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THE EFFECTS OF RESISTANCE TRAINING ON SELECTED PHYSIOLOGICAL PARAMETERS

By

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The Effects of Resistance Training on Selected Physiological Parameters

A Thesis Presented to the Department of Physical Education of Lakehead University

In partial fulfillment of the requirements of the Master of Science Degree

by

George Baras

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ABSTRACT

The literature presents contradictory statements concerning the effectiveness of free weights, isokinetic devices and plyometric exercises on the development of lower extremity power, and lean body mass (Coyle, Feiring, Rotkis, Cote, Roby, Lee, & Wilmore, 1981; Gettman, Cutler & Strathman, 1980; Pipes & Wilmore, 1975; Promoli & Holt, 1979; Verhoshanski & Tatyan, 1983; and Scoles, 1978). There is limited evidence in the literature measuring the effectiveness of combining plyometrics and various alternative resistance training devices.

The training effects of four experimental groups were investigated: free weights (FW), Hydra-Fitness (HF), Hydra-Fitness plus plyometrics (HFP), and free weights plus plyometrics (FWP). Pre-training and post-training tests for the lower extremity measured lean body mass, muscular peak power at slow and fast speeds (60, and 180 degrees/second), power-endurance and vertical jump power. Forty Physical Education students were randomly assigned into four groups; free weights, Hydra-Fitness, Hydra-Fitness plus plyometrics, and free weights plus plyometrics. The intensity of each group was equated. Subjects were trained three times per week for seven weeks. A 4 (groups) by 2 (tests) ANOVA with repeated measures on the last factor ($p<.05$) was employed on pre and post training raw data. Post-hoc technique (Scheffe' method) was employed when significant interactions were found. All groups improved the lean body mass, vertical jump, and power-endurance after training.

There were no significant differences found between the four training groups. Plyometrics in combination with free weights or Hydra-Fitness appear to have a positive training effect on power.

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To my parents, whose continuous support helped me to accomplish this goal.

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Chapter 1

INTRODUCTION

Purpose

This study was designed to investigate lower extremity training using four experimental groups: free weights (FW), Hydra-Fitness (HF), Hydra-Fitness plus plyometrics (HFP), and free weights plus plyometrics (FWP). Pre-training and post-training tests measured lean body mass, muscular peak power (60, and 180 degrees/second), power-endurance, and vertical jump power.

Significance of the study

Maximizing performance through lower extremity training methods is reflected through measures of muscular power, and power-endurance (Jensen & Fisher, 1979; and Kitagawa & Miyashita, 1978). This study is designed to compare the effectiveness of training methods presently available to coaches.

The literature indicates extensive research concerning weight training using different resistance devices. Since many resistance training devices are available, comparisons between free weights, and other training devices and methods have been researched in the literature (Coyle, Feiring, Rotkis, Cote, Roby, Lee, & Wilmore, 1981; Gettman, Cutler, & Strathman, 1980; and Wilmore, 1974). However, there is limited research concerning the comparison of free weights with plyometrics versus Hydra-Fitness devices combined with plyometrics. Plyometric exercises were employed by many coaches in sports which required strength-speed, and their athletes reportedly experienced tremendous success (Verhoshansky, 1973; Verhoshansky & Tatyan, 1983). Plyometric exercises became an important part of supplementary training but are rarely combined with Hydra-Fitness machines.

This study investigated the effects of free weights, Hydra-Fitness, Hydra-Fitness plus plyometrics, and free weights plus plyometrics on lean body mass, muscular peak power (60, and 180 degrees/second), power-endurance, and vertical jump power in the lower extremity. The study was completed to provide trainers, and coaches with additional guidelines for the design, and combination of training methods.

Delimitations

1. Subjects were forty (40) students from the department of Physical Education of Lakehead University, ranging from 18 to 24 years of age.

2. The dependent variables were lean body mass, muscular peak power at slow and fast speed, power in the vertical jump, and power-endurance.

3. The total training period lasted 9 weeks. The two first weeks were for orientation, and were followed by 7 weeks of training.

4. The subjects were tested at the same time each day in order to

avoid diurnal variations.

Limitations

1. It was assumed that the subjects had a similar athletic background and they were not involved in any other training program.
2. The ability to motivate the subjects to exert maximum effort during the tests.
3. It was assumed that the subjects followed the training instructions when not directly supervised.
4. Muscular power and power-endurance were measured by an isokinetic device.
5. The accuracy of predicted skinfold measurement technique for subcutaneous fat was a predicted method using a Harpenden caliper.
6. Quantification of the plyometric exercises was variable due to individual somatotypes.
7. There are very limited guidelines for plyometric training protocols.

Definitions

Free Weights: resistance training using barbells, dumbbells, and weight plates.

Hydra-Fitness: devices in which a hydraulic cylinder provides variable resistance during double concentric bidirectional muscle work.

Isokinetic Contraction: muscular contraction at a constant velocity throughout the full range of motion.

Isotonic Contractions: dynamic contractions including; a) concentric (shortening of the muscle) and b) eccentric (lengthening of the muscle).

Lean Body Mass: total body weight minus total weight of body fat (Kg).

Muscular Endurance or Fatigue: the capacity of a muscle or group of muscles to maintain or repeatedly develop a certain degree of tension in a given period of time (20 seconds).

Muscular peak Power: the ability to release maximal force in the fastest possible time. Power = Force x Velocity or P = F x D/t

Plyometrics: training drills which cause the muscle to prestretch performing an eccentric contraction followed by a concentric contraction. This loads the elastic and contractile components of the muscle and produces greater force.

