heights at which drop jumping should be performed. They looked at 20, 40, and 60cm, and found that mechanical output about the joints during the push-off phase from the 60cm drop jumping was less effective than the 20 or 40 cm jumps. The results showed no difference in mechanical

output between jumping from 20 or 40 cm. Bobbert et al. (1987b) felt that it was unnecessary to jump from heights greater than 40 cm because of the amount of stress placed on the various joints. One advantage the researchers noted was that depth jumping offered a change of training technique which was a variation from their normal workout.

Brown, Forman, DiBrezza, and Fort (1988) studied the effect of three different training modes on vertical jumping. In their study, one group trained on a Universal leg press machine, using a three set, eight to twelve repetition protocol. A second group trained using a 30-second isometric squat, and a third group trained using a "Motivational Vertical Jump" program, which involved a target bell that was placed one inch below the subjects maximum vertical reach. The subjects were required to ring the bell ten times consecutively or until they had performed 40 attempts. The subjects included 34 males and females who trained five days per week for six weeks. The only group to show significant improvement in vertical jumping was the "Motivational Vertical Jump" group. The leg press and jumping groups improved an average of one inch in six weeks.

Clutch et al. (1983) noted similar findings when they looked at 16 members of a weight training class and 16 members of the men's volleyball team. Statistics showed that depth jumps did not produce jump increases beyond that of a jumping routine that was a normal part of practice. Thus, depth jumps did not appear to be as good as the more common training methods.

In another comparison of the combination of weight training and plyometrics, Gemar (1986) divided fifty high school boys into three training groups: group one trained with plyometrics and sports activities; group two with weight training and sports activities; and group three with weight training and plyometrics. The boys trained four times a week for ten weeks. In the vertical jump test, all

groups improved significantly ($p < .05$) from pre- to post- test. The vertical jump means of groups two and three were significantly higher than group one, but were not significantly different from each other. Blattner and Noble (1979) found similar results with plyometric training and isokinetic training in that vertical jump improved, but neither training method resulted in greater increases.

CMC Shuttle 2000

In 1965, the Boeing Company Aerospace Group conducted studies on the astronauts in space. The main concern was astronauts' ability to stay physically fit and withstand the rigors of re-entry throughout the long period they were to remain in zero gravity. To prevent cardiovascular deconditioning, the scientists proposed the "Boeing Trampolining" which subjected the crew to intermittent positive and negative acceleration forces parallel to the long axis of the body (Yamamoto, 1985). One problem was the effect of the weightless environment, and researchers needed to find a form of resistance that itself was not affected by the lack of gravity. The solution was a "plyometric resistance"

In 1984, Gary Graham and his wife decided to revive the Boeing trampoline studies and designed the CMC Shuttle 2000 for the NASA Space Program. What makes the CMC Shuttle 2000 different from any other machine, is the fact that you are actually lying down in a horizontal position while you are continually pushing off from a "launch pad". This pushing action stimulates and strengthens the leg muscles in the same manner as squats or jumping rope (Yamamoto, 1985). The calves, hamstrings, gluteals, and quadriceps can be trained to produce greater, and more sustained power burst without detrimental impact or gravitational stress on the lower lumbar, knees and feet

According to Bonnie Buzzard, President of Leading Technologies, the

"Shuttle 2000 duplicates critical sports movements such as running and jumping" (personal interview, Dec. 1990). Clive Brewster, Director of Physical Therapy for the Kerlan-Jobe Orthopedic Clinic says that "the Shuttle 2000 subjects people to less than half the impact trauma of running on a hard surface and basketball players like it because it simulates the jumping they do on the court" (Yamamoto, 1985, p.2).

Research on the Shuttle 2000 has not been completed, but various universities and professional sports organizations are in the process of studying key physiological factors, such as oxygen uptake, enhancement of fast-twitch muscle fiber on both injured and healthy subjects (Bonnie Buzzard, personal interview, Dec. 1990).

Training Components for Basketball

The four training components for a basketball athlete include: (a) work capacity, (b) strength, (c) speed strength, and (d) speed. It is important to remember that the various positions in basketball (center, guard, and forward), require different ability levels of these components (Vermeil, 1988). A good example, might be that the strength requirement for a center is much greater than for a guard.

Work Capacity

"Work capacity consist of anaerobic capacity, body composition, joint mobility, strength endurance and aerobic capacity" (Vermeil, 1988, p. 64). These are the subcomponents that should be initially developed for the game of basketball (Palmieri, 1987). Anaerobic capacity enables an athlete to play a fast-paced game. Proper body composition development allows for longevity of playing the game. Joint mobility reduces the chance of injury. Strength endurance provides better rebounding and position ability.

