THE EFFECT OF WEARING STRENGTH SHOES DURING PLYOMETRIC TRAINING ON VERTICAL JUMP PERFORMANCE

by

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(ABSTRACT)

The purpose of this investigation was to determine whether plyometric training in Strength shoes (Strength Footwear, Inc.) increased vertical jump performance, decreased elasped time in the 40 yard dash and increased calf circumference. Thirty-one male and female college-aged students served as subjects. Twenty-two subjects, enrolled in a college physical fitness class, were randomly assigned to one of two experimental conditions: Strength shoe (S) group or traditional shoe (T). A third condition, a control (C) group consisted of 9 volunteers enrolled in a college badminton class. Subjects in both experimental conditions trained for ten weeks, three times per week, 45 minutes per day. Subjects performed plyometric drills designed to increase vertical jump and increase running speed. Subjects were pre-tested and post-tested for vertical jump performance, speed in the 40 yard dash, and right and left calf circumference.

There was no significant ($p>.05$) change in either experimental group from pretest to posttest on vertical jump performance, speed in the 40 yard dash and right and left calf circumference. It was concluded that, regardless of the footwear being worn, plyometric

training did not increase vertical jump performance, calf circumference or decrease the elapsed time in the 40 yard dash of the participants.

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CHAPTER 1

Introduction

Power is a key component in physical activity. Power is the ability to generate maximum force in a minimum amount of time. It is dependent upon the strength of the muscle involved and the speed of the movement.

Power is a functionally significant component in various sporting events. Rapid, forceful movements are required for such activities as throwing a baseball, swinging a bat or golf club, kicking a soccer ball, punting a football, jumping in basketball, volleyball and track events and in sprinting activities.

Many athletes when training tend to emphasize the strength component of power more than the speed component. There has been much research in the area of power training. Methods proposed to increase power are: isometric training, isotonic training, isokinetic training, and plyometrics. Much of the research has been in the area of isokinetics and isotonics.

Studies have shown that increases in vertical jump are not just related to increases in strength. (Considine & Sullivan, 1973; Eisenman, 1988; McClements, 1964) "The contribution of strength to power is minor and power is a more complex entity"(McClements, 1964). Plyometrics is designed to increase both the strength and speed components of power. Plyometrics, an isotonic method, was developed specifically to "bridge the gap between strength and speed" (Wilt, 1975; Scoles, 1978). The principle behind plyometrics is that maximal tension develops when a muscle is stretched rapidly. There are three phases to plyometric training: the eccentric (lengthening) phase, the ammorization (transition) phase and the concentric (shortening) phase. The muscle is pre-stretched in the eccentric (lengthening) phase. The faster a muscle is forced to lengthen the greater tension it exerts (Wilt, 1975). Leg muscles must be trained to react as rapidly as possible. "Plyometric training appears to maximize the coordination of neuromuscular skills and muscular strength" (Brown, et al., 1986).

Statement of the Problem

Recently, Strength Footwear, Inc. brought to the market a training shoe, called the Strength shoe, which is designed to enhance certain components of power. These components are speed, agility and power. Strength Footwear claims that by wearing their shoe and training in it for 10-12 weeks an individual can increase their vertical jump, increase the diameter of the calf muscle and decrease time in the 40 yard dash. Vertical jump tests and sprinting tests have been used as an indirect way of measuring power. Therefore, the purpose of this study was to determine the effect of wearing Strength shoes during a sport specific plyometric training program. Specifically, this study was designed to determine whether plyometric training in Strength shoes' increases vertical jumping performance, decrease speed in the 40 yard dash and increase calf circumference.

Significance of the Study

This study was conducted to determine whether Strength shoes actually can increase speed and power. Years of research has been devoted to training methods of increasing vertical jump. In general, the increases reported in these studies have ranged between .7 to 3.2 inches (Eisenman, 1978). Strength Footwear, Inc. claims that the Strength shoe can increase vertical jumping performance from 5 to 9 inches, decrease time in the 40 yard dash by two-tenths of a second and increase calf circumference up to two inches. These claims, if valid, suggest that training in these shoes, will provide the athlete with an advantage over others who train without this equipment.

Strength shoes are very costly and the consumer is entitled to know the value of their purchase. Consumers need to know if training in Strength shoes will enhance athletic performance.

Research Hypothesis

To carry out this investigation the following hypotheses were formulated:

Ho: Wearing the Strength shoe during a 10 week plyometric training period will have no effect on vertical jumping performance.

Ho: Wearing the Strength shoe during a 10 week plyometric training period will have no effect on sprinting performance as measured in a 40 yard dash.

Ho: Wearing the Strength shoe during a 10 week plyometric training period will have no effect on calf circumference.

Delimitations

The following delimitations were imposed by the investigator:

1) Subjects were 31 college aged male and female students.
2) The response variables chosen for evaluation were:
    a) vertical jumping height
    b) 40 yard dash time
    c) calf circumference
3) The subjects trained plyometrically 3 days a week for 10 weeks.

Limitations

The following limitations affect the generalizations of the findings:

1) The sampling technique employed by the investigator limited the generalizability of this investigation.

Basic Assumptions

1) Subjects gave a maximal effort during the pre- and post- vertical jump tests.
2) Subjects gave a maximal effort during the pre- and post-

40 yard dash tests.

3) Subjects refrained from exercise/training outside of the prescribed training session.

Summary

Power is a functionally significant component in many sporting events. Coaches and trainers are constantly looking for methods to increase power. Power is dependent upon the strength of a given muscle and the speed of contraction. Plyometrics consists of drills designed to increase both strength and speed. Strength Footwear, Inc. has developed a shoe that they claim will increase certain components of power. This investigation was designed to determine the effect of wearing Strength shoes during a 10 week plyometric training program. Specifically, this investigation was designed to determine whether training in Strength shoes will increase vertical jumping performance, decrease speed in the 40 yard dash and increase calf circumference.

The answer to this research question is important for coaches, trainers and athletes who are constantly seeking an advantage over competitors. These shoes may make a significant contribution in performance or they may just be a waste of money.

CHAPTER II

Literature Review

This chapter is a review of related literature. It provides a historical perspective of the measurement of power, the mechanics involved in the vertical jump test and sprinting performance and the mechanisms utilized to increase power.

Measurements of Power

In 1921, Dr. D. A. Sargent designed a test that claimed to measure the physical efficiency of man. This test was called the Sargent Jump test. In 1924, L.W. Sargent did research on the Sargent jump test and concluded that it was a "test of neuromuscular efficiency involving strength, speed, coordination and driving power" (Sargent, 1924). This test later became popular as an effective instrument of measuring power in physical education. Muscular power is often referred to as explosive power. It involves strength and quickness. Power is specific to the muscle group involved (Jensen & Hirst, 1978). There have been many methods used by physical educators to measure power. The Sargent jump test or vertical jump and reach test, the standing broad jump and sprinting for time have been used by teachers and coaches to measure power (Considine, 1971; Gray, et al., 1962; Jensen & Hirst, 1978). Some examples of more functional tests have been the softball throw or shotput for total body power emphasizing the upper extremities. The football punt has also been used as a measure of leg power (Jensen & Hirst, 1978).

R. Margaria developed a test to determine maximal anaerobic power in short bursts of activity. This test involved placing a switchmat on the 4th and 6th step of a flight of stairs. The subject would run the stairs and the time between the 4th and 6th step would be recorded. Power was determined using the following equation: Power = Body weight x vertical distance/time elapsed. As the time decreased, then the power increased. This was considered a test of overall power (Margaria, 1966). A study was later conducted (Coutts, 1975) that compared the relationship of the Margaria test and the vertical jump and reach test. The study was conducted on the Canadian national female volleyball team in which they preformed both tasks and the results were correlated. Coutts reported a .69 correlation coefficient ($p<.05$). These results indicate that the Margaria test for overall power is not significantly related to the vertical jump and reach test that measures leg power.

The relationship between the 50 yard dash and the Margaria power test was also investigated. The results indicated a high relationship ($r=.97$) between the two measures as a test of power (Fox & Matthews, 1981). However, Kalamen reported an insignificant relationship between the Margaria power test and the Sargent Jump Test when merely height of jump is recorded.

The vertical jump test is used frequently as a measure of leg power, however, it is not a true measure of pure leg power. This is because of the contribution of the arms thrusting upward and the extension of the trunk which allow for greater vertical jump (Considine, 1971; Gray, et al., 1962). When administering a test to subjects it is extremely important to have thorough, standard instructions so that the performance of each jump is consistent when compared to previous jumps and other individuals.

Biomechanical Analysis of Vertical Jumping

Understanding the relative contribution of a muscle group to the performance of an activity is important for coaches, physical therapists, athletic trainers or anyone who is designing an exercise program. Researchers have attempted this using several different analysis techniques such as the segmental technique, the work-energy approach, etc. This section will report the results of these different techniques on the analysis of musculature contributing to the performance of the vertical jump.

Two different types of vertical jumps are frequently used, the squat jump (SJ) and counter-movement jumps (CMJ). The CMJ begins from an upright posture and involves, in one continuous movement, first squatting down and then extending the knee and ankle joints. The SJ begins in a squat position with knees bent and involves extension of knee and ankle joints. "The major difference between these two techniques is the manner in which the powerful knee extensors are used; namely, the squat jump involves only a concentric contraction of the knee extensors, whereas a CMJ requires an eccentric-concentric sequence" (Enoka, 1988).

Using segmental analysis, Luthanen and Komi (1978) studied the vertical jump with respect to the contribution of the different body segments to the forces acting on the whole body center of gravity. They reported great variance among the eight subjects in total performance although they were similar in the utilization of the performance of individual segments. The results showed that maximum take off velocity was caused by the different components as follows: knee extension 56%, plantar flexion 22%, trunk extension 10%, arm swing 10% and head swing 2%.