Peak Torque: is the maximum muscular force which acts about a joint axis of rotation during a maximum muscular contraction.

Chapter 2

REVIEW OF LITERATURE

Research has shown that lean body mass, muscular power, power-endurance, are contributing factors to performance improvement. The proper incorporation of power and endurance into a training program using resistance training techniques is of paramount importance for explosive events, and team games (Verhoshansky & Tatyan, 1983; Matveyev, 1981; Bompa, 1983; and Wilt, 1976). This review will deal with studies designed to measure the effectiveness of free weights, hydraulics and plyometric training methods for the development of strength and power.

Lean body mass

The success of many athletes is not only attributed to physical and technical abilities, but also to lean body mass (LBM). Training effects on lean body mass, and percentage of body fat has been extensively researched (Coyle et al., 1981; Pipes et al., 1975; Gettman et al., 1980; Hickson, 1980; Hetrick & Wilmore, 1979; and Wilmore, 1974). Pipes et al. (1975) studied the effects of isotonic versus isokinetic low and high speed training on lean body mass and body fat. Thirty six male volunteers, ranging from 20-38 years of age, trained three times per week for eight weeks. Body density, lean body mass and relative fat were estimated by the hydrostatic procedure

(Wilmore, 1969). The subcutaneous fat was measured using a Harpenden caliper. An analysis of covariance and a post-hoc procedure using Scheffe tests for mean comparisons demonstrated that all groups increased the lean body mass (LBM) significantly. However, no significant differences were observed amongst groups. The isokinetic high speed group exhibited the highest reduction in percent body fat. The subcutaneous fat was significantly reduced in all the seven skinfold sites for the isokinetic fast speed group. The isokinetic slow speed group and the isotonic group had a significant decrease in six and two skinfold sites respectively (Wilmore, 1974; Fahey, 1973; and Capen, 1950). Coyle, Feiring, Rotkis, Cote, Roby, Lee, and Wilmore (1981) investigated the effects of isokinetic training on subcutaneous fat. Twenty-two college volunteer males trained on a Cybex Orthotron at low, high, and mixed low and high speeds. A test-retest study showed a coefficient of reliability of r=.96. One way analysis of variance and the Duncan's test indicated that all groups had no significant changes in body weight. However, the slow speed group exhibited a significant reduction of the thigh skinfold site by 2.9 mm. Conversely, the groups trained at fast and mixed speeds had only a small reduction of the thigh site by 0.6 and 0.2mm. Gettman, Cutler, and Strathman (1980) examined the effects of isotonic and isokinetic weight training on anthropometric measurements. Twenty-one volunteer males trained three times per week (30-40 min) for 20 weeks. An analysis of covariance and a post-hoc procedure showed that both groups increased significantly in lean body mass by 1.61 Kg and 2.13 Kg and decreased significantly in body fat by 1.9% and 2.8%. There were no significant changes in body weight (Wilmore, 1974).

Pipes (1978) investigated the changes of body weight, body fat, and lean body mass due to constant, and variable resistance of weight training. The subjects were trained for ten weeks, three days per week. There were no significant changes in body weight. However, the body weight of the constant, variable resistance, and the control group increased by 1.6 kg, 2.3 kg and 1.5 kg respectively. The control, and variable resistance training groups had a significant gain in lean body mass of 2.6 kg and 3.1 kg and a significant reduction in percent body fat of 1.6% and 1.5% respectively. There were no significant differences between the groups. Hickson (1980) compared a strength (S), an endurance (ET), and a combined stength endurance (SE) training program, relative to body changes. Twenty-three subjects of both genders were trained for ten weeks, 5 times per week for 30 - 40 minutes. The S, ET and SE training groups increased their body weight by 1.9 kg, and 2.2 kg, while the body weights in the mixed group remained stable. The thigh circumference for the S and SE groups increased by 2.3 cm, and 1.7 cm respectively, while it remained unchanged for the E group. There was a significant reduction of relative body fat in the E, and the SE group. The highest value of fat reduction occurred in the E group. Hetric and Wilmore (1979) postulated that changes in body fat, and lean body mass were similar for both genders. Twenty-four subjects, both men and women, participated in an 8 week isokinetic training program. The program included three hourly training sessions per week of one hour each. Both groups, males and females, had a significant reduction in body fat by 10.6% and 10.8%, and a significant increase in lean body mass by 0.3% and 3.8% respectively. Body weight remained unchanged in both groups.

Jensen and Fisher (1979), postulated a positive correlation between the muscle's cross section and strength. Theory suggests that muscle hypertrophy causes an increase in the size and number of myofibrils which keeps an optimum diffusion distance of calcium so that muscular contraction is facilitated. In many sports, however, extreme muscular hypertrophy is less preferable as compared to neural adaptations. Since, athletes of different events are distinquished by different somatotypes the optimal levels of (% BF) and (LBM) will vary amongst them as they would with sedentary or low activity individuals. Kitagawa and Miyashita (1966) found high correlations between lean body mass (LBM, %LBM), strength, and work output (Nagle, 1975). Girandola and Katch (1973) commented that changes in lean body mass, and body fat would positevely affect power, and maximal oxygen consumption (Wasserman, Whipp, Koyal & Beaver, 1973). An increase of body fat would cause a decrease in maximal oxygen consumption. Conversely, Ergen, Gambuli, Leonardi, and Monte (1983) failed to find similar results.

Following a resistance training program a decrease in percent body fat (% BF) with a subsequent increase in lean body mass (LBM) is regularly reported in the literature. Although there is limited information on the effect of plyometrics on body fat and lean body mass, the literature indicates that resistance training employing free weights or hydraulic machines cause a body fat reduction and an increase in lean body mass. Various resistance training methods are commonly employed to decrease body fat and increase lean body mass.