Strength

Tension is the key to strength development. The amount of stress put on the muscle spindles allows for the recruitment pattern of the proper units (Palmieri, 1983). A fast powerful contraction is the result of a short burst of impulses from a large number of motor neurons, and a slower and less powerful contraction results from a more prolonged discharge from fewer motor neurons. Gains in muscle strength during training result from the gradual increase in the ability of the contractile elements in each fiber to contract more strongly, and to gradually recruit a higher proportion of the total available fibers in each contraction (Astrand, & Rodahl, 1986). These constituents can be developed with the application of the "Overload Principle," which states that strength, endurance and muscle size increase, within limits, in response to repetitive exercise, against progressively increased resistance (Palmieri, 1983).

It is most important for the coach or trainer to understand that the object of strength training is to improve sport performance. Kroll (1984) took a component of strength and developed two important subcomponents of training for basketball: (a) absolute/relative strength and (b) eccentric strength. Absolute strength is the maximum amount of weight or pounds an athlete can lift, whereas the relative strength takes into the consideration of bodyweight of the individual and the amount of weight that can be lifted (Vermeil, 1988). An example might be, that if one athlete weighs 170, and lifts 200lbs; and another athlete weighs 220, and lifts 300 lbs, then the first athlete has more relative strength. Absolute and relative strength are very important components to take into consideration when developing a strength program for a team (Hitchcock, 1988). One must take into consideration the important factor of an individualized program when developing a strength and conditioning program.

Thomas (1988) refers to eccentric strength as "tension via lengthening or

stretching when the athlete stops or comes down from a jump" (p.50). This lengthening while the muscle is contracting, is known to have higher mechanical efficiency and lower energy expenditure than concentric exercise. (Komi, Kaneko, & Aura, 1987). When compared to concentric contraction forces, Knuttgen (1986) found that eccentric contractions result in a far greater external force development. One would expect then that eccentric training would be a more effective method of strength training when compared to other types of training. Astrand and Rodahl (1986) point out that eccentric training is effective in increasing muscle strength, but is no more effective than isometric or concentric training.

Speed Strength

Speed strength is the ability to exert strength quickly and causes maximal gains in strength and endurance at velocities of movement equal to or slower, but not faster, than the training velocity. In theory, and in comparison with other programs, speed strength should lead to the greatest improvement in muscular improvement (Fox & Mathews, 1981).

Vermeil (1988) has broken down speed strength into explosive strength, elastic strength, and starting strength. All of these are important in conditioning for basketball. Explosive strength allows the athlete to develop high levels of strength rapidly with the major portion of power coming from concentric contraction (Hitchcock, 1988). The summation of joint forces is accomplished by "producing the fastest, most powerful movement possible, and all the joints that can contribute to the movement must be used to their fullest extent" (Smith, 1961, p. 405). Semineck and Adams (1987) believe this important source of explosive power comes from the plantar flexors of the ankles during the takeoff phase of rebounding. Other major contributors to the summation of forces are derived from concentric contractions of the powerful extensors of the knee and

of the lumbar-thoracic spine.

Bobbert, Huijing, and Van Ingen Schenau (1987a) found similar results when they took ten subjects who executed drop jumps from a height of 20 cm. and counter-movement jumps. They found that power output about the knee and ankle joints reached higher values during the drop jumps than during the counter-movement jumps.

Studies conducted on the biomechanics of joint forces, are conflicting. Fukashiro and Komi (1987) found that the hip extensors power output was much greater than the work by the knee extensors and the ankle plantar flexors. Whereas Hubley and Wells (1983) reported 49% contribution from the knee , 23% from the ankle, and 28% by the hip extensors. This may be attributed to the various methods used, however, these conflicting results show that it is important to design a program which incorporates all the major muscle groups of the lower extremity in order to obtain maximal height. Elastic strength is used in the movement into flexion which prepares the jumper for the speed needed for upward propulsion (Semenick & Adams, 1987). This slight crouching position places key muscles on stretch and stores energy in them which is then available during contraction. Thomas (1988) supports the theory of elastic recoil and points to its integral role as an additive factor in the performance of skills following a load induced prestretch.

Starting strength is the strength used to initiate a movement. This type of strength assists both explosive and elastic strength (Vermeil, 1988). The advantage goes to the performer who can step into the takeoff position and "uncoil" at the ankle, knees, and hip joints (Semenick & Adams, 1987). Starting strength is used to prepare for a rebound; the basketball player crouches somewhat, allowing gravitational forces to pull the body into flexion at the hips and knees and into dorsiflexion at the ankles.