Hubley and Wells (1983) used a work-energy approach to determine individual joint contributions to vertical jump performance. They studied the relative contributions of a muscle to the total performance output of the vertical jump. More specifically, measurement were taken of mechanical work which was indicative of a dynamic contraction and joint moment which was indicative of the net muscular activity about a given joint. Six subjects performed two CMJs and two SJs. Results showed the hip and knee extensors had the highest average work output for both jumping conditions. The knee contributed on the average 49% to the total work with the hip contributing 28% and the ankle contributing 23%. However, they did note large individual variability in the hip and knee and less variability with the ankle. Hubley and Wells (1983) concluded that the knee extensors were "the largest single contributor" to the vertical jump. The hip and ankle joints were responsible for the remaining 51% and therefore important contributors to the total work output. "There is a tendency in both research and training programs to concentrate on the knee extensors and flexors; often neglecting the hip and ankle muscle groups. Quite possibly a re-examination of some experimental and training protocols could result in an enhancement of the desired output" (Hubley & Wells, 1983).

Robertson and Fleming (1987) studied the contribution of the leg muscle groups to the external work done in vertical jumping. During this study the subjects performed counter-movement jumps and the subjects arm movement was restricted. The results of vertical jump contribution were 40.0% for the hip musculature, 35.8% for ankle musculature and 24.2% for the knee musculature. These results indicate that the muscles crossing the knee joint are not as important in contributing to the net work done during jumping as the ankle and hip muscles (Robertson & Fleming, 1987). These results differ from other research where the knee musculature has been shown to be more significant when compared to the ankle and hip musculature.

The vertical jump is initiated by an acceleration of the trunk as a result of activation of the hamstrings. At the end of the hamstring activity, the knee extensors are activated. The angular velocity of the trunk on the velocity of the center of gravity decreases. Further acceleration by the gluteus maximus is opposed by the rectus femoris. The gluteus maximus continues to deliver power that is used for knee extension and plantar flexion by the tendons of the rectus femoris and the gastrocnemius, respectively

(Van Ingen Schenau et al., 1987; Gregoire et al., 1984).

Van Ingen Schenau et al. (1987) studied the role of bi-articular muscles in the vertical jump. Ground reaction forces were measured with a Kistler force plate while subjects performed counter-movement jumps. Electromyographic patterns of the vastus lateralis, rectus femoris and both heads of the gastrocnemius were recorded with surface electrodes. In the results, they showed the velocity differences between the hip and ankle(V_{HA}), between the ankle and ground(V_{AG}) and between the hip and ground(V_{HG}). The velocity difference V_{HA} reached maximum at a mean knee angle of 132 degrees. the velocity difference between the ankle and ground was due mainly to plantar flexion. Shortly before lift-off, there is an increase in the velocity difference V_{AG}. This allows the velocity difference V_{HG} to continue to increase despite the decrease in V_{HA}.

Van Ingen Schenau et al. (1987) concluded that to prevent hyperextension of the knee, the actual knee angular velocity has to be decelerated to zero velocity at full extension. The gastrocnemius plays an important role in the last stages of push-off. Due to a fast plantar flexion, the hip can be accelerated up to 25ms before lift-off. There is a phase lag between the increase of the gastrocnemius and the increase in the velocity between the ankle and the ground. This is caused by an electro-mechanical delay of 30-50ms and by the catapult-like action of the Achilles tendon (Van Ingen Schenau et al., 1987). The gastrocnemius opposes knee extension and reinforces plantar flexion. Because the gastrocnemius is a bi-articular muscle it allows the knee extensors to contract and deliver power for plantar flexion. This optimal use of the capabilities of all these muscles would be impossible if man had only mono-articular muscles (Van Ingen Schenau et al., 1987; Gregoire et al., 1984)

Gregoire et al. (1984) studied the transfer of power in the lower body during vertical jumping. More specifically, the transfer of power through the gluteus maximus to the rectus femoris to the gastrocnemius to the ankle joint. Gregoire et al., (1984) found vertical jumping power was delivered by the monoarticular extensors of the hip and knee joints distally via the biarticular muscles to the ankle joints. At the end of push-off, there is a high plantar flexion velocity and high knee and hip extension velocities resulting in relatively low contraction velocities for the biarticular muscles. As a consequence, the biarticular muscles deliver high forces, which allows them to transport energy in a proximodistal direction. "This power transport is essential in the execution of explosive movements" (Gregoire et al., 1984).

Stretch-Shortening Cycle

The stretch-shortening cycle (SSC) is a normal type of muscle function which occurs both in running and jumping. In the SSC, there is an eccentric contraction followed by a concentric contraction. The preceding eccentric contraction allows for the storage and utilization of elastic energy. This series of action allows the final action to take place with greater force or power output than would a movement with no prior eccentric contraction or stretch (Jones, 1986).

The enhancement of performance in the SSC can be attributed to the combined effects of restitution of elastic energy and stretch reflex potentiation of muscle. Any increase in myoelectrical potentiation results in an increase in elastic potentiation (Jones, 1986).

To determine whether there will be an increase in mechanical efficiency or actual performance due to the SSC, the efficiency of the eccentric exercise must be examined. Isolated eccentric exercise has a very high efficiency, however, it is seldom constant and exhibits both inter- and intra-individual differences that depend on the stretch velocity of the eccentric contraction.

Bosco and Viitasalo (1982) studied the potentiation of myoelectrical activity of human muscles during three types of vertical jumps. The jumps performed were from a static squatting position (SJ), with a counter-movement (CMJ), and after dropping from five different heights (DJ). Electromyographic (EMG) activity was recorded from gluteus maximus, rectus femoris, vastus lateralis, vastus medialis, and the gastrocnemius.

During the CMJ and DJ an eccentric contraction precedes the concentric contraction. When this happens, there is a storage and utilization of elastic energy (Jones, 1986; Bosco & Viitasalo, 1982). The results of Bosco and Viitasalo's (1982) research did not show any constant pattern of myoelectrical potentiation at the individual muscle level. However, there was an increase in all muscle activity during the eccentric phase of the CMJ and DJ when compared to the SJ. They concluded this result as being "due to the reflex activity at the supraspinal level" (Bosco & Viitasalo, 1982). Viitasalo and Bosco (1982) conducted another study in which they suggested that muscle structure may dictate jump height. They divided the subjects into one group with predominately slow-twitch fibers and one group with predominately fast-twitch fibers. They performed different types of vertical jumps including counter-movement jumps and drop jumps. Viitasalo and Bosco (1982) reported no significant difference between muscle fiber type and jumping height during counter-movement jumps. However, they did discover a difference between the two groups in jumping height when performing drop jumps. The "slow" group jumped higher in the drop jump condition, however, there was no real difference in the EMG activity of the muscles between the groups. Viitasalo and Bosco (1982) explained this as a difference in the utilization of the storage of elastic energy between the "slow" and "fast" groups. Part of the elastic energy is stored in the crossbridges between the actin and myosin filaments. Viitasalo and Bosco (1982) suggested that the difference between the two groups may be due to the lifetime of the crossbridge and the stiffness.

Certain conclusions can be drawn from the studies presented about the effect of the SSC. By increasing the stretch velocity you may be able to increase the efficiency of the eccentric exercise. There may be differences between the utilization of elastic energy in the SSC due to individual muscle types. There is also a difference in the myoelectrical potentiation of the muscles between individuals.

The ability to utilize stored elastic energy is affected by three variables: time, magnitude of stretch, and velocity of stretch (Enoka, 1988). There should be no time delay between the ECC and CONC contractions so that there is no loss of stored elastic energy. If the magnitude of the lengthening contraction is too great, a lesser number of crossbridges will remain attached following the stretch, and hence less elastic energy will be stored. The greater the velocity of the stretch, the greater the storage of elastic energy (Enoka, 1988).

Another possibility for the increase in positive work can be associated with an increase in the amount of available chemical energy. This is called the preload effect (Enoka, 1988). In an ECC-CONC sequence, the force at the beginning of the CONC phase is much greater, due to the preceding ECC activity, than the initial force had only a CONC contraction been performed. The initial force is greater in the ECC-CONC sequence.

It was concluded that both the storage and utilization of elastic energy and the preload effect (chemical energy) both contribute to improved performance in the CMJ. This was determined by comparing the vertical heights attained with one- and two-legged squat and counter-movement jumps. Results included the following: 1) Higher height was attained for both one- and two-legged CMJ than with the SJ; 2) Heights attained with the two-legged jumps were greater than those attained with the one-legged jumps due to greater muscle mass available (chemical energy); 3) Height jumped in the two-legged situations, however, was not twice that jumped in the one-legged jumps despite twice the leg mass available. However, because the height reached in the one-legged jump was greater than expected, "the difference must be due to some feature of muscle performance, that is, preload for the squat jump and preload plus elastic energy for the CMJ" (Enoka, 1988).

In order to understand the effects of elasticity in vertical jumping the soleus and gastrocnemius muscles were studied (Komi, 1991). The muscle tendon complex was modelled and it's velocity and length changes were studied. The soleus muscle is exposed to increased velocity and length changes compared to the gastrocnemius. This is due to the fact that the gastrocnemius in a bi-articular muscle and it responds to knee angle changes as well an ankle angle changes. Looking at the power generation of the muscle-tendon complex during push-off, more power was generated by the tendon than the muscle fibers. "Most of the mechanical work performed originates from elastic energy released from the tendon fibers during the push-off as a consequence of decreasing muscle force" (Komi, 1991). This elastic energy also originated from a muscular source; "the tendon fibers are stretched by high forces possible because of eccentrically acting muscle fibers" (Komi, 1991). Another source of energy is from the transport of energy through the knee extensor muscles to the ankle causing plantar flexion. Komi (1991) concluded that elastic energy plays an important role in human movements. Due to the elastic potential of the soleus and gastrocnemius during push-off of the vertical jump, high levels of power were actually measured at the ankle joint. A higher level of force may be delivered if the fibers are at an increased length. "It is likely that explosive movements such as jumping and throwing could not be performed adequately without the elastic potential of muscle-tendon complexes" (Komi, 1991).

Biomechanical Analysis of Sprinting

This section will summarize the phases involved in sprinting and the musculature involved in this movement. This section will also discuss the prediction of sprinting performance.

Mann (1981) conducted a kinetic analysis of sprinting. Fifteen highly skilled sprinters served as subjects. Subjects were marked with black dots at the wrist, elbow, shoulder, knee, hip and ankle joints. They were filmed in action in the saggital plane and a force platform recorded external ground forces on the body.