Muscular Peak Power

Many researchers have studied the effects of different training methods on muscular strength, power and endurance. Free weights, various isokinetic devices and plyometric exercises have been compared against each other in order to find the most effective training program (Pipes et al., 1975; Polhemus & Burkhardt, 1980; McKethan & Mayhew 1974; Coyle et al., 1981; and Barnes, 1981). Pipes and Wilmore (1975) investigated the effects of isotonic, isokinetic fast speed and isokinetic slow speed on strength and power for 36 adult males. The subjects executed strength-speed exercises for the upper and lower body three times per week, for 8 weeks. All groups performed the leg press, bench press, bicep curl, and bent rowing. Strength and power were measured using a cable tensiometer, one repetition maximum

(Berger, 1962), a Cybex II, and a hydraulic device at velocities of 24 and 136 degrees per second. The author reported that the isokinetic training was superior to the isotonic training. Moreover, the isokinetic fast speed group demonstrated the highest values. The results for the isotonic group were similar to those values found by Wilmore (1974), Fahey and Brown (1973), and O'Shea (1966). However, Berger (1962, 1965) reported higher improvements in power, due to isotonic training. The improvements for the isokinetic groups were higher than those values presented by Moffroid (1969) and lower than those values reported by Thistle, Hislop, Moffroid and Lowman (1967). Promoli and Holt (1979) commented that fast speed isotonic exercise (Olympic barbell), dynamic variable resistance exercise (Universal seated leg press), and isokinetic exercise (Mini Gym Leaper) produced similar improvements in power. Katch, La Chance, and Adams (1986) tested 58 university football players on a Hydra-fitness Total Power Omni-Tron device. The players performed three sets of 15 repetitions at approximately 75% of their maximum strength, at setting 10. The highest peak torque of the best set represented strength. The average power output of the first five contractions defined power, and the total work output of the fifteen repetitions represented endurance. The results revealed that the players varied in strength, power, and endurance according to different positions. The defensive backs, and offensive linemen scored higher in the strength test as compared to defensive linemen, and quarterbacks. The defensive linemen exhibited the highest power, and endurance respectively, followed by the offensive linemen, defensive backs, and running backs. Smith, Stokes, and Kilb (1986) investigated the effects of Hydra-fitness resistance training on power using a intervarsity female volleyball team. Ten volleyball players trained with 6 different Hydra-fitness machines in addition to their volleyball practice. The control group was comprised of five volleyball players who followed only the volleyball practice. All subjects trained three times per week in the first three weeks, and twice in the last three weeks. Both groups were tested on knee extension using a Cybex II dynamometer at 30, and 180 degrees per second. An ANCOVA with repeated measures and Scheffe tests showed that the experimental group improved at both speeds. However, significant improvements were found only at 180 degrees per second. There was no significant increase for the control group. Schmidtbleicher (1985) reported that hydraulic machines provide an artificial resistance which interferes with acceleration and that elite athletes showed a high preferance for free weights.

Polhemus and Burkhardt (1980) examined the effects of weight training, and various plyometric exercises on speed-strength abilities of college football players. The subjects were randomly separated into three groups. The training program lasted six weeks. The first group trained only with free weights for three times per week (half squat, power clean, bench press, and military press exercises). Each practice consisted of five sets of five repetitions each. The workload used was from 65-75% of a maximum repetition (1 RM). The second group combined both free weights and plyometric exercises. The plyometric program included three sets of depth jumps of ten repetitions each. The height of the depth jump (rebound jump) was 45 cm. Running in place with high knee lifts and bounding drills were also used. The third group performed the same program as group two but, in the DJ the subjects wore a vest of approximately 10-12% of the subject's body weight. In the bounding drill ankle weights of 2.5 pounds were added on each foot. An one way factorial analysis and a post-hoc procedure revealed that the third group improved more than the other groups when they performed the half squat, power clean, and bench press test. There was no significant difference between the groups in the military press. The third group enhanced performance by 50%, while the other groups improved by 30%. Improvements in speed-strength were similar to the findings reported by Verhoshansky and Tatyan (1983), Adams (1984), and Dursenev and Raeysky (1979). Conversely, Clutch et al. (1983), and Herman (1976) found no significant differences between similar training programs.

Zatsyoski's study (cited in Bompa, 1983) recommended that the strength-speed magnitude of an athlete depended on the following factors; (a) on the co-ordination of various muscle groups, or the intermuscular co-ordination, (b) on ones ability to recruit the neuromuscular units synchronously during maximal exercise, or the intramuscular co-ordination, and (c) the strength magnitude depended on the degree of force with which the muscle fibers react as a result of nervous stimulation. Levchenko (1985) examined the effects of high load volumes for speed strength training. Sprinters were trained for 16 weeks. The study showed that during the 11 weeks high load volume training the absolute, explosive and starting strength of the leg, and ankle exensor muscles were decreased significantly by 8.7%, 11.6% and 11% respectively. This was more apparent in the seventh week in which the volume of the training was very high and combined both weights and jumping exercises. During the twelfth, and fifteenth week, the load volume decreased. The training procedure resulted in an increase in strength. In the fifteenth week the absolute, explosive and starting strength increased significantly by 10%, 18.2%, and 18.3%. The author concluded that, training at high concentrated load volume for a short period of time, followed by a decrease in the load volume would result in a remaining cumulative training effect that improves the neuro-muscular mechanism of the body and enhances performance (Verhoshansky, 1985). Madvedyev and Verhoshansky (1986) recommended that the athletes who need explosive strength should improve their speed of movement. Thus, the time of execution, and the time required for the working effort should be shorter. In sports such as sprinting, throwing events, and team games power is achieved employing, loads from 50 to 80% (1 RM), explosive rhythm, and eight to ten repetitions; in long distance events the load can be lower (Bompa, 1983). As power training should be specific to each sport, training methods using various resistance with different speeds can be employed to maximize power (Matveyev, 1981). Schmidtbleicher (1985) suggested that isokinetic machines should be used only during the general preparation training phase because their fixed resistance interferes with acceleration. The success of many west German athletes was attributed mainly to training with free weights of sub-maximal, and maximal loads.