Speed

To increase power, one must decrease movement time or increase strength. If the athlete holds force and distance constant and simply jumps quicker, he can increase power and thus the height of the jump (Myers, 1987). In vertical jumps, an even more important factor might be how fast the athlete can change from the eccentric contraction of the crouch to the concentric contraction of the jump (Palmieri, 1983). The elastic recoil or transfer of energy from the eccentric phase to the concentric phase should be instantaneous; a pause at the bottom of the crouch would result in a poorer performance (Komi, 1984). Myers (1987) believes that speed and quickness cannot be improved drastically, but every small improvement can have dramatic consequences.

Relative Stresses on Lower Extremities

Varying degrees of injuries occur as a result of sports participation. Injuries also can, and do, occur as a result of strengthening programs designed to reduce the chance of injury during sports (Shankman, 1984). It is important to construct a well supervised workout with proper training technique. Stone and Kroll (1979) found that during strength training for the lower extremities, the reclining position is best, because the pressure is relieved on the spine and is safer for leg development.

The most frequent injuries observed in basketball that result from lack of strength are tendinitis of the knee and low back problems. Jensen and DiFabio (1989) attributed patellar tendinitis (jumper's knee) to an overuse of the musculoskeletal unit. This injury is found in athletes involved in activities requiring repetitive jumping, kicking, or running. "The lack of eccentric strength could be a possible cause of tendinitis because an athlete cannot resist the forces; thus, greater stress is placed upon the tendons" (p. 66).

Negative effects of eccentric training are expressed by Knuttgen (1986); he noted that delayed muscle soreness is most likely accompanied by actual structural damage in the muscle, especially during eccentric exercise. Jensen and DiFabio (1989) agree that the high tension level developed during eccentric contraction of the quadriceps femoris muscle has been implicated as a possible factor in microscopic failure of patellar tendon fibers.

Low back problems can develop in basketball players because of the forces that are generated upon the landing phase, and because of a lack of elastic reactive strength; they land harder and these forces are transmitted to the lower back (Vermeil, 1987).

Summary

Vertical jumping ability is of considerable importance in numerous athletic events. Coaches, clinicians, and physical educators have used various strength training methods to improve this ability (Blattner & Noble, 1979). Pauletto (1987) believes that the most important objective of strength training is to improve sport performance.

Elastic energy plays important role in regulating the mechanical efficiency of work. Plyometric training utilizes the rapid stretching of a muscle that is undergoing eccentric stress and followed by a rapid concentric contraction of that muscle for the purpose of developing a forceful movement over a short period of time (Chu, 1983). According to Thomas (1988) the most popular form of plyometrics is depth jumping. Utilization of the stored elastic energy helps to explain why plyometrics can result in increases in maximal vertical jumping ability (Thomas, 1988). The CMC Shuttle 2000 is a relatively new apparatus that allows for concentric/eccentric contraction to be initiated during training of the lower extremity, without gravitational forces being employed.

Strength training for basketball is crucial for increasing work capacity, strength, speed strength, and speed. These components must be efficiently worked through the "overload principle" in order to perform to their maximal capabilities. It is important to improve the neuromuscular apparatus because the initiation, execution, and control of motor skills lies in neuromuscular system (Miller, 1980). Through training for a specific sport, there are relative stress demands that are placed on the athlete. In basketball, the most frequent injuries observed are associated with a lack of strength (Vermeil, 1987).

Chapter III

Procedures

Description of Subjects

The subjects for this study were 48 female physical education students between the ages of 18 and 26 years of age. The subjects were volunteers recruited from San Jose City College and West Valley College. Subjects were given written and verbal instructions, stating the purpose and methodology of the study; all subjects gave their informed consent prior to participation in the study (approved by the San Jose State University Institutional Review Board - Human Subjects; see Appendix A). The subjects were asked to comply with the following: (a) not to participate in any sports competition during the experimental period; (b) perform no vertical jumping exercises outside of experiment; and (c) attend 90% of the training sessions, allowing for one make-up, otherwise be disqualified from the study. Subjects completed the Information Questionnaire during this initial session (see Appendix B).

Research Design

Subjects were randomly assigned, except that four of the subjects were specifically placed based on their ability to get to the training sites. The groups consisted of the CMC Shuttle 2000 training and jump training (ST), isotonic (leg press) and jump training (LP), and jump training only (JTO), which did maximal vertical jump training only. The experiment was 10 weeks in duration, with testing during the first and tenth weeks, and training during the eight weeks in between. There were three training periods per week each lasting 45 minutes. All groups were tested for vertical jump heights in the San Jose City College (SJCC) gymnasium. The various sites for training consisted of the jump

training at West Valley College, the leg press training in the weight training room at SJCC, and the Shuttle 2000 training at Santa Clara Sports Therapy. Prior to any testing or training, the investigator instructed the subjects on procedures and training methods. Throughout the training and testing periods all groups were verbally encouraged by the investigator.