There are two phases to sprinting: the air phase, beginning at toe-off and ending with foot-strike and the ground phase, beginning at foot-strike and ending at toe-off. Results indicated that the air phase is dominated by the muscle activity of the knee extensors. The knee extensors work ECC to slow down the angular momentum of the leg and foot. They also work in a CONC manner during the swing through to help rotate the leg anteriorly. During the ground phase, the knee extensors briefly continue to cause flexion followed by an ECC contraction to slow down the negative vertical velocity of the body. Just before toe-off, the knee extensors are contracting concentrically but not with much force as to cause hyperextension of the knee. During the air phase, there was little activity of the muscles of the ankle. During foot-strike the plantar flexors are contracted ECC to slow down the negative velocity of the body. During toe-off, there is a CONC contraction to generate vertical and horizontal velocity forward.

Alexander (1989) reported the relationship between muscle strength and sprint kinematics in elite sprinters. Thirty-three subjects were measured for lower limb peak torque and average peak torque values. Correlations were made between strength variables and kinematic variables. A step-wise multiple regression was used to determine the best predictor of sprinting speed. Measurements were taken on hip flexion/extension, knee flexion/extension and ankle dorsi/plantar flexion. Results showed the peak torque scores by knee EXT muscles to have the highest relationship to sprinting speed in the male subjects (14) but not with the female subjects (9). Peak torque of the hip muscles and the ankle PF were not significantly related to sprint speed. The peak torque score of the DF were significantly related to sprint speed. Alexander (1989) concluded that strength of knee EXT muscles in a fast, CONC contraction was found to be a good predictor of sprint performance for both males and females. Additional predictors for males were strength variables for fast, ECC knee EXT and slow, ECC and CONC knee EXT. Additional predictors for the female was strength of the hip flexor in a fast, ECC contraction.

Mann et al. (1986) compared electromyographic data of the lower limb during jogging, running and sprinting. Fifteen subjects performed three trials at each speed. Subjects were filmed for a period of time from the 17th to the 23rd meters of the 35 meter runway. Data was taken from the gluteals, tensor fascia lata, quadriceps, hamstrings, gastrocnemius, tibialis anterior and the intrinsic muscles of the foot. Results showed that the iliopsoas was the major hip flexor and as the speed of running is increased, "it is the activity of this muscle that brings about the greatest change in the movement of the lower extremity in the line of progression" (Mann et al., 1986). The momentum of the flexing hip brings about EXT of the knee joint. The last part of knee EXT is brought about by a CONC contraction of the quadriceps. The length of quadriceps activity increases as the speed of gait is increased. The EXT of the knee joint is linked to the flexion of the hip to produce forward movement of the lower extremity. The muscles of the calf demonstrated similar activity at all speeds. During the swing phase, the tibialis anterior brings about DF of the ankle joint and following foot contact helps to stabilize the ankle joint. The gastrocnemius was active just prior to foot contact, providing stability to the ankle joint. Activity continued from foot contact to mid-support phase. During this time the gastrocnemius then undergoes a CONC contraction which initiates PF, which begins with the toe-off phase of support. The amount of PF occurring during activity of the was 6 degrees out of 33 degrees for sprinting. Based on this data, they concluded that little or no push-off was occurring from the posterior calf muscles. They theorized that the "majority of the forward propulsion during jogging, running and sprinting is brought about by the rapid hip flexion of the swing limb, rather than by the push-off of the stance limb" (Mann et al., 1986). This action combined with knee EXT, along with the action of the arms, propels the body forward.

Mann and Hagy (1980) studied the biomechanics of walking, running and sprinting. They studied hip, knee and ankle joint motions in the sagittal plane and electromyographic data from specific muscle groups. Results showed that as speed of gait increased, the length of the stance phase decreased. As the speed increased, the range of motion of the lower extremity increased. The body lowered it's center of gravity by increasing flexion at the hip and knee joints and increasing DF of the ankle joint. In sprinting, there was greater FLEX of the hip and slightly less EXT. In sprinting, there was increased FLEX of the knee and slightly decreased EXT of the knee. The activity of the quadriceps muscle increased as speed increased. During sprinting, the ankle joint was still in DF at the time of ground contact, then, there was a rapid PF so that the heels never touch the ground. There was also increased activity of the PF muscles during the swing phase compared to walking and running. "It almost appears as though the sprinter is using his legs as if they were spokes on a wheel, moving along on a very smooth course with the leg only in contact with the ground long enough to give him an instant of support as the body is accelerating forward" (Mann & Hagy, 1980).

Mero et al. (1992) reviewed the biomechanics of sprint running. The sprint run was divided into four phases: starting (take-off) phase, acceleration phase, constant speed phase and deceleration phase. At the beginning of sprint running it is important to generate a high amount of force/power and a high velocity.

During the beginning of the take-off phase, the gluteus maximus is very active. The rectus femoris muscle of the rear leg and the gastrocnemius muscle are also active just before actual take-off. The front leg produces force during the entire phase just before take-off. The biceps femoris muscle was found to be very active in the beginning of force production which emphasized its importance during the early stages of the sprint start.

During the acceleration phase, the position of the body center gravity with respect to the ground contact point changes. During the first few strides the center of gravity is ahead of the contact point and by the third contact point the center of gravity is behind the contact point. This phase is further divided into a braking phase where the body center of gravity is moving downward and a propulsion phase where the body center of gravity is moving upward. There is a 4.8% higher maximal integrated EMG activity during contact than during the maximum constant speed phase. "This may imply that neural activation of a sprinter achieves its maximum in the acceleration phase" (Mero et al., 1992).

Running velocity is determined by the product of stride length and stride rate. At high speeds runners can increase their velocity by increasing stride rate to a relatively greater extent than stride length. EMG activity has been shown to increase with increases in running speed. In sprinting, there is high EMG activity of the leg muscles before contact. At the beginning of contact there a high impact force. It is therefore important that the leg extensor muscles are activated prior to contact. High preactivation increases stiffness in the muscles to help resist impact. The reflex potentiation is also high after contact. "Energy is transferred by the elastic elements from the braking phase to the propulsion phase and utilization of the elastic properties has been shown to be important in increasing explosive force production during contact" (Mero et al., 1992).

During sprint running, the rectus femoris seems to be more important as a hip flexor than as a knee extensor. At the end of and after contact, the rectus femoris muscle acts eccentrically due to extension at the hip joint and flexion at the knee joint. In the next flight phase, the muscle begins to shorten while flexing the thigh. The biceps femoris and the gastrocnemius were fairly active in the propulsion phase and seemed to play a primary role in the propulsion phase.

Training to increase power

Power is a combination of strength of a given muscle and speed of movement. There has been research in the areas of isometrics, isokinetics and isotonics as methods of increasing vertical jump performance, a power measurement.

Isometric training programs involve training a muscle or muscle group against a fixed, immovable resistance (Wilmore & Costill, 1988). A study was conducted concerning the effects of isometrics on vertical jumping (Ball et al., 1964) of 63 college men. They exerted isometric force upward against shoulder pads of a specially constructed device. They did repeated measures of vertical jump pre- and post-training. They reported that there was a gain in strength associated with isometric training however, there was no associated increase in vertical jumping. Another study (McKethan & Mayhew, 1974) supported these findings. They investigated three different training groups, an isometric group, an isotonic group and an isometric-isotonic combined group. They reported that there was an increase in strength but no increase in vertical jumping with the isometrically trained group. "This may further verify that strength training should involve a degree of neuromuscular specificity to be effective" (McKethan & Mayhew, 1974). Different neuromuscular patterns are involved in dynamic exercise than involved in static exercise. This supports the theory of specificity of training. Strength training should be closely associated with performance patterns to bring about significant functional benefits.

Isokinetic training involves exerting force against a resistance that has a fixed speed (Wilmore & Costill, 1978). The speed is constant and the resistance is dependent upon the force applied. Since functional activities are performed at high velocities it would appear that training at high velocities would have a more favorful outcome on performance than training at a slow speed. Studies in this area have conflicting results. Coyle and Feiring (1980) conducted a study to determine the specificity of training velocity for increasing muscular power. They employed three training groups, one at a slow speed (60 deg/sec), one at a fast speed (300 deg/sec) and one group was a combination of fast and slow speeds. They reported that fast muscular power was only improved by including training at a fast speed. Another study (Genuario & Dolenger, 1980) investigated the correlation between peak torque of leg flexion and extension and foot plantar flexion at 30 deg/sec and 180 deg/sec angular velocity and the ability to vertically jump. They concluded that the correlations were so low that there was little, if any relationship between torque at fast and slow velocities and the ability to vertical jump. Another study conducted by Blattner and Noble (1979) determined the effects of isokinetic and plyometric training on vertical jumping performance. They concluded that both training programs resulted in improvements in vertical jumping but neither method resulted in a greater increase in vertical jumping performance.

Isotonic training is a dynamic process involving fixed or alternating resistance. Most traditional methods include the use of barbells and pulleys. During the last decade, there has been machines developed, such as Nautilis and Hydrafitness, which apply accomadating resistance. Accomadating resistance is when the resistance varies as the force-producing capabilities of the muscle changes throughout the joint range of motion (Wilmore & Costill, 1988).

Research in the area of weight training has conflicting results. One study investigated the influence of Olympic power lifts on vertical jumping performance (Garhammer & Gregor, 1979). The olympic power lift primarily involves vertical jumping with a barbell. From their research they found that Olympic weight lifters were usually excellent jumpers. They concluded that athletes requiring superior jumping ability could benefit by using olympic lifts as part of their training program. Hayden (1981) studied the relationship between selected olympic lifts and hip and leg power. Forty male athletes served as subjects. The maximum amount of weight lifted in the power clean and pushpress movements was determined and correlated with the criterion power measure (vertical jump test). Pearson Product Moment correlation revealed no significant ($p>.05$) correlation between the amount of weight lifted in the Olympic style weightlifting movements and the power of the hips and legs. Hayden concluded the reason for this poor relationship may be that the Olympic style lifts were more "strength oriented" power tests and the vertical jump power test was a more "speed oriented" power test.