Studies concerning the relationship between the absolute and relative strength of males, and females is extensive (Wilmore, 1976; Schantz, Randall-Fox, Hutchinson, Tyden, & Astrand, 1983; Davies, White, & Young, 1983; and Hosler & Morrow, 1982). In an attempt to investigate the relationship between males and females, Wilmore (1976) reported that the lower body absolute strength for females was 27% lower than the males. This difference was decreased when leg strength was expressed relatively to lean body mass. Moreover, the relative leg strength was slightly higher (5-10%) for females rather than males. Hosler and Morrow (1982) found only a 2% difference in relative leg strength between males, and females (Hetrick & Wilmore, 1979). Schantz et al. (1983) reported no difference between the two genders in relative strength of the lower body.

Grimby and Hennerz (1968) pointed out that during voluntary contraction the regularity in neural discharge rate of a motor unit is associated with the strength of its afferent input. Burke and Enderton (1975) commented that the central nervous system was able to adjust the selective recruitment of motor units. Thus, during very forceful and/or rapid movements, the fast twitch motor units were recruited. Moreover, heavy olympic weight lifting required the recruitment of all motor units (synchronous recruitment). Slow twitch motor units were activated when light weights were used. Fast twitch motor units displayed a higher tetanic tension than ST motor units, even though the tension was related to unit cross-sectional area. Thorstensson, Larsson, Tesch, and Karlsson (1977) postulated that athletes with a higher proportion of fast twitch fibers demonstrated a higher peak torque (PT), but they fatigued faster than athletes with slow twitch fibers. The predominantly fast twitch athletes had a 11%, 10%, 23%, and 47% higher peak torque than slow twitch athletes at testing velocities of 115 , 200 , 287, and 400 degrees per second (Ivy, Withers, Brose, Maxwell, & Costill, 1981).

Muscular power is extremely vital to sports which require explosive movements (Matveyev, 1981). The present study emphasized explosive movement, twenty seconds duration, and 60% (1 RM) load. The literature indicates contradictory statements concerning the effectivenes of free weights, hydraulic machines and plyometrics on power. The implementation of resistance loads into training emloying different speeds is a common form of power training.

Vertical Jump Power

The vertical jump is widely used as a field or lab test. The literature indicates that test-retest reliability of the vertical jump was found to be high. Bosco, Luhtanen, and Komi (1983a), and Gray, Start and Glencross (1962) reported reliability coefficients of .95, and .98 respectively. Due to the anaerobic nature of the test it is also used to measure anaerobic power. Plyometrics derived from the Greek words "pleythein" or "plio-metric" which means to augment or measure more. (Chu, 1983; Gambeta, 1981; and Wilt, 1970). Morris (1974) suggested that plyometric exercises, such as depth jumps (DJ) caused a myotatic reflex facilitation which improved power (Lagasse, 1974). Asmussen, Bonde, and Peterson (1974) stated that prior to a DJ mechanical energy might be stored in the elastic components of the muscles so that it enhances performance. Similar statements as concerning the changes of the muscles elastic components, and the proprioceptive feedback mechanism were commented by Schenau, (1984), Cavagna (1975), and Bosco (1981). Verhoshansky and Tatyan (1983) trained three different groups of 36 athletes for 14 weeks (36 sessions). The first group performed hops with a barbell on the shoulders, vertical jumps, long standing jumps, and triple jumps. Two sets of three maximal repetitions with free weights preceeded the workout. The second group executed the same exercises but in the opposite order. The third group performed depth jumps from heights of 40 to 70 cm. The results demonstrated that the last group improved significantly more in the vertical jump test, than the other two groups. The first two groups improved without any significant difference. The investigator concluded that this type of training was more effective in the improvement of the athlete's power. It was also suggested that a good combination of depth jumps with traditional weight training program would be more effective. Many East European athletes such as Janus Lusis, Valeri Borzov, and Valeri Brumel used a combination of free weights and various plyometric exercise (Zanon, 1974; and Wilt, 1976).