Instrumentation

The Vertec is a jump and reach measurement tool which has a two foot range of half-inch spaced plastic slats (Kroll, 1984). As the subject jumps and hits the slats, they are displaced rotationally around a metal pole and the investigator can measure jump height within a half inch of the exact height of jump. At the end of each jump, the investigator replaced the last slat moved and the one below it to insure subjects had reached their previous maximum. The Vertec was used for training purposes only, not for vertical height testing; (a) because it was unknown how reliable the Vertec would have been, and (b) using the marked board measured to the 1/4 inch was more accurate.

Testing

Subjects were pre and post tested for weight, height, one-hand standing reach, and standing vertical jumps. The one-hand standing reach was measured by having subject stand upright, facing the wall, feet flat on the ground and measure to the finger tip (middle finger) with the arm extended upward (Fox & Mathews, 1981). The highest height attained in three extend and reach attempts was recorded. The stand and reach test was conducted in the training room.

Vertical jump performance was assessed in the gymnasium where the subject was instructed to jump straight up as high as possible (hands on hips at

start) for one practice and three trial jumps (Fox & Mathews, 1981). These measurements were taken on a board, marked in feet and inches to the nearest 1/4 inch which was placed on a wall that extended four feet from the main wall and seven feet above the ground, so that the subjects would not be inhibited by hitting the wall. For each trial, the subject: (a) chalked the fingers of the preferred hand with a colored chalk, (b) stood facing the wall behind a line 3 inches in front of the board, (c) placed her feet approximately shoulder-width apart and bent her knees to approximately 90 degrees, and (d) jumped as high as possible touching the wall with the preferred hand. The maximal vertical jump was determined by taking an average of three jumps, and the jump height was calculated by subtracting one-hand standing reach from mean vertical jump height. The vertical jump heights were assessed one week before and one week after the eight week training session. Prior to all testing, all three groups warmed-up with four minutes of light jogging around the gym, stretching of the calves, quadriceps, and hamstrings.

The leg press training group were tested for maximum weight pressed in one repetition (1RM), and a percentage of that weight pressed was the subjects initial starting weight. Initially, each subject's seat was adjusted so that her knees were bent at 90 degrees. To determine the subject's 1RM the investigator had her press with the maximum weight she believed she could lift in one lift (Palmieri, 1987). Weight was added or taken off the machine depending on the ease or difficulty of the attempt. The subject rested until they felt ready to successfully lift the weight, but no more than one minute was given between lifts.

The CMC Shuttle 2000 group were tested for the proper apparatus resistance by bounding successfully 1 RM to a mark designated by the investigator which allowed for good extension of the surgical tubing (1 1/2 feet

from the foot plate). Resistance was given by eight surgical tubes which were added or subtracted depending on the ease or difficulty with which the subject reached the designated mark.

Jump Training

All three groups ST, LP, and JTO performed jump training exercises three times per week; this was the only training the JTO group did. Each group participated so that "learning" could be eliminated as a factor for the increases in vertical jump ability. Jump training sessions began with a warm-up which consisted of four minutes of light jogging around the gym, stretching of the calves, quadriceps, and hamstrings, and concluded with jumping in place for ten seconds. The LP and ST groups began their workouts with jump training prior to their resistance training.

Subjects performed two types of vertical jumps. Kroll (1984) believes it important to measure both the standing completely stationary two foot jump as well as the running jump, which allows a two step approach. "This is because the 'heel-toe' conversion of momentum from the horizontal to the vertical is so critical to success in most sports requiring vertical jumping" (p. 19). Subjects were encouraged to improve their maximums each day, and were required to complete five successful jumps at their previous best or 10 attempts, whichever came first. The second jump technique used was the approach jump. Subjects performed jumps using a 2-step approach, a one foot take-off, and a single-arm jump and reach to simulate a basketball lay-up (Chu, 1986). Based on studies done by other researchers (Blattner & Noble, 1979; Clutch et al., 1983), the stationary two foot jump was the method used for testing. The Vertec device was used in training to determine the maximum heights achieved for both techniques.