One study compared the effects of weight training combined with plyometric training. Clutch and Wilton (1983) did two experiments. In the first experiment they had two groups, one group lifted weights and performed depth jumps and one group just lifted weights. In the second experiment, one group lifted weights and performed maximal vertical jumps, one group lifted weights and performed 0.3 meters depth jumps and one group lifted weights and performed 0.75 and 1.10 meter depth jumps and one group only lifted weights. They found that depth jumps were effective but not more effective than a regular jumping routine and that weight training combined with jumping showed improvement in vertical jumping capability.

Improvements in power is related to more than just improvements in strength (Considine & Sullivan, 1973; Eisenman, 1988; McClements, 1964). Eisenman (1988) investigated the initial strength levels and the relationship between strength increases and vertical jumping increases. She used two experimental condition groups, a trained group and an untrained group. The trained group experienced significant gain in strength and vertical jumping. However, the strength gains were not proportionate to the vertical jumping gains and not related to initial strength levels. Eisenman (1988) concluded that there may be "additional factors that account for improvements in vertical jumping performance associated with strength training."

Considine and Sullivan (1973) correlated values of selected tests of leg strength and leg power on thirty eight college men. Leg strength was measured using a cable tensiometer and leg power was measured using vertical jump, standing broad jump, chalk board jump, 5 yard sprint, 10 yard sprint and vertical jump using a force platform. They found all correlations to be low to moderate and concluded that "the contribution of strength to power is minor and that power is a more complex entity."

McClements (1964) measured power relative to strength of leg and thigh muscles. He included four training groups, group one trained the leg flexors, group two trained the leg extensors, group three trained the leg flexors and extensors and group four trained for total body fitness. Power was measured using a vertical jump test. All groups had an increase in power but gains in strength were not related with gains in power.

Plyometrics involves lengthening a muscle prior to a powerful contraction (Brown et al., 1986; Wilmore & Costill, 1988; Wilt, 1975). The principle behind this is that maximal tension develops when a muscle is stretched rapidly. The faster a muscle is forced to lengthen the greater tension it exerts (Wilt, 1975). The rate of stretch is more important than the magnitude of stretch. There are three phases to plyometric training: the eccentric (lengthening) phase, the ammorization (transition) phase, and the concentric (shortening) phase. The muscle is pre-stretched during the eccentric phase. Slack is taken up during the ammorization or gathering phase as the muscle gets ready for a powerful contraction (Wilt, 1975). Plyometrics are used to train the eccentric aspect of a muscle contraction.

Some research has reported improvements in power following plyometric training while others have reported no improvement. Seoles (1978) investigated the effect of depth jumping on vertical jump and standing long jump of college age men. Subjects trained eight weeks doing depth jumps. He reported some improvement in vertical jumping but not at a significant level (alpha=0.05).

Clutch et al. (1983) and Blattner et al. (1979) reported similar results. They both reported improvements in vertical jumping with plyometric training. The reported gains were not statistically significant.

Another study (Bedi et al., 1987) investigated the increases in jumping performance when dropping from different heights. Subjects were 32 young males divided into volleyball players and nonjumpers. Bedi et al. (1987) measured the vertical jump height after jumping from 0, 25, 35, 45, 55, 65, 75, and 85cm. They were unable to report a significant difference between the performance of maximal effort vertical jumps following a prior drop from any height.

Brown et al. (1986) conducted a study looking at the effects of plyometric training on vertical jumping performance of high school basketball players. Twenty-six male freshman and sophomores serve as subjects. The subjects were pre-tested and then randomly assigned to one of two groups (control and plyometric training group). The plyometric group trained in addition to regular basketball practice. The control group participated only in regular basketball practice. Brown et al. reported that plyometric training significantly ($p<.05$) improved vertical jumping performance. They concluded that plyometric training "appeared to maximize the coordination of neuromuscular skills and muscular strength." For vertical jumping performance to increase leg muscles must be trained to react as rapidly as possible. He also concluded that for maximal effectiveness, in season training should be as specific to the sport as possible.

SUMMARY

The purpose of this chapter was to review the relevant literature concerning the measurement of power, the biomechanical analysis of vertical jumping and sprinting and the methods of increasing power.

There have been many tests developed to measure power. The vertical jump, standing broad jump, sprinting, the softball throw and kicking a football are just a few examples. The vertical jump test is an indirect measure of leg power.

Methods to increase power have included training isometrically, isokinetically and isotonically. Isometric training has not been shown to improve vertical jump performance. Isokinetic training studies provide conflicting results with studies showing no improvement and studies showing significant improvement in vertical jump performance. Forms of isotonic training used to increase vertical jump have included weight training, Olympic lifts and plyometric training. Plyometrics was designed specifically to increase power.

Different studies have used different methods to study the muscular components contributing to vertical jumping and sprinting. Overall, the consensus has been that the knee extensors are significant to vertical jumping height. The hip and ankle joints were considered the next most important joints contributing to vertical jumping performance. The stretch-shortening cycle is also important to producing greater force or power output. During sprinting, the knee extensors torque was found to be related to sprinting speed. The hip flexors were also found to be an important contributor to sprinting performance.

CHAPTER III

JOURNAL MANUSCRIPT

ABSTRACT

The purpose of this investigation was to determine whether plyometric training in Strength shoes (Strength Footwear, Inc.) increased vertical jump performance, decreased elasped time in the 40 yard dash and increased calf circumference. Thirty-one male and female college-aged students served as subjects. Twenty-two subjects, enrolled in a college physical fitness class, were randomly assigned to one of two experimental conditions: Strength shoe (S) group or traditional shoe (T). A third condition, a control (C) group consisted of 9 volunteers enrolled in a college badminton class. Subjects in both experimental conditions trained for ten weeks, three times per week, 45 minutes per day. Subjects performed plyometric drills designed to increase vertical jump and increase running speed. Subjects were pre-tested and post-tested for vertical jump performance, speed in the 40 yard dash, and right and left calf circumference.

There was no significant ($p>.05$) change in either experimental condition from pretest to posttest on vertical jump performance, speed in the 40 yard dash and right and left calf circumference. It was concluded that, regardless of the footwear being worn, plyometric training did not increase vertical jump performance, calf circumference or decrease the elapsed time in the 40 yard dash of the participants.

Introduction

Power is an important functional component in many sporting activities. Power is dependent upon the strength of the muscle involved and the speed of the movement. Events such as sprinting, batting, pitching, kicking and jumping are considered power events.

Coaches and trainers are constantly looking for ways to enhance power. One method of enhancement has been plyometric training. Plyometric training was developed to bridge the gap between strength and speed (Wilt, 1975). Using this technique, the muscle is pre-stretched during the eccentric (lengthening) phase. There is gathering phase as the muscle prepares for a powerful concentric (shortening) contraction (Wilt, 1975; Wilmore & Costill, 1988). The faster the muscle is forced to lengthen the greater the tension it exerts. Plyometrics is designed to enhance this force.

Recently, Strength Footwear, Inc. marketed a shoe, called the Strength shoe, which is designed to enhance the components of power. Strength shoes are designed with a round disk on the bottom of the shoe so that there is approximately a two inch space between the heel and the floor. During normal standing 70% of the body weight is distributed to the heels. While wearing the Strength shoes, all of the body weight is supported by the forefoot and the calf muscle. This overloads the calf muscles and the achilles tendon.

The purpose of this investigation was to determine whether plyometric training in Strength shoes increased vertical jump, decreased elapsed time in the 40 yard dash and increased calf circumference.

Methodology

Subjects

The subjects in this investigation were male (N=19) and female (N=12) students enrolled in a College Basic Instruction Program physical fitness class. Subjects were randomly assigned to one of two groups. These groups were then randomly assigned to one of two experimental conditions, a Strength shoe (S) group and a traditional shoe (T) group. A control (C) group was selected and consisted of 9 volunteers enrolled in a College Basic Instructional Program badminton class.

Mean subject characteristics are located in Table 1. Male and female subjects age ranged from 18-40 years and 18-21 years, respectively. Male and female subjects bodyweight ranged from 56.3-92.8 (kg) and 40.8-76.1 (kg), respectively. Male and female subjects height ranged from 164.47-184.15 (cm) and 154.31-175.26(cm), respectively.

Procedures

The subjects were pre-tested for vertical jump performance,

Table 1

Subject Characteristics

	Male			Female		
	Mean	SD	SE	Mean	SD	SE
Age (yrs)	22.11±5.78		1.32	19.58±1.08		0.31
Bodyweight (kg)	74.54±9.84		2.26	59.74±1.08		0.31
Height (cm)	176.33±5.13		0.46	164.21±5.08		0.73

SD-Standard Deviation

SE-Standard Error of the mean

speed in the 40 yard dash and calf circumference. Vertical jump was measured using a vertical jump board. The subjects were given an oral explanation of the test and three practice trials before the pretest. The subjects were given the "Jump" command. Subjects were instructed to drop into a squat position and without pause, jump as high as possible and touch the vertical jump board with the preferred hand. Individual preference was allowed as to the angle of knee and hip flexion prior to jumping. The subjects were encouraged to extend the body as high as possible. The subjects were given six pretest trials. The highest jump of the six trials was recorded as the criterion score for that subject.

Speed in the 40 yard dash was measured with a stopwatch. Measurement was taken inside in a gym where 40 yards was marked. Subjects were instructed to warm-up prior to measurement. Subjects were given three pretest trials. The lowest elapsed time was recorded as the criterion score for that subject.

Calf girth was measured to the nearest sixteenth of an inch with a steel tape measure. Measurement was taken six inches below the midpoint of the knee joint. Two measurements were taken. The average of the two trials was recorded as the criterion score for that subject.

Plyometric Training

Both the Strength shoe subjects (S) and the traditional shoe subjects (T) trained for ten weeks, three times a week, 45 minutes per day. Subjects initially warmed up by jogging and performing lower body stretches. Subjects then performed plyometric drills designed to increase vertical jump and running speed, such as, bounding, cone jumps, high knees, rim jumps, wall jumps, box jumps, depth jumps and 40 yard sprints. The intensity of the exercises were increased after 2 weeks and 6 weeks by either increasing the number of repetitions or increasing the time of the repetition. The control group did not participate in any of the training sessions but did attend badminton class for the ten week experimental period. Upon completion of the ten week period, all subjects completed a posttest identical to the pretest for vertical jump, 40 yard dash, and right and left calf circumference.