Although there was no methodology in the translated journals, Verhoshansky's (1973) extensive research recommended that the height of the depth jumps was more effective for developing maximum speed, and dynamic strength at 80, and 1.10 (cm) centimeters respectively. Training intensities were suggested at 40 depth jumps for advanced athletes and 20-30 jumps for less prepared athletes in each session. The jumps are executed twice a week in a series of 10 repetitions followed by jogging, and relaxation exercises. Depth jumps can be executed prior to sprinting and jumping sessions. Additional weight on the body, or an increase in the height of the DJ would alter the speed with which the muscles change from eccentric to concentric contractions. Because the training effect of the depth jumps last much longer than other strength exercises (6-8 days) the jumps should be discontinued 10-14 days prior to competition. However, Adams (1984), Katscharov, Gomberaze, and Revson (1976) and Komi, and Bosco (1978) suggested alternative heights of DJ of 40 cm, 150 cm, and 80 cm. Marteen, Huizing, Schenau, and Insen (1987a) found no significant differences between drop jumps from heights of 60 cm, 40 cm, and 20 cm. Marteen, Huizing, Schenau, and Insen (1987b) compared the effect of two jumping techniques on the biomechanics of jumping. Ten male volleyball players executed bounce drop jumps from 20 cm height (Subjects reverse the downward velocity into upward velocity as soon as possible after landind), versus counter-movement jumps (subjects were making a larger downward movement). The results demonstrated that during broad depth jumps (BDJ), the values for moments, and power output about the knee and ankle joints were significantly higher than those values of the counter-movement jumps (CMJ). Thus, broad depth jumps were recommended for enhancement of mechanical output of knee extensors, and plantar flexors. Bosco, Luhtanen, and Komi (1976) commented that the best performance in the long jump occured when the center of gravity of the jumpers rose as soon as they touched the board. The contact time of the take-off was negatively correlated to the length of the jump.

Clutch, Wilton, McGowan, and Bryce (1983) investigated the effectiveness of combined plyometrics and free weights versus free weight training programs. Thirty-two male volleyball players and weight trained college students were randomly selected and divided into two groups. The training period lasted 16 weeks. Group A executed DJ (from 75, and 1.10 cm), and weight lifting exercises. Group B lifted weights of 80% of 1RM, three times a week. The weight program consisted of half squats, bench press, and dead lift exercises. The findings indicated that DJ incorporated with weight training was no more effective than maximum vertical jumps. The conclusion was that any type of jump combined with weight training can improve the vertical jump (Scoles, 1978). Levchenko (1984) investigated the effects of weight training of young weight lifters, and sprinters on strength and standing long jump. He observed that the weight lifters exhibited higher strength values than the sprinters. However, the sprinters showed higher initial values than the weight lifters in the standing long jump by 6%. The author suggested that the track and field athletes possessed higher speed qualities, and recommended that track and field athletes should train with weights to improve their strength-speed.

Power is an important training component in many sports involving the affiliation of force, and speed, and is more prominent in events which require explosive movements. Free weights, hydraulic machines and plyometric exercises have a positive effect on power. However, there are controversial statements on which training method is the most effective. The implementation of resistance loads into training at different speeds is a common form of power training.

Power-Endurance (fatigue)

Power-endurance is crucial to sports which require to maintain or repeatedly develop a certain degree of tension at a given distance or over a specific period of time. Peak force declines with muscular fatigue. Power-endurance is measured through the ability of the athlete to maintain maximal force.

Lesmes, Costill, Coyle, and Fink (1978) investigated the changes of power and fatigue due to isokinetic training (Cybex II) at velocity of 180 degrees per second. The subjects trained one leg for 6 seconds, and the other leg for 30 seconds four times per week, for seven consecutive weeks. Coefficients of reliability and validity were r>.99 and r>.99 respectively. The trained group showed a significant improvement in PT for both legs at velocities of 60, 120, and 180 degrees per second by 14.6%, 16.2%, and 13.6%. There was no significant increase at 240, and 300 degrees per second. The percent work output increased significantly in the 6 second test (180 degrees/ sec.) by approximately 32%. In the 30 second test the 30 second trained leg performed significantly better (27%) than the 6 second trained leg (18%), by a 9% difference. In the 60 second fatigue test (180 degrees/sec) both trained legs showed significant improvements. The 30 second trained leg fatigued less or performed more work (19%) than the 6 second trained leg (15%). Although, there was no significant difference between the two legs the former trained leg performed more efficiently in the last 10 seconds of the test. Barnes (1981) compared isokinetic fatigue curves at different velocities. Twenty-five physically active adult males were trained on the isokinetic device Cybex II. The subjects performed 10 repetitions at velocities of 60, 120, 150, and 300 degrees per second. The results showed that the athletes fatigued less in each post-test. There was a decrease in PT due to fatigue by 27.1%, 29.6%, 23.6%, and 33.6% at 60, 120, 150, and 300 degrees per second. Fatigue curves were similar at all testing velocities. Torque production was significant different between the initial, and final trial at all speeds. The ten maximal contractions were fatiguing in nature. Peak torque was higher at slow rather than fast velocities (Gransberg & Knutsson, 1983).

Sahlin and Henrikson, (1984) stated that elite athletes, fatigued less than untrained subjects due to the following factors: trained athletes could recruit more motor units, activate more cross bridges, enhance the turnover ratio for Adenosine Triphospate (ATP), and maximize velocity (V.max) of the enzymatic reactions (Mikhaelis Principle). It was also suggested that athletes might have a higher buffer capacity and tolerate high levels of lactic acid, and a lower intracellular pH. (Shahlin, 1986; Davis, 1985; Brooks & Fahey, 1984; Astrand & Rodahl, 1977; and Endgerton, 1976). Jacobs, Tesch, Bar-Or, Karlsson, and Dotan (1986) found that the glycolytic pathway was involved in exercise of less than 10 seconds duration. Thus, the alactic and lactic system probably get involved simultaneously after the beginning of the exercise and the accumulated lactic acid (La) would cause fatigue. The accumulated lactic acid releases hydrogen ions which causes intramuscular acidity and decreases the intracellular pH. This interferes with the muscle's excitation-contraction coupling (Shahlin, 1986). A decrease of the peak torque might occur due to central (proximal to the neuromuscular junction (NMJ), and peripheral fatigue (distal to NMJ). Also, the depletion of the immediately available substrates, and the exhaustion of the elastic component can be another cause of fatigue. (Tesch, Komi, Jacobs, Karlsson, & Viitasalo, 1983; Tesch, 1980; and Asmussen,1979).