Universal Leg Press Training

During training, each subject was instructed on the proper technique for lifting to prevent injury (Appendix C). The exercise was performed with a slow smooth/concentrated motion, resting between sets as additional weight was added. The protocol for this exercise training included three sets of six to ten repetitions using concepts from Delorme and Watkins (1948) principles of progressive resistance training. The investigator chose to begin at a higher percentage of maximal weight than Delorme's protocol because the training period consisted of only eight weeks of training.

Set 1 consisted of 10 repetitions at 60% of 1RM

Set 2 consisted of 8 repetitions at 70% of 1RM

Set 3 consisted of 6 repetitions at 80% of 1RM

When the subject pressed three sets of ten at the various loads without difficulty (determined by investigator), then additional weight was added in each of the sets and the subject began the 10, 8, 6 repetitions. Workouts were recorded on a worksheet to structure workouts based on previous height attained, and previous amount of resistance or weight used (see Appendix D).

CMC Shuttle 2000 Training

The Shuttle 2000 was designed so that the subject lies supine approximately two inches from the floor. There is a foot rest which is perpendicular to the base of the apparatus and approximately 1 1/2 feet high; the feet are pressed against foot rest while the buttocks remain on the base. The foot plate can be moved horizontally so that the amount of flexion in the knees can be adjusted by the investigator. There are up to eight surgical tubes used to apply resistance. The subject pushes off the foot rest and slides up and down in the horizontal plane (gravity eliminated).

The protocol for this exercise session consisted of the subject lying supine with knees flexed at a 90 degree angle and the feet approximately shoulder width apart on the foot rest. During the first four weeks of the experiment, the Shuttle group performed three sets of ten repetitions utilizing an explosive/quick two foot bounding method. The final four weeks consisted of the subjects performing three sets of ten repetitions using a one foot take-off, therefore executing three sets of ten on each leg. One tube of resistance was added when the subject could bound three sets of ten to the designated mark (approximately 1 1/2 feet from the foot plate) on the apparatus without difficulty.

Analysis of Data

Mean measures and variability measures were calculated for each group for jump and reach heights. Statistics utilized to descriptively examine collected data were descriptive statistics on subjects age, weight, height, standing reach, and vertical jump scores. In addition, reliability was obtained on post- test scores using Coefficient Alpha on three scores per person. Parametric assumptions were examined for all planned tests. The planned tests included: (1) one-way ANOVA on pre-test scores. If scores were significantly different an ANCOVA would be needed to examine post-test scores; (2) one-way ANOVA on post-test scores to examine the null hypothesis; and (3) the investigator was also interested in improvement within protocol therefore, a dependent t-test was planned for each group.

Chapter IV

Results & Discussion

This study was conducted to investigate the differences between strength training with the CMC Shuttle 2000, Universal leg press machine, or jump training in relation to increasing vertical jumping ability. The data was processed by utilizing the Apple Stat program in the San Jose State Human Performance Department.

Descriptive Statistics

Table 1 shows the mean subject characteristics in each of the three groups, according to : age, weight, height, one hand standing reach, and vertical jump. All three groups were similar in age, weight, height, and standing reach. Subjects who missed more than three training sessions throughout the eight weeks of the study were eliminated from further participation. Of the 48 subjects, two of the subjects missed one training session each, and made-up the absence by working out the next day.

Table 1

Subject Characteristics, Means and Standard Deviations:

Group	N	Age (yrs)	Wt. (lbs)	Ht. (in)	Stand Reach (in)
Leg Press	16	20.3 (2.27)	141.6 (24.46)	65.6 (3.02)	84.7 (3.71)
Shuttle	16	21.6 (2.8)	136.2 (14.88)	65.0 (2.92)	84.3 (3.38)
Jump	16	19.4 (1.15)	142.9 (16.21)	65.6 (3.29)	84.9 (3.67)

Non-Parametric Test and Reliability:

Since parametric assumptions were not met, the Kruskal-Wallis test on pre-test scores was used. It showed that the groups were not significantly different 2.5 ($p < \chi^2 .05$); therefore, the null-hypothesis could not be rejected.

Coefficient Alpha was computed for the post-test vertical jump scores in order to determine the consistency of the measurements. The coefficient ($R=.86$) indicated good consistency.

ANOVA

The investigator violated the normality assumption, but thought the test was robust enough to continue. Since the pre-test scores were not significantly different, an ANOVA was conducted on the post-test scores to examine null hypothesis. Table 3 presents the critical F ($p < .01$) at 5.18, and the degrees of freedom at 2 and 45. The results of the post- test analysis of variance on post-test scores showed no significant difference ($p < .01$) in means across the groups with an F of 1.67. Therefore, there was no significant difference across the various training protocols in post-test vertical jump.