Results

Repeated measures analysis of variance was used to test the statistical hypotheses involving the dependent measures of vertical jump. There was no difference, $F(2,28)= 1.61$, $P>.05$, between either of the two experimental conditions or the control group in vertical jump performance.

Repeated measures analysis of variance was also used to test the statistical hypotheses involving the dependent measures of 40 yard dash. There was no difference, F(2,28)= 1.22, P>.05, between either of the two experimental conditions or the control group in the 40 yard dash scores.

Repeated measures analysis of variance was again used to test the statistical hypotheses involving the dependent measures of right and left calf circumference. As in the other two dependent variables, there was no difference, F(2,28)= 0.61, P>.05, for the right calf circumference. Posttest scores also revealed that there was no difference, F(2,28)= 0.94, P>.05, in left calf circumference.

The descriptive statistics for the pretest and posttest scores on all dependent variables are presented in Table 2. Mean and standard deviations are reported for pretest and posttest vertical jump, 40 yard dash and left and right calf circumferences for the Strength shoe group, traditional shoe group and the control group.

Discussion

The results of this study contribute information regarding the effect of wearing Strength shoes in a plyometric training program. Since there was no significant (P>.05) increase from pretest to posttest on vertical jump, decrease in elapsed time in the 40 yard dash and increase in right and left calf circumference, it was concluded that, regardless of the footwear being worn, the designed plyometric training program did not increase vertical jump performance or calf circumference nor decrease the elapsed time in

Table 2

Descriptive Statistics For Dependent Measures

	Strength Group	Traditional Group	Control Group
Vertical Jump (inches)			
Pre	19.56±2.19	16.47±2.68	15.0±1.52
Post	19.60±2.40	17.30±2.30	16.35±1.20
Forty Yard Dash (seconds)			
Pre	5.56±0.25	5.95±0.29	6.18±0.27
Post	5.62±0.17	5.90±0.19	6.32±0.16
Right Calf (cm)			
Pre	14.10±0.83	13.59±0.99	13.85±1.20
Post	14.21±0.86	13.68±0.99	13.79±1.22
Left Calf (cm)			
Pre	14.13±0.85	13.49±1.03	13.80±1.05
Post	14.18±0.89	13.56±0.95	13.81±1.16

the 40 yard dash of the participants.

Although there were no significant increases from pretest to posttest between the Strength shoe group and the traditional shoe group on any of the selected dependent measures, it does not exclude the possibility of these variables being increased if the duration per day of the training program and the overall length of the training program were significantly increased. Bosco (1981) reported an improvement in jumping following "bouncing training". However, his training period lasted for 18 monthes. Secondly, the subjects in the present study were of variable fitness levels, therefore the intensity of the exercises may not have been sufficient for many of the subjects and thus, may have affected the results of this study. This is supported by the fact that the Traditional shoe group showed no changes.

Wearing Strength shoes in a plyometric training program had no effect on vertical jumping performance, speed in the 40 yard dash and calf circumference. Since there has been no published research on the effect of wearing Strength shoes, one can only contrast the implications of wearing the Strength shoe and the biomechanical components of vertical jumping and sprinting.

According to Strength Footwear, Inc., Strength shoes are designed so that "every time an athlete lands after a jump, that impact is equal to six times his/her weight. While wearing the Strength shoe, that same athlete lands on his/her forefoot, and the heel never touches the ground." Therefore, the muscles of the lower leg, the gastrocnemius-soleus complex, is supporting "six times the body weight on impact". The theory behind Strength shoes seems to be based on increasing the strength of the muscles in the lower leg.

Research has shown that the lower leg muscles may not be the most significant contributor to vertical jumping and sprinting. This would be in contrast to the theory behind Strength shoes. According to Luhtanen and Komi (1978) who studied the vertical jump with respect to the contribution of the different body segments, results showed that knee extension contributed 56% where plantar flexion contributed 22%.

Hubley and Wells (1983) studied the relative contribution of a muscle to the total performance output of the vertical jump. Results of their study were similar to the previous study, reporting the knee contributing 49% to the total work with the hip contributing 28% and the ankle contributing 23%. Hubley and Wells (1983) concluded that the knee extensors were "the largest single contributor" to the vertical jump.

Robertson and Fleming (1987) reported results different from the previous studies. They reported results of vertical jump contribution to be 40% for the hip musculature, 35.8% for the ankle musculature and 24.2% for the knee musculature.

Similar results have also been reported for the muscles contributing to sprinting performance. Alexander (1989) reported that the strength of the knee extensor muscles were a good predictor of sprint performance. Mann et al. (1986) theorized that the "majority of the forward propulsion during jogging, running, and sprinting is brought about by the rapid hip flexion of the swing limb, rather than by the push-off of the stance limb." This action combined with knee extension, along with the action of the arms, propels the body forward.

The previous studies imply that the calf muscles contribute only a small percent to overall vertical jump performance and sprinting performance. Even if Strength shoes increased vertical jump and sprinting performance due to calf strength increases, the increase would still only be minor.

The results of the present study also suggest that plyometric training had no effect on vertical jumping performance regardless of the footwear of the subjects. Some research has reported improvements in vertical jumping following plyometric training while others have reported no improvement.

Seoles (1978) reported some improvement in vertical jumping in his subjects who trained for eight weeks doing just depth jumps. However, similar to the present study, his gains were not significant. Clutch et al. (1983) reported improvements in vertical jumping, however, these gains were not significant. Blattner et al. (1979) also reported similar results in their subjects who trained three times a week for eight weeks performing only depth jumps. Their gains in vertical jumping were also not significant.

Brown et al. reported results that differ from the previous studies presented. They reported significant ($p<.05$) gains in vertical jumping performance for their subjects who were high school basketball players and trained in a plyometric training program in addition to their regular basketball practice. However, the training period in this study lasted for twelve weeks whereas, the present study only lasted 10 weeks. In addition, the subjects were also participating in basketball practice which may have provided additional jumping exercises.

The results of the present study may have been due to an ineffecient gain in elastic energy due to the plyometric training. According to Enoka (1988) the ability to utilize stored elastic energy is affected by three variables: time, magnitude of stretch and velocity of stretch. In the present study, the magnitude of the stretch may have been too great so that a lesser number of cross-bridges remained attached and less elastic energy was stored. Another possibility, supported by Clutch et al. (1983), is that during the stretch of the muscles a Golgi tendon reflex was elicited, inhibiting instead of facilitating a myotatic reflex from the muscles spindles. This would have inhibited an increase in strength. Plyometric training is a method of increasing the stretch shortening cycle which aims at adaptations of the nervous system. These exercises are best received when performed in a completely rested state (Komi, 1992; Yessis, 1991). Fatigue tends to ofset these neural adaptations. They recommended 5-10 minutes of rest between sets. The present study due to time restraints allowed only a 30 second rest between sets. The velocity of the stretch is the key to "exploiting the elastic structures of the muscle" (Lundin, 1989). There should be minimal hesitation between the eccentric and concentric contractions of the muscle to maximize the storage and release of elastic energy in the muscle. During vertical jumping there may have been a hesitation in the eccentric and concentric contraction which would have inhibited the storage and utilization of elastic energy.

The results of this study also showed no improvement in calf circumference regardless of the designed plyometric training program and the assignment of experimental condition. Increases in calf circumference is related to hypertrophy of the muscle. Chronic hypertrophy results from strength training and is due to structural changes in the muscle. Gains in muscle girth are paralleled by gains in strength. However, an individual may gain strength without gaining muscle size. (Wilmore & Costill, 1988). Muscle strength is usually gained by performing high intensity work with low repititions. The present study consisted of plyometrics which involved alot of moderate intensity, high repitition work.

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CHAPTER IV

Results and Discussion

Summary

This study was designed to determine whether plyometric training in Strength shoes increases vertical jumping performance, decreases elapsed time in the 40 yard dash and increases calf circumference.

Subjects were thirty-one male and female students enrolled in a College Basic Instruction Program physical fitness class. Subjects were randomly assigned to one of two groups, a Strength shoe (S) group and a traditional shoe (T) group. A control (C) group was selected and consisted of 9 volunteers enrolled in a College of Education Basic Instruction badminton class. All three groups were pretested for vertical jumping performance, speed in the 40 yard dash and left and right calf circumference. The Strength shoe group and the traditional shoe group trained for ten weeks, three times a week for 45 minutes per day. The subjects performed plyometric drills designed to increase vertical jump and running speed. The control group did not participate in any of the training sessions but did attend badminton class for the ten week experimental period. Upon completion of the ten week period, all subjects completed a posttest for vertical jumping performance, speed in the 40 yard dash and left and right calf circumference.

Results

Repeated measures analysis of variance was used to test the statistical hypotheses involving the dependent measures of vertical jump, 40 yard dash and right and left calf circumference.

There was no statistical difference observed for the main effects of group on the dependent variable of vertical jump. The changes observed from pretest to posttest on this measure were not of sufficient magnitude for statistical significance ($p>.05$). Any changes recorded from pretest to posttest on vertical jump were not a function of treatment conditions.

There was no statistical difference observed for the main effects of group on the dependent variable of 40 yard dash. The changes observed from pretest to posttest on this measure were not of sufficient magnitude for statistical significance ($p>.05$). Any changes recorded from pretest to posttest on vertical jump were not a function of treatment conditions.

There was no statistical difference observed for the main effects of group on the dependent variable of right and left calf circumference. The changes observed from pretest to posttest on these measures were not of sufficient magnitude for statistical significance. Any changes recorded from pretest to posttest on left and right calf circumference were not a function of group assignment.

Discussion

The results of this study contribute information regarding the effect of wearing Strength shoes in a plyometric training program. Since there was no significant ($p<.05$) increase from pretest to posttest on vertical jump, decreases in elapsed time in the 40 yard dash and increase in right and left calf circumference, it was concluded that, regardless of the footwear being worn, the designed plyometric training program did not increase vertical jump performance or calf circumference and decrease the elapsed time in the 40 yard dash of the participants.

Although there were no significant increases from pretest to posttest between the Strength shoe group and the traditional shoe group on any of the selected dependent measures, it does not exclude the possibility of these variables being increased if the duration per day of the training program and the overall length of the training program were significantly increased. Bosco (1981) reported an improvement in jumping following "bouncing training". However, his training period lasted for 18 months. Secondly, the subjects in the present study were of variable fitness levels, therefore the intensity of the exercises may not have been sufficient for many of the subjects and thus, may have affected the results of this study.