Jensen and Fisher (1979) reported a high positive correlation (.75-.97) between strength, and muscular absolute endurance (the amount of time an individual can work against a constant resistance when the resistance is not related to his/her strength). Conversely, there was a low negative correlation between strength, and relative endurance (the ammount of time a subject can work when the resistance is adjusted according to his/her strength). Thus, absolute strength would be beneficial in events which require acceleration of external objects such as a shot put, and hammer throw. Relative strength or high strength /body mass ratio would be more effective to the sprinters, and jumpers who have to accelerate their body mass quickly. Also, endurance runners, and soccer, field hockey, and basketball players had a high relative strength, and power-endurance (Berger, 1982; and Withers, Roberts, & Davies, 1977; and Ayalon, Inbar, & Bar-Or, 1974). Weight training causes hypertrophy in both the fast (FT), and slow twitch (ST) fibers but it is more obvious in the FT fibers (MacDougal,1980). Gregor, Enderton, Rozen, and Castleman, (1981) commented that sprinters who had a high percentage of FT fibers had a higher PT than endurance runners but they fatigued faster. Thorstensson, Grimby, and Karlsson, (1976) have shown the importance of fast (FT), and slow twitch fibers (ST) in short, and long distance events (Karpovich, 1971).

Power- endurance is a very important training component for events in which fatigue interferes with performance. Free weights, hydraulic machines and plyometric exercises improve power- endurance but there it is not certain which training method is superior to the other.

In summary, the literature presents confounding, and often contradictory statements about the effect of free weights, hydraulic machines and plyometric exercises on lean body mass, power and power- endurance. Training methods employing resistance loads at different speeds are commonly employed to enhance power and power- endurance.

Chapter 3

METHODOLOGY

Research Design

This study investigated the training effects of four training programs, free weights (FW), Hydra-Fitness (HF), free weights plus plyometrics (FWP), and Hydra-Fitness plus plyometrics (HFP). Pre and post-tests measured lean body mass, muscular peak power (60, and 180 degrees/sec), power-endurance or fatigue, and vertical jump power.

Subjects

Subjects included 40 male and female students from the department of Physical Education of Lakehead university. Subjects were actively involved in practical courses in Physical Education, and were restricted from additional training programs. Ages ranged from 18 to 24 years. Subject's (No. 29) physical characteristics are listed in Table 1. Due to injuries and sickness the subject number decreased to twenty nine. The free weights, Hydra-Fitness, Hydra-Fitness plus plyometrics and free weights plus plyometrics groups had ten subjects in each group but in the post-test each group had eight, eight, six and seven subjects respectively. In the post-test there were two females in each group.

Investigative Period

The investigative period lasted 7 weeks, commencing February 7, 1987 to March 29, 1987.

TABLE 1

Mean characteristics of subjects (No. 29)

Group	Age	Height	Weight (pre	& post)
Free Weight	22	175	74.5	74.6
Hydra-fitness	23	172	71.7	72.1
Hydra-fitness + Plyometrics	21	174	69.5	70.2
Free weights + Plyometrics	23	172	71.4	71.9

Pre Training Warm-up

All subjects warmed up (10-15 min), performing jogging, bicycling and stretching exercises. Light resistance was used for specific warm-up (5 min.).

Training Programs

Two weeks prior to training the subjects completed a free weight orientation circuit program three times per week. The program included thirteen exercises for total body preparation (Appendix A). Subjects performed repetitions for 20 seconds at a resistance based on the percentage of body weight. Subjects were randomly assigned into one of the following four groups:

1. Free weights (FW)
2. Hydra-Fitness (HF)
3. Hydra-Fitness plus plyometrics (HFP)
4. Free weights plus plyometrics (FWP)

All subjects performed one repetition maximum (1 RM) half squat with a barbell (Berger, 1962) and calculated 60% (1 RM). Maximum number of repetitions were executed in 20 seconds at 60% (1 RM). The FW group trained with a 60% (1 RM) workload, and subjects in the HF group found the setting closest to resistance that allowed the same number of repetitions as the 60% (1RM) on free weights. All exercises were performed with maximum effort. The intensity of the training program increased to provide a training adaption. Sets increased progressively from 4 to 7 for all the groups, and up to eleven for the plyometric exercises (Table 2 & 3). The training period included three sessions per week with no more than two sessions completed on consecutive days. Due to the training demand of the plyometrics the resting period between sets was 3-5 minutes and the duration of each session was approximately 30-40 minutes. Subjects maintained a record of all training sessions completed.

The FW group trained with the barbell (squats), the HF group used the Hydra-Fitness machine (a hydraulic squat device with variable resistance), and the HFP, and FWP groups combined Hydra-Fitness plus plyometrics, and free weights plus plyometric exercises (Table 2, 3, Appendix B & C). In the first session of each training week the FW group trained with free weights, while the HF group used the leaper. Both groups in the second session trained with plyometric exercises. The last session of each training week combined both plyometrics and either Hydra-Firness, or free weights resistance.

TABLE 2

Training Programs: Free Weights (FW), Hydra-Fitness (HF), Hydra-Fitness + Plyometrics (HFP), Free Weights + Plyometrics (FWP).

	Group 1 (FW)	Group 2 (HF)
Week	1 2 3 4 5 6 7	1 2 3 4 5 6 7
# of Sets	4 4 5 5 6 6 7	4 4 5 5 6 6 7
Load	60%	
Duration	20 sec.	
Rhythm	Explosive	
Rest	3 - 5 min.	