Table 2. Summary of Analysis of Variance on Post-Scores of Jump Height

Source of Variation	SS	df	MS	F*
Between Groups	27.26	2	13.63	1.67
Within Groups	366.34	45	8.14	
Total	393.60	47		

* for significance at $p < .01$, critical F value= 5.18

Dependent t-Test

The investigator violated the normality assumption, but thought the test was robust enough to continue. The dependent t -test for significance was used to identify differences between pre-test vertical jump and post-test vertical jump scores. A significant difference was found for all groups ($p < .01$), with a critical t value of 2.95. Table 3 presents the means of pre and post test scores, the mean difference, and the t value.

Table 3

Effects of Training on Standing Vertical Jump Test:

Group	N	Pre Test M score (in)	Post Test M score (in)	M Difference (in)	t Value#
Leg Press	16	14.6	15.4	.8	8.04*
Shuttle	16	15.1	16.3	1.2	8.1*
Jump	16	13.6	14.5	1.0	9.7*

* critical t value = 2.95

*significant at $p < .01$

t -test done by subtracting pre from post test.

The results indicated that all programs improved vertical jump performance. Mean gains of .8, 1.2, and 1.0 inches resulted from Leg Press, Shuttle, and Jump Training programs, respectively (see Table 2). The average vertical jump improved 6%, 8%, and 7% from the initial to the final test for Leg Press, Shuttle 2000, and Jump Training Only, respectively.

Discussion. The findings of this study are in agreement with other researchers, indicating that the vertical jump can be improved by practicing maximum vertical jumping (Semenick & Adams, 1987), and by additional

sport-specific training techniques, including weight training (Blattner, et al., 1989; Chu, 1986; Clutch, et al., 1983). Kroll (1984) found that vertical jump can be expected to improve 1 to 2 inches during a six to eight week strength program, which is similar to increases in this study.

Knudtson (1957) used female basketball players to investigate the effects of weight training and jumping exercises on vertical jump. After six weeks of weight training and jumping, there was a significant increase in vertical jumping performance.

The statistical analysis showed no significant difference across the means between the Leg Press, Shuttle 2000, and the Jump Training Only groups. Thus, the null hypothesis, which states that there would be no significant difference in mean vertical jump heights by physical education students as a function of training protocol (progressive resistance weight, Shuttle 2000, or jump training) cannot be rejected.

Pestolesi (1989) found similar results, when he looked at high school athletes and the effect of weight training and jump training on vertical jump heights. He found no significant difference between the groups, but significant increase in vertical jump height of .63 for the weight training group, a .45-inch increase for the jump group ($p < .01$).

Clutch et al. (1983) divided undergraduate students in beginning weight training classes into three groups; group I maximum vertical jumps, group II 0.3 m depth jumps, and group III .75 m depth jumps. In addition, all groups weight trained. The three groups resulted in increases in vertical jump; however, depth jumps, when combined with weight training, were no more effective than a program of regular maximum jumps.

Yessis (1978) found the following factors to affect jumping height: (a) the time needed to achieve force equal to body weight, (b) static strength, (c) the

working angle in the knee joint, (d) body size (height & weight), and the player's qualification. The various differences between the groups at the onset of the investigation might have played a role in the outcome. An example of this is shown in Table 2, when looking at the mean scores of the pre-test data, the Shuttle group appears to have a higher mean jump score, and therefore their amount of improvement might be limited, whereas the other two groups had more room for improvement because of their initial pre-test score.

Chapter V

Summary, Conclusions and Recommendations

Summary

The purpose of this study was to determine if vertical jump heights differed as a function of the following training methods: the CMC Shuttle 2000, Universal leg press machine, or jump training alone. The CMC Shuttle 2000 is used to increase leg strength by training in a horizontal position without the gravitational forces. The Shuttle 2000 duplicates critical sport movements such as running and jumping by producing greater and more sustained power burst without the detrimental impact on the lower lumbar, knees, and ankles.

The subjects in the study were female college students from San Jose City College and West Valley College, who participated on the women's basketball team, softball team, and six of the students were students in physical education classes. The experiment was conducted within a span of ten weeks. The first and tenth week were used for testing: measuring weight, height, one-hand standing reach, and vertical jump. The training regimen consisted of eight weeks of training, three days a week for approximately 45 minutes each session,

The Universal leg press training consisted of three sets of 6-10 repetitions at 60%, 70%, and 80% of one repetition maximum. When subjects could lift three sets of ten without difficulty, additional weight was added. The same procedure was used for the Shuttle 2000 group, except that elastic cords provided the resistance. All groups participated in the jump training, so that the learning factor could be eliminated.