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These exercises are best received when performed in a completely rested state (Komi, 1992; Yessis, 1991). Fatigue tends to offset these neural adaptations. They recommended 5-10 minutes of rest between sets. The present study due to time restraints allowed only a 30 second rest between sets. The velocity of the stretch is the key to "exploiting the elastic structures of the muscle" (Lundin, 1989). There should be minimal hesitation between the eccentric and concentric contractions of the muscle to maximize the storage and release of elastic energy in the muscle. During vertical jumping there may have been a hesitation in the eccentric and concentric contraction which would have inhibited the storage and utilization of elastic energy.

The results of this study also showed no improvement in calf circumference regardless of the designed plyometric training program and the assignment of experimental condition. Increases in calf circumference is related to hypertrophy of the muscle. Chronic hypertrophy results from strength training and is due to structural changes in the muscle. Gains in muscle girth are paralleled by gains in strength. However, an individual may gain strength without gaining muscle size. (Wilmore & Costill, 1988). Muscle strength is usually gained by performing high intensity work with low repetitions. The present study consisted of plyometrics which involved a lot of moderate intensity, high repetition work.

Recommendations for Further Study

Although the present study reported no significant gains in the selected dependent measures while wearing Strength shoes during a plyometric conditioning program, recommendations are made for further research in this area. The first recommendation is that the specific training sessions be lengthened. The present study consisted of only 45 minute training sessions. Training sessions lasting at least one hour are recommended. The second recommendation is that the actual length of the study be extended to at least 16 consecutive weeks. The present study lasted only 10 weeks and included one week of break. The third recommendation is that a pure random sampling technique be employed to ensure that all experimental conditions are of similar performance levels across the various dependent measures. This will allow the subjects to progress at the same training intensity. Also, it will decrease the probability of bias sampling. A final recommendation is that a study be conducted in which a Strength shoe group trains plyometrically, a Strength shoe group trains plyometrically in addition to a lower body weight training program, a group that only participates in a weight training program and a control group which does not participate in any training. A study of this nature may help determine whether it is more important to develop strength or speed or both when trying to improve vertical jump performance.

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APPENDIX A

METHODOLOGY

Pilot Study

Prior to this investigation, a pilot study was conducted on 12 volunteers, by the researcher, to become more experienced with the testing procedures and estimate the reliability of the dependent variable, vertical jump. The results of the pilot study are presented in Appendix B.

SELECTION OF SUBJECTS

Permission to carry out this investigation was granted from the Human Subjects Committee of the Division of Health and Physical Education of Virginia Polytechnic Institute and State University.

The subjects involved were male (N=19) and female (N=12) students enrolled in a College of Education Basic Instruction Program physical fitness class. Subjects were randomly assigned to one of two groups. These groups were then randomly assigned to one of two experimental conditions. A control group was selected and consisted of 9 volunteers enrolled in a College of Education Basic Instructional Program badminton class.

Subjects were given a written and oral explanation of the risks, benefits and the procedures involved in this investigation. Subjects completed a medical history form (Appendix C) and read and signed for understanding the informed consent (Appendix D) form prior to participating in the study.

Prior to administering the pretest dependent variables, subjects' age, bodyweight and height were recorded (Appendix E).

Pretest Measurement of Dependent Variables

The subjects were pre-tested for vertical jump performance, speed in the 40 yard dash and calf circumference. Vertical jump was measured using a vertical jump board. The subjects were given an oral explanation of the test and three practice trials before actual measurement. The subjects were given the "Jump" command, after which they were allowed to jump. The subjects were instructed to drop into a squat position and without pause, jump as high as possible and touch the vertical jump board with the preferred hand. Individual preference was allowed as to the extent of knee and hip flexion prior to jumping. The subjects were encouraged to extend the body as high as possible. The subjects were given six trials and the best of these six was recorded as the criterion score for that subject.

Speed in the 40 yard dash was measured with a stopwatch. Measurement was taken inside in a gym where 40 yards was marked. Subjects were allowed to jog and stretch prior to measurement. Subjects were given three trials with the lowest elapsed time being recorded as the criterion score for that subject.

Calf girth's were determined with a tape measure to the nearest sixteenth of an inch. Measurement was taken six inches below the midpoint of the knee joint. Two trials were given. The mean of the two trials was recorded as the criterion score for that subject.

Experimental Conditions

Both the Strength shoe subjects (S) and the Traditional shoe subjects (T) trained for eleven weeks, three times a week, 45 minutes per day. The subjects performed plyometric drills. The exact protocol, intensity, and duration of this training program are described in Appendix F. The control group did not participate in any of the training sessions.

Posttest Measurement of Dependent Variables

Reliability Estimate

To estimate the internal consistency of the measurement techniques designed to assess the subjects' pretest scores, intraclass reliability estimates were calculated on the following dependent measures: vertical jump (R=.99), 40 yard dash (R=.97), right calf girth (R=.99) and left calf girth (R=.99). The statistical calculations are presented in Appendix G.

Validity Estimates

External Validity

The subjects of this study were male and female college-aged students enrolled in college physical education classes. The subjects were randomly assigned to one of two groups. These groups were then randomly assigned to one of two experimental conditions. The sampling procedure allows the researcher to generalize to a college-aged population.

Internal Validity

Variance was minimized in this study by: (a) explanation of the testing procedures before actual testing; (b) having a control group; (c) having the post-testing identical to the pretesting procedures.

Posttest Data Analysis

Repeated measures analysis of variance was used to test the statistical hypotheses involving the dependent measures of vertical jump, 40 yard dash and right and left calf circumference. The statistical computations for this level analysis are located in Appendix H.

There was no statistical difference observed for the main effects of group on the dependent variable of vertical jump. There was a significant main effect for time (pretest to posttest), however, there was no significant interaction.

There was no statistical difference observed for the main effects of group or time on the dependent variable of 40 yard dash. The changes observed from the pretest to the posttest on this measure were not of sufficient magnitude for statistical significance.

There was no statistical difference observed for the main effects of group or time on the dependent variables of right and left calf circumferences. The changes observed from pretest to posttest on these measures were not of sufficient magnitude for statistical significance.

The desriptive statistics for the pretest and posttest scores on all dependent variables are presented in Appendix I.

Perceived Rating of Muscular Soreness

Subjects in the two experimental conditions (S) and (T) were administered a Perceived Rating of Muscular Soreness Scale (Appendix J) the first three training days to determine the effect of condition on training. The scale ranged from 0-10, with 0 representing no muscular soreness and 10 representing maximal soreness. Subjects recorded individual soreness before each training session.

A Two Way Repeated Measures ANOVA was used to test the main effects of conditions and days on the dependent measure of muscular soreness. Appendix K contains the statistical computations for these comparisons. There was no statistically significant difference ($P > .05$) between the main effect of Condition. It was concluded, therefore, that the difference in the mean values among the two levels of condition were not great enough to exclude the possibility that the difference is just due to random sampling variability.

There was a significant difference ($P < .01$) between the main effects of Days. It was concluded therefore that the differences in the mean values among the different days were greater than would be expected by chance. A multiple comparison Neuman-Keuls reduced across day 1 to day 3. The means reported from subjects were statistically reduced from day 1 ($x=4.15$) to day 2 ($x=2.41$). The ratings were also significantly reduced from day 2 ($x=2.41$) to day 3 ($x=1.74$).

There was not a statistically significant ($P > .05$) interaction between Condition and Day.

APPENDIX B

PILOT STUDY

Measurement of Vertical Jump

Twelve male and female volunteers served as subjects. Each subject stretched prior to measurement of vertical jump. Vertical jump was measured with the a Vertical Jump Board. Subjects were given an oral explanation of the test prior to jumping. Subjects were given the "Jump" command, after which they were allowed to jump. The subjects were instructed to drop into a squat position and without pause, jump as high as possible and touch the vertical jump board with the preferred hand, which was chalked prior to jumping. Individual preference was allowed as to the extent of knee and hip flexion prior to jumping. Subjects were encouraged to extend the body as high as possible. Subjects performed 10 trials. The mean of the first five trials was correlated with the mean of the last five trials to estimate the internal consistency reliability. Pearson Product Moment Correlation yielded a statistical relationship of $r=.95$.

APPENDIX C

MEDICAL HISTORY FORM

Medical History

All information will be kept confidential.

PLEASE PRINT

NAME:______________________________ AGE:_______________________

YR. in SCHOOL:_____________

PRIOR TRAINING EXPERIENCE:

1. Have you ever trained with Strength shoes? YES NO

MEDICAL HISTORY:

1. Do you currently have any orthopedic problems(knee, calf, ankle,etc.) which may limit you in this study? YES NO

2. Are you currently taking any medications? YES NO

If you answered yes to any of the above questions, please explain each(when it occured and exact nature of injury):

____

____

____

____

____

APPENDIX D

INFORMED CONSENT

INFORMED CONCENT

I, ______________________________________, do hereby voluntarily agree and consent to participate in a testing and training program conducted by personnel of the Muscular Function Laboratory of the Division of Health and Physical Education and Recreation of Virginia Polytechnic Institute and State University.

The purpose of this study is to determine if training plyometrically while wearing Strength shoes increases vertical jump significantly when compared to plometrically training without Strength shoes.

I voluntarily agree to participate in this study. It is to my understanding that my participation will include:
a) A short period of adjustment to wearing the Strength shoe, if in this group, b)Two testing sessions(pre-training and post-training) which includes measurement of vertical jump (best jump out of six trials), measurement of speed in 40 yard dash, and measurement of calf girth, c) a training program three times a week for ten weeks which will consist of plyometric drills such as vertical jumping and sprinting.

I understand that my participation in this experiment may produce certain discomforts and risks. These discomforts may include extreme muscular soreness following the testing and training sessions. The risks included are possible knee and/or calf strains and/or sprains. In extreme situations, there is the possibility of bone damage such as fracture.

Certain personal benefits may be expected from participation in this experiment. These may include improved muscular strength and quickness which may be associated with improvement in vertical jumping performance.