	Group 3 (HFP)	Group 4 (FWP)
Week	1 2 3 4 5 6 7	1 2 3 4 5 6 7
# of Sets	4 4 5 5 6 6 7	4 4 5 5 6 6 7
Load	60% & Maximum Effort	
Duration	20 sec.	
Rhythm	Explosive	
Rest	3 - 5 min.	

Training Week	
First Session:	FWP : Hydra-Fitness
	HFP : Free Weights
Second Session:	HFP : Plyometrics
	FWP : Plyometrics
Third Session:	HFP : 50% Hydra-Fitness
	HFP : 50% Plyometrics
	FWP : 50% Free Weights
	FWP : 50% Plyometrics

Table 3

<u>Plyometric Exercises</u>

Excercise	Set Number						
1. Exercise A	4	4	4				
2. Exercise B	4	4	4				
3. Exercise C				4	5	5	4
4. Exercise D				4	5	5	4
5. Exercise E							3
Weeks	1	2	3	4	5	6	7

Plyometric Exercises

The plyometric exercises included: Exercise A. The subjects executed side hops over a bench of 22.5cm; Exercise B. Each subject jumped as high as possible from a 3/4 squat position. The first three weeks consisted of these two exercises (Table 3 & Appendix C). In the fourth week two exercises with higher benches were introduced (exercise C & D). Exercise (C) included a long bench of three different heights (46, 76, and 56 cm). The subjects standing on the floor jumped on the first part of the bench (30 cm), down (20 cm), then to the floor (56 cm), into a 3/4 squat, and finished with a maximum vertical jump. This was completed in both directions for 20 minutes. Exercise (D) was executed in the same way with a bench of 52 cm in height. These two exercises remained the same during the fifth and sixth week but the number of the sets increased to five. The last week consisted of exercise C, exercise D, and exercise E. Exercise E combined the two previous exercises (C & D), but a bench of 32 cm high was also introduced at the begining of the routine. All plyometric exercises were performed with maximum speed. Due to subjects absence during mid term study week each subject completed a maintenance program three times and included the following exercises: squat jumps, bent knees, sit ups, push-ups (3 sets of 10 reps. each), bur-pees (30 reps.), and stationary half squats (50 reps.). The rest period between sets was 3 - 5 minutes.

Cool down

Ten minutes of walking, jogging and stretching exercises concluded each training session.

Testing Schedule

The pre-test and post-tests were administered in the laboratory. Subjects were familiarized with the testing equipment, procedure, and environment, and the tests were completed between the hours of 9:00 a.m. and 4:00 p.m. to avoid any diurnal effects. Subjects warmed up by jogging around the gymnasium and by cycling on a Monarc bicycle for ten minutes. Prior to vertical jump test each subjects specific warm up included three vertical jumps. Prior to power (isokinetic) testing the subjects warmed up on an isokinetic device (Orthotron) for three minutes. Then they attemted three trials on the testing machine (Cybex II).

Testing Procedure

A pilot study was employed to test the reliability of the testing devices. Four randomly selected Physical Education students were pre-tested and after three days they were post-tested. The method error ("SD") of repeated measurements expressed in percentage as a coefficient of variation was 2%, and 3% for the slow, and fast speed, and 4%, and 3% for the power-endurance , and the vertical jump test (Mac Dougal, Wenger, Green, 1982).

Subjects were advised to abstain from vigorous activities for at least twelve hours prior to testing and to avoid eating, taking medication, and drinking (except water) two hours before the test. All participants were required to wear running shoes, T-shirts and shorts. Subject's age was recorded. Body weight was measured to the nearest 0.1 Kg using a calibrated balance scale (Continental Scale,Bridgeview, Illinois). Height was measured to the nearest 0.5 cm using a metric wall tape.

Test Parameters

Table 4 demonstrates the test parameters used for pre and post testing.

TABLE 4

Description of Tests

Test	Instrument	Test Description
FAT %. LBM	Harpenden Caliper	Bicep, tricep, sub-scupular supra-iliac (Kg of LBM)
Vertical Jump	Metric Tape	Jump and reach (Cm/Kg - LBM)
Peak Power	Cybex II	60 degrees / second 180 degrees / second (N.m / Kg - LBM)
Power-Endurance	Cybex II	180 degrees / second (% of PT)

Predicted Skinfold Measurements

One experienced tester used a Harpenden skinfold caliper that exerts a constant pressure of 10 gm/mm2 at the opening of the jaws. The scale on the instrument allowed the tester to read each skinfold site to the nearest 0.2 mm. The caliper jaws were completely released 1 cm below the identified skinfold site. The pressure exerted by the caliper was read within 2 sec to the nearest .02 millimeter. The measured skinfold sites of each individual were the right side of the bicep, tricep, sub-scapular, and supra-iliac muscle. According to standardized procedures (C.S.F.T.) the midpoint of the bicep muscle belly was measured with the arm resting at a semiflexed postion. Similarly, the mid-point of the tricep muscle was located between the tip of the acromion and the olecranon. The sub-scapular skinfold site was measured 1 cm below the inferior angle of the scapula and at 45 degrees to the spine. The suprailiac was located 3 cm above the iliac crest so that the fold ran forward and slightly downward. The percentage of body fat was calculated based on the norms of Durnin and Womersley (1974). Lean body mass was then calculated.

Lean Body Mass = Body weight (Kg) - body fat weight (Kg).

Predicted skinfold measurements are less accurate than the Hydrostatic technique. Although the error margin may be as high as 15-20% (Brooks & Fahey, 1984) the present study used an experienced tester who regularly takes skinfold measures.