Conclusions

The results of this investigation indicated that all training methods can

improve vertical jump heights, but there was no significant difference in mean jump heights across the Leg Press, Shuttle 2000, or Jump Training Only groups. Thus, the Shuttle 2000 is as effective as other training methods, and might be used with athletes who decrease jarring and the stress on the lower body during training.

Recommendations for Further Study

It is recommended that further investigation is warranted in regard to the CMC Shuttle 2000. The advantages of training on the Shuttle 2000, despite the fact that it is no more effective than the other methods might be: (1) the implications of decreased detrimental effects from training to the serious athlete, (2) the investigator found that the female subjects enjoyed training on this apparatus because it was different, (3) it is a type of resistive exercise that can be used year round.

Suggestions for further study on the Shuttle 2000 include: (1) examine the effects of bolting the Shuttle apparatus to a metal frame so that it won't move on the floor during training; (2) biomechanically measure the amount of resistance in the eight surgical tubes, because this can be a limitation to stronger subjects; (3) repeat this study and match groups by pre-test scores to get more similar means at the beginning; (4) test the female elite athlete or female college athlete who is training for a specific sport; and (5) repeat this study using a larger sample size for greater statistical power.

In regards to the leg press training, it is suggested that the method of determining 1RM max was difficult for some subjects. The effects of training for longer than eight weeks should also be examined. Research utilizing the Shuttle 2000 to determine the effectiveness of various workout protocols for specific training purposes, should be undertaken.

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APPENDIX A

Subject Informed Consent in Accordance with the San
Jose State University Institutional Review Board
for the Protection of Human Subjects

A COMPARISON OF THREE TRAINING PROGRAMS
FOR INCREASING VERTICAL JUMP

Principle Investigator: Terri Lynn Oberg

Informed Consent Form

You are invited to participate in a study which will possibly improve your vertical jumping ability through a training program.

If you decide to participate, you will first be measured for weight, height, and for one-hand standing reach. These measurements will be taken at San Jose City College under the supervision of Terri Oberg, who is conducting this research project, and an athletic trainer. You will also be tested for standing jump and an approach (2-step) jump measurements. The total time for testing should take between 15-20 minutes.

Three days later, you will be tested for 1RM (repetition maximum) to determine the maximum weight lifted with both legs on a leg press machine. The actual training will consist of two jump training exercises (standing and approach), and an isotonic training on the leg press or shuttle machine consisting of three sets of six to ten repetitions three times per week for a period of eight weeks. A final post test will be given, testing your standing and approach jumping ability.

The exercise in this study may be accompanied by some physical muscle soreness, and is expected to subside after several days. There is also the risk of sprains and strains to the lower extremities because jumping is involved. If any abnormality is observed by the investigator or reported by you, the test will

be discontinued. By participating in this study, one can increase general fitness, increase strength in lower extremities, learn jumping techniques, and acquire knowledge of strength training.

If you have any questions regarding procedures please ask for explanation. Any information in connection with this study that can be identified with you will remain confidential and will be disclosed only with your permission or as required by law.

My consent is given voluntarily without being coerced; I may refuse to participate in this study or in any part of this study, and I may withdraw at any time, without prejudice to my relations with San Jose State University or San Jose City College.

Any questions about my participation in this study will be answered by Terri Oberg (408) 288-3730 x3828. Complaints about the procedures may be presented to Dr. Greg Payne, Graduate Coordinator (408) 924-3028, or Dr. Craig Cisar, Department Chair (408) 924-3010. For questions or complaints about research subject's rights, or in the event of research-related injury, contact Serena Stanford, Ph.D. (Associate Academic Vice President for Graduate Studies & Research) at 924-2480.

I have received a copy of this consent from for my file.

I HAVE MADE A DECISION WHETHER OR NOT TO PARTICIPATE. MY SIGNATURE INDICATES THAT I HAVE READ THE INFORMATION PROVIDED ABOVE AND THAT I HAVE DECIDED TO PARTICIPATE.

DATE

SUBJECT'S SIGNATURE

INVESTIGATORS SIGNATURE

APPENDIX B
Student Information Questionnaire

APPENDIX B

Subject Information Questionnaire

NAME: _____ AGE: _____

ADDRESS: _____

DAY PH# () _____ EVE PH# () _____

Have you weight trained in the last year? Yes _____ No _____
 If so, are you currently weight training now? Yes _____ No _____

What time and days will you participate?