I understand that it is my responsibility to advise the researchers of any pre-existing medical problem that may affect my participation or any medical problems that might arise in the course of this experiment and that no medical compensation is available if injury is suffered as a result of this research.

I have read the above statements and have had the opportunity to ask questions. I understand that the researchers will, at any time, answer my inquiries concerning the procedures used in this experiment.

Date________________

Participant signature____

Witness____

APPENDIX E

SUBJECT CHARACTERISTICS

Subject Characteristics

	Male			Female		
	Mean	**SD**	**SE**	**Mean**	**SD**	**SE**
Age (yrs)	22.11±5.78		1.32	19.58±1.08		0.31
Bodyweight (kg)	74.54±9.84		2.26	59.74±1.08		0.31
Height (cm)	176.33±5.13		0.46	164.21±5.08		0.73

SD-Standard Deviation
SE-Standard Error of the mean

APPENDIX F

PLYOMETRIC CONDITIONING PROGRAMS

Warm-up/cool down stretching procedures

1. Jog 2 laps around gym.

2. Seated hamstring stretch. While in seated postion, straighten out legs and reach forward until feel stretch in hamstrings. Hold 30 sec.

3. Groin "butterfly" stretch. Sit in Indian-style position and gently press knees downward with the elbows.

4. Supine hamstring stretch. Lie on back and pull one knee to chest and hold 30 sec. Then extend the leg upward, grasp with both hands and stretch hamstrings in a comfortable position for 30 sec. Do same to opposite leg.

5. Quadriceps stretch. Lie on one side with the palm of the hand supporting the neck. With the opposite hand grab ankle and pull back toward buttocks until stretch is felt in thigh. Keep thighs parallel to the ground. Hold 30 sec and repeat to other side.

6. Standing calf stretch against wall. Facing the wall, place one foot forward close to the wall and the other back. Keep the heel of back foot on the ground and feel the stretch in the calf. Hold 30 sec and repeat to other side.

Training procedures

Weeks 1 & 2

Drill	Time	Reps	Rest
High Knees	25yds	3	30
Bounding	25yds	3	30
Cone Jumps S-S(11.5")	15sec	3	30
Power Slides	25yds	2	30
Quick Feet	25sec	3	30
Rim Jumps	10X	3	30
Wall Jumps	15sec	3	30
Jog-Sprinting	50yds	4	30

Weeks 3,4,5 & 6

Drill	Time/Distance	Reps	Rest
High Knees	50yds	3	30
Bounding	25yds	3	30
Rim Jumps	10X	3	30
Cone Jumps S-S(11.5")	30sec	3	30
Depth Jumps(24.5")	10X	2	30
Box Jumps(11.75",19")	3Left/3Right	3	30
Wall Jumps	30sec	3	30
Sprinting	40yds	3	30

Weeks 7,8,9,10 & 11

Drill	Time/Distanc	Reps	Rest
Box Jumps(same as above)	3Left/3Right	5	30
Rim Jumps	10X	4	30
Wall Jumps	30sec	4	30
Cone Jumps S-S(11.5")	30sec	4	30
Depth Jumps(24.5")	10X	4	30
Depth Jumps(18")	10X	4	30
Step-Ups	30sec	4	30
Sprinting	40yds	3	30

APPENDIX G

RELIABILITY ESTIMATES

Analysis of Variance for Pretest Measurement of Vertical Jump

Source	DF	SS	MS	F	P
A(GroupID)	2	320.85	160.43	2.15	0.13
Subject(A)	30	2236.52	74.55		
B(Trials)	5	6.47	1.29	4.14	0.001*
AB	10	3.17	0.32	1.01	0.44
ERROR	150	46.88	0.31		
TOTAL	197	2613.88			

Intra-Class Reliability(R)

$$R = \frac{\text{Mean Square Subjects} - \text{Mean Square Error}}{\text{Mean Square Subjects}}$$

R= 74.55 - 0.313/74.55

R= 0.99

Analysis of Variance for Pretest Measurement of 40 Yard Dash

Source	DF	SS	MS	F	P
A(GroupID)	2	2.39	1.19	1.18	0.32
Subject(A)	30	30.45	1.01		
B(Trials)	2	0.53	0.27	7.60	0.001*
AB	4	9.44E-02	2.36E-02	0.68	0.61
ERROR	60	2.10	3.50E-02		
TOTAL	98	35.56			

Intra-Class Reliability(R)

$$R = \frac{\text{Mean Square Subjects - Mean Square Error}}{\text{Mean Square Subjects}}$$

R= 1.01 - 0.035/1.01

R=0.97

Analysis of Variance for Pretest Measurement of Right Calf Girth

Source	DF	SS	MS	F	P
A(GroupID)	2	2.52	1.26	0.65	0.53
Subject(A)	30	58.39	1.95		
B(Trials)	1	2.37E-04	2.37E-04	0.04	0.84
AB	2	5.11E-03	2.56E-03	0.47	0.63
ERROR	30	0.16	5.40E-03		
TOTAL	65	61.08			

Intra-Class Reliability(R)

$$R = \frac{\text{Mean Square Subjects} - \text{Mean Square Error}}{\text{Mean Square Subjects}}$$

R= 1.95 - 0.005/1.95

R=0.99

Analysis of Variance for Pretest Measurement of Left Calf Girth

Source	DF	SS	MS	F	P
A(GroupID)	2	3.85	1.92	1.04	0.36
Subject(A)	30	55.36	1.85		
B(Trials)	1	2.29E-04	2.29E-04	0.02	0.88
AB	2	2.33E-02	1.16E-02	1.16	0.33
ERROR	30	0.30	1.00E-02		
TOTAL	65	59.53			

Intra-Class Reliability(R)

$$R = \frac{\text{Mean Square Subjects - Mean Square Error}}{\text{Mean Square Subjects}}$$

R= 1.85 - 0.010/1.85

R=0.99

APPENDIX H

POSTTEST DATA ANALYSIS

Repeated Measures Analysis of Variance of Posttest Measurement of Vertical Jump

Source	DF	SS	MS	F	P
A(GroupID)	2	80.62	40.31	1.61	0.218
S(A)	28	700.65	25.02		
B	1	5.98	5.98	9.37	0.005
AB	2	2.69	1.35	2.11	0.140
ERROR	28	17.86	0.64		
TOTAL	61	807.81			

Repeated Measures Analysis of Variance
of Posttest Measurement of 40 Yard Dash

Source	DF	SS	MS	F	P
A(GroupID)	2	1.36	0.68	1.22	0.312
S(A)	28	15.68	0.56		
B	1	3.87E-02	3.87E-02	1.40	0.247
AB	2	9.82E-02	4.91E-02	1.77	0.189
ERROR	28	0.78	2.77E-02		
TOTAL	61	17.96			

Analysis of Variance of Posttest Measurement of Right Calf Girth

Source	DF	SS	MS	F	P
A(GroupID)	2	2.53	1.26	0.61	0.549
S(A)	28	57.80	2.06		
B	1	0.06	0.06	3.28	0.081
AB	2	5.92E-02	2.96E-02	1.51	0.239
ERROR	28	0.55	0.02		
TOTAL	61	61.00			

Analysis of Variance of Posttest Measurement of Left Calf Girth

Source	DF	SS	MS	F	P
A(GroupID)	2	3.72	1.86	0.94	0.402
S(A)	28	55.19	1.97		
B	1	4.24E-02	4.24E-02	1.73	0.199
AB	2	5.47E-02	2.74E-02	0.11	0.895
ERROR	28	0.69	0.02		
TOTAL	61	59.65			

APPENDIX I

DESCRIPTIVE DATA FOR DEPENDENT MEASURES

Descriptive Statistics for Dependent Measures

	Strength Group	Traditional Group	Control Group
Vertical Jump (inches)			
Pre	19.56±2.19	16.47±2.68	15.0±1.52
Post	19.60±2.40	17.30±2.30	16.35±1.20
Forty Yard Dash (seconds)			
Pre	5.56±0.25	5.95±0.29	6.18±0.27
Post	5.62±0.17	5.90±0.19	6.32±0.16
Right Calf (cm)			
Pre	14.10±0.83	13.59±0.99	13.85±1.20
Post	14.21±0.86	13.68±0.99	13.79±1.22
Left Calf (cm)			
Pre	14.13±0.85	13.49±1.03	13.80±1.05
Post	14.18±0.89	13.56±0.95	13.81±1.16

APPENDIX J

MUSCULAR SORENESS SCALE

MUSCULAR SORENESS SCALE

INTENSITY	CHARACTERISTICS
0	NONE
1	
2	LIGHT- Barely noticable
3	
4	
5	MODERATE- Can easily be distracted away from the soreness
6	
7	
8	SEVERE- Can not be easily distracted away from the soreness
9	
10	MAXIMAL- Most excruciating soreness/pain ever experienced

APPENDIX K

PERCEIVED MUSCULAR SORENESS
DATA ANALYSIS

Two Way Repeated Measures ANOVA
for Perceived Muscular Soreness Data

Source	DF	SS	MS	F	P
Condition	1	3.10	3.10	0.88	0.36
Subject(Cond)	2	71.46	3.57	1.22	
Day	2	149.15	74.57	25.52	0.001
ConditionXDay	2	1.49	0.74	0.26	0.78
Residual	3	87.66	2.92		

Neuman-Keuls Test for
Rating of Perceived Exertion

	Day 1	Day 2	Day 3
Mean	4.91	2.91	0.98

APPENDIX L

RAW DATA

PRETEST DATA

SUBJECT	VJ1	VJ2	VJ3	VJ4	VJ5	VJ6
1	21	23	23	23	23	22.5
2	18.5	18.5	19.5	19.75	19	19.5
3	20	20	21	21.5	21	21
4	17.5	17.25	17.25	17.5	17.25	17.75
5	18	19	18.5	17.5	18.5	18.5
6	15	16	15.5	16.25	15.5	15.25
7	22	22.5	23	21.5	21.5	22
8	11.5	11.5	12.75	12.5	12.75	13
9	20	19.5	20.75	20.5	20.5	20.5
10	22	21.75	21	21.25	21.5	20.75
11	19.75	21.25	20.75	19.75	19.75	20.5
12	14	14	13.5	14.5	15	15
13	18	18.5	19	18.5	18.5	18
14	23	22.5	24	23	24	24
15	15	15.5	15	15.25	15.25	15.25
16	15.5	15	16.5	16	16	16.75
17	16.5	17	16	17.5	17.25	17.5
18	9.5	9	10	9.5	10.75	10
19	15.25	15.5	16.25	16.5	15	15.5
20	19	17	19.5	18.5	18	19
21	14	14	13.75	13.5	14.25	14
22	13.25	13.5	14	14	14.25	14.5
23	21	19.75	20.75	20.25	18.25	19.5
24	19.25	19.75	18.75	18.75	20.25	20.25
25	18.5	18.25	18	18.5	18.5	18.5
26	20	20.5	20.25	19.75	20.5	20.5
27	19.75	19	20	19.25	19.25	18.5
28	11.75	10.75	12.25	11.75	11.75	12
29	8.75	8.75	9.75	9	9.25	8.75

Pretest Data

SUBJECT	VJ1	VJ2	VJ3	VJ4	VJ5	VJ6
30	16.5	17	17	15.5	17.5	16.75
31	18.5	19.75	20	18.5	19.5	19.75

SUBJECT	40YD1	40YD2	40YD3	RCALF1	RCALF2	LCALF1	LCALF2
1	5.09	5.46	5.25	14.125	14.063	14.063	14
2	5.66	5.42	5.14	14.813	14.938	15	14.938
3	5.32	4.96	4.96	14.5	14.438	14.125	14.313
4	6.28	6.00	5.81	14.813	14.875	14.875	14.938
5	6.05	5.72	5.90	12.875	13	12.75	12.689
6	6.18	6.53	6.46	14	13.938	14.125	14.125
7	5.62	5.08	5.19	14.625	14.563	14.563	14.689
8	6.81	6.54	6.34	13.375	13.438	13.563	13.625
9	5.75	5.61	5.57	12.563	12.625	12.75	12.75
10	5.53	5.11	5.09	14.689	14.813	14.813	14.813
11	5.91	5.72	5.80	14.625	14.625	14.75	14.75
12	6.27	5.84	5.76	14.188	14.188	14	14.063
13	6.11	5.76	5.82	14.689	14.75	14.438	14.375
14	5.49	5.45	5.35	14.938	15	15.125	15.125
15	7.19	6.70	7.32	13.813	13.813	13.938	13.813
16	6.63	7.01	6.42	11.813	11.875	11.875	11.813
17	5.53	5.63	5.81	13.938	14	13.813	13.813
18	6.20	6.10	6.25	13.063	13.063	13.438	13.5
19	6.11	6.23	6.09	14.875	14.938	14.689	14.75
20	5.41	5.55	5.43	12.75	12.5	12.5	12.438
21	6.16	6.29	6.02	14.125	14.188	13.563	13.938
22	6.21	6.02	6.03	11.938	11.689	11.5	11.5
23	5.92	5.65	5.31	13.938	13.813	13.625	13.625
24	6.00	6.17	5.73	13.125	13.125	13.25	13.313

Pretest Data

SUBJECT	40YD1	40YD2	40YD3	RCALF1	RCALF2	LCALF1	LCALF2
25	5.58	5.10	5.83	13.25	13.375	13.5	13.438
26	5.27	5.07	5.20	16.125	16	15.813	15.25
27	5.33	5.15	5.12	13.25	13.188	12.813	12.938
28	7.20	6.80	7.28	12.563	12.75	12.813	12.75
29	7.43	7.22	7.25	14.5	14.438	14.375	14.313
30	5.43	5.56	5.48	14.25	14.25	14.438	14.438
31	5.75	5.70	5.62	15.125	15.188	15	15.125

Posttest Data

SUBJECT	VJ1	VJ2	VJ3	VJ4	VJ5	VJ6
1	24	23.5	24.25	23	22.75	25.25
2	18.75	20	19.5	19	19.75	20
3	20	20.75	20.5	20.75	21.25	21.25
4	15.5	17	17.5	17.75	17.75	16.75
5	17.25	17.75	18	18	17	17.25
6	15.75	16.5	16.75	15	15.75	16.5
7	20.5	21.5	21.5	21	23	21.25
8	10.5	12.25	12.25	12.5	12.25	12
9	18.5	20	19.75	20.25	19.5	20
10	21	21.5	20	21.75	21.75	22.5
11	18	18	17.75	17.5	17.5	17.25
12	15.25	16	17.25	17.25	16.75	17
13	20	17.75	19.25	19.75	18.5	19.5
14	22.75	23.25	21.75	25	25.25	25.25
15	14.25	14.5	14.75	14.5	15	15.25
16	15	16	16	17.25	16.75	16.75
17	14.5	17.25	15.5	16.25	17.5	16
18	11.75	11	11.25	13.5	13.75	12.5
19	15.5	15.5	17.25	16.5	16	17.25
20	19.5	19.75	19.5	19.75	20	19.5
21	11.25	12.5	12.75	13	13.5	13.5
22	14.25	14.25	14.75	15	15.5	15
23	22	22	21	22	22.5	22.5
24	22.5	22	22.75	22.5	22.75	22.5
25	18.25	18	18.75	18.75	18.25	19.5
26	21.25	22.25	22.5	22	22.75	21.25
27	17.5	19.75	20.5	20.75	20	19.5
28	10.5	11.25	11	10.75	11.75	12.25
29	10.5	11.25	11	11.5	11.5	11.5

Posttest Data

SUBJECT	VJ1	VJ2	VJ3	VJ4	VJ5	VJ6
30	18.5	19	17.25	18.75	19	18
31	18.25	18.5	18	17.5	18.25	18

Posttest Data

SUBJECT	40YD1	40YD2	40YD3	RCALF1	RCALF2	LCALF1	LCALF2
1	5.27	5.17	5.13	14.438	14.313	13.938	14
2	5.30	5.39	5.23	15.125	15.188	15.25	15.125
3	5.09	5.11	5.01	14.5	14.5	14.313	14.313
4	6.21	5.94	5.77	15.25	15	15	15.125
5	6.13	5.94	6.07	12.689	12.625	12.5	12.5
6	6.09	6.20	6.17	14.125	14.125	13.875	14.25
7	5.50	5.56	5.44	14.375	14.689	14.625	14.5
8	6.34	6.37	6.16	13.938	13.938	14	14
9	5.49	5.40	5.47	12.689	12.938	12.75	13
10	5.45	5.48	5.45	14.75	14.5	14.75	14.75
11	5.85	5.87	5.93	14.5	14.625	14.689	14.75
12	6.28	5.96	6.16	14.063	14.125	13.875	13.813
13	5.85	6.09	5.92	15.125	15	14.875	14.813
14	5.51	5.38	5.16	15.25	15.375	15.25	15.375
15	6.17	6.44	6.54	13.75	13.938	13.813	13.875
16	6.17	6.08	6.30	11.875	11.813	11.75	11.625
17	5.54	5.70	5.77	14.25	14.125	14	13.875
18	6.21	6.13	6.16	13.25	13.125	13.375	13.5
19	5.91	5.72	5.87	14.625	14.5	14.563	14.375
20	5.63	5.57	5.48	12.875	12.813	13	12.938
21	6.51	6.26	6.39	14.188	14.813	13.75	13.625
22	6.27	6.32	6.31	11.938	11.875	11.75	11.875
23	5.91	5.70	5.96	13.75	13.813	13.625	13.625
24	6.36	6.12	5.98	13	13.125	13.188	13.188

Posttest Data

SUBJECT	40YD1	40YD2	40YD3	RCALF1	RCALF2	LCALF1	LCALF2
25	5.24	5.35	5.65	13.563	13.375	13.188	13.063
26	5.25	5.28	5.29	15.875	15.938	15.75	15.625
27	5.46	5.73	5.67	13.25	13.5	13.75	12.938
28	7.17	7.56	7.44	12.438	12.438	12.563	12.689
29	7.11	7.34	7.33	14.375	14.5	14.438	14.438
30	5.63	5.58	5.71	14.313	14.375	14.5	14.375
31	5.37	5.25	5.34	14.875	15.188	15.25	15.188

VJ is represented in inches.
40 yard dash is represented in seconds.
Calf girth is represented in inches.

VITA

Karen Michelle Jenkins was born on June 16, 1969, in Roanoke, Virginia. Karen's parents are Mr. and Mrs. William H. Jenkins, of Vinton, Va. She is the youngest of the family having two older brothers. Karen went to Wiliam Byrd High School and was very active in extracurricular activities. Karen was a member of such clubs as the National Honor Society and the Fellowship of Christian Athletes. She was also active in sports playing varsity volleyball for a year and varsity basketball for three years. Karen also participated in the track program in addition to playing recreation softball. In basketball, her team won the district championship her sophomore, junior and senior years. They won the Regional championship two years and finished second in the State championship one year. Karen was honored as being named All-District her senior year and named to the District All-Tournment team her junior and senior years. Karen also received the Unsung Hero award her senior year.

After graduating from high school, Karen attended Roanoke College in Salem, Va. to play basketball and study athletic training. Karen played basketball for four years for Roanoke College. Karen received many awards while at Roanoke such as being named to the Marymount Tip-Off Tournament team her sophomore and senior years, the Old Dominion Athletic Conference(ODAC) tournment team her sophomore, junior and senior years, the All-ODAC team her junior and senior years, the South Regional team her junior and senior years, and ODAC player of the year her senior year. Karen also received the prestigious honor of being the first woman in the history of Roanoke College named to the Division III Kodak All-American basketball team. At Karen's senior awards banquet, she was named the Roanoke College Female Athlete of the Year and had her #42 jersey retired. Karen received recognition for her accomplishments at the Roanoke County Board of Supervisors and Vinton Town Council meetings. Karen went on to graduate from Roanoke College with a Bachelor of Science degree in Physical Education with a concentration in athletic training.

After graduation Karen was accepted in to the Exercise Physiology department at Virginia Tech, in Blacksburg, Va. During the summer after her first year at Tech, Karen passed the National Athletic Trainers Association exam and is currently a certified Athletic Trainer. Karen was married on August 7, 1993 to William Bryan Harvey. The week before she was married she recieved a teacher/athletic training job at Staunton River High School in Bedford, VA where she will continue working upon completion of her Masters degree in Exercise Physiology.