TIME: _____ / _____ / _____

 do not write below this line

	Group	1	2	3
Date: _____				
Weight: _____				
Height: _____				
Stnd Rch: _____				
Vertical Height: _____				
1) _____ 2) _____ 3) _____				
average of heights _____				

APPENDIX C

Proper Lifting Techniques

Appendix C

Proper Lifting Techniques

1. Make sure all major muscles are properly stretched and warmed up.
2. Never lock a joint into full extension. Make sure there is a slight bend.
3. Breathing is a must! Breathe out at maximal effort.
4. Smooth concentrated movements are a must! Do not perform ballistic, jerky motions when exercising.
5. rest approximately 20-30 seconds between sets.
6. If you feel any pain while exercising, stop and notify the investigator immediately!!!

APPENDIX D
Subject Strength Training Worksheet

PLEASE NOTE

**Page(s) not included with original material
and unavailable from author or university.
Filmed as received.**

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APPENDIX E
Raw Scores of Subject Characteristics, for Pre-Test, Post -Test and
Differences
for Vertical Jump Heights

Raw Scores of Subject Characteristics, Pre-Test, Post -Test, and
Differences for Vertical Jump Heights (VJ)

Group	Age (yrs)	Wt. (lbs)	Ht. (in.)	One-hand Reach (in)	Pre-Test VJ (in)	Post-Test VJ (in.)	Diff.
L	20	140	68.5	88.5	11.1	12.5	1.4
L	19	126	60.25	78.75	13.9	14.6	.8
L	22	141	67.25	87.25	11.1	12.0	.9
L	20	128	70.25	89.5	17.1	18.1	1.1
L	25	109	65.25	86.25	14.1	15.2	1.1
L	20	108	66.0	85.0	13.8	15.3	1.5
L	19	123	63.0	81.25	15.3	16.1	.9
L	19	147	63.0	81.5	12.0	12.7	.7
L	18	156	63.75	81.0	17.6	18.3	.7
L	19	161	68.0	87.0	14.7	14.7	0
L	26	120	60.25	79.0	17.5	18.6	1.1
L	20	166	68.5	88.5	13.8	14.4	.6
L	18	164	66.25	88.5	15.8	16.3	.5
L	19	203	67.5	88.5	15.5	16.1	.6
L	20	138	63.75	87.0	12.6	14.2	1.6
L	20	135	68.5	83.25	17.9	18.3	.4
S	19	130	66.5	87.5	18.9	21.5	2.6
S	22	139	65.5	83.5	20.5	21.8	2.6
S	20	149	63.75	83.75	19.2	20.2	1.0
S	19	140	69.5	90.75	17.8	20.1	2.3
S	20	129	61.5	82.25	11.7	12.8	1.1
S	18	137	67.5	84.5	14.4	15.8	1.4
S	18	150	64.75	83.5	14.0	14.6	.6
S	19	98	60.0	82.0	6.9	7.3	.3
S	19	109	60.5	77.25	15.1	16.9	1.5
S	25	145	67.0	87.5	15.6	16.8	1.2
S	25	154	67.5	88.0	14.3	15.2	.9
S	25	130	61.5	81.0	15.4	16.7	1.3
S	24	146	63.5	83.5	14.8	15.7	.9
S	25	135	67.0	85.0	12.9	13.6	.7
S	24	145	67.75	89.0	13.9	15.3	1.4
S	23	143	67.0	85.0	16.0	16.6	.6
J	20	146	69.25	90.0	15.6	15.8	.2
J	19	131	61.5	82.5	7.2	7.8	.6
J	18	142	61.25	78.0	12.5	13.3	.8

APPENDIX E (con't)

Group	Age (yrs)	Wt. (lbs)	Ht. (in.)	One-hand Reach	Pre-Test VJ (in)	Post-Test VJ (in.)	Diff.
J	19	145	67.5	86.25	11.2	13.1	1.9
J	19	145	63.0	83.5	13.0	14.0	1.0
J	19	130	61.0	79.5	11.4	12.8	1.4
J	20	122	66.5	86.5	14.2	15.1	.9
J	20	162	66.0	85.5	16.6	17.4	.8
J	18	180	69.75	90.5	9.8	10.3	.5
J	18	119	63.5	84.0	14.7	15.7	1.0
J	19	165	69.0	89.0	13.6	14.5	.9
J	18	125	60.25	80.0	16.5	17.3	.8
J	20	140	67.0	84.0	17.4	18.2	.8
J	20	147	68.0	87.25	15.0	16.0	1.0
J	21	140	68.25	85.5	14.0	15.0	1.0
J	22	148	67.5	87.5	14.3	15.1	.8

L= Leg Press Training Subject
 S= Shuttle 2000 Training Subject
 J= Jump Training only subject
 Diff= Post-test VJ minus Pre-test VJ