Muscular Peak Power

All groups were familiarized with the training apparatus. Prior to testing the subjects warmed up on a bicyle ergometer for 5min and on a isokinetic orthotron machine for 3 min . A Cybex II isokinetic dynamometer (Lumex Bay Shore, N.Y.) was used for the isokinetic power tests. Each individual sat upright with the arms folded over the chest. Straps were placed around the subjects hip, thigh and tibia to stablize them on the (Cybex II) chair. The input shaft of the dynamometer was aligned with the rotational axis of the knee joint with the knee flexed at 90 degrees. Physiologically this is the optimal angle for maximum peak torque, while biomechanically a 120 degrees angle is recommended (Thorstensson et al., 1977). The input shaft of the dynamometer was adjusted according to the length of each subjects right leg. The number of holes located on the dynamometer's shaft were recorded for post testing. Peak torques (PT), and range of motion were recorded and interpreted by the standard monogram provided by Lumex. The dynamometer was previously calibrated (Moffroid et al., 1969).

In the muscular power tests (60 and 180 degrees /sec.) all subjects performed three isokinetic contractions from 90 degrees knee flexion to 0 degrees extension at each velocity. Since peak power is achieved at approximately 50% or below of the maximal velocity, the 180 degrees speed was employed (MacDougal, Wenger, & Green, 1982). For slower speed power the velocity of 60 degrees was used. The highest peak torque (PT) out of the three trials was measured for each test. The highest PT was converted from ft-lbs to N.m. This value was divided by each individual's lean body mass (N.m/Kg-LBM).

Vertical Jump

The vertical jump was administered in the main gymnasium at Lakehead University. Prior to the jump, the subject's height was measured with hands and arms fully extended on a scale taped on the wall. Each individual executed maximal vertical jumps facing sideways. The difference between these two heights was calculated to the nearest 0.5 cm. The tester was standing on a ladder and had a clear view of each subject's fingertips. All participants warmed-up before the test by jogging around the gymnasium for 5-10 minutes. Three trials were employed for specific warm-up, and the best out of the three jumps was recorded.

Power-Endurance (fatigue)

In the power-endurance or fatigue test all groups executed as many repetitions as possible for 20 sec. The tester equallyencouraged all subjects verbally . The percentage of the decreased PT was calculated by subtracting the lowest PT from the highest PT. The obtained value was divided by the highest PT (HPT-LPT/HPT x100). The rest period between the 60 and 180 degrees per second test was 1 minute, and before the fatigue test 3-5 minutes.

Analysis of Data

The data were analyzed using the SPSSx system software (the statistical package for the social sciences). A 4 (groups) by 2 (time) ANOVA with repeated measures on the last factor was employed. A post-hoc technique (Scheffe' method) was used when a significant interaction was found. The level of significance chosen by the experimenter was $p < .05$.

Chapter 4

RESULTS

Appendix D includes the raw data of the participants. The means, standard deviations, mean differences, percentage of improvement, and source of variations are presented in Table 5, 6, 7, 8 and 9. The graphs of the test variables are presented in figures 1 to 5.

Lean Body Mass

The lean body mass was increased significantly for all the groups after 7 weeks of training. The free weights (FW), Hydra-Fitness (HF), Hydra-Fitness plus plyometrics (HFP) and free weights plus plyometrics (FWP) increased lean body mass by respective values of 2.0% or 1.2 Kg, 1.2% or 0.7 Kg, 1.4% or 0.8 Kg and 2.2% or 1.3 Kg. There were no significant differences between the groups and no interactions were found (Table 5 & Fig. 1).

Slow Speed Power (60 degrees/second)

All groups improved significantly in the slow speed power test (60 degrees/sec). The free weights, Hydra-Fitness, Hydra-Fitness plus plyometrics, and free weights plus plyometric groups enhanced power by 8.9% (0.31 N.m/Kg-LBM), 8.7% (0.26 N.m/Kg-LBM), 8.9% (0.29 N.m/Kg-LBM) and 11.8% (0.45 N.m/ Kg-LBM).

The free weights plus plyometrics exhibited the highest value. There was no significant groups by time interactions found and therefore no significant differences between the training groups (Table 6 & Fig. 2).

Fast Speed Power (180 degrees/second)

In the fast speed test (180 degrees/sec) all training groups improved significantly. There was no significant interaction found and no significant differences between the groups. (Table 7 & Fig. 3). The free weights, Hydra-Fitness, Hydra-Fitness plus plyometrics, and free weights plus plyometric groups increased power by 14.1% (0.36 N.m/Kg-LBM), 9.9% (0.21 N.m/Kg-LBM), 13.3% (0.33 N.m/Kg-LBM), and 14.0% (0.36 N.m/Kg-LBM). The free weights, and free weights plus plyometric groups showed the highest values.

Vertical Jump

The vertical jump test showed that all groups improved significantly but there was no significant interaction present and there was no significant differences between the groups (Table 8 & Fig 4). The free weights, Hydra-Fitness, Hydra-Fitness plus plyometrics, and free weights plus plyometric exercise groups increased the vertical jump by 7.7% (0.07 cm/LBM), 6.8% (0.06 cm/LBM), 8.0% (0.08 cm/LBM) and 8.2% (0.08 cm/LBM) respectively.

Power-Endurance (Fatigue)

All groups improved power-endurance or fatigued less after training. The free weights, Hydra-Fitness, Hydra-Fitness plus plyometrics and free weights plus plyometric groups improved the percentage of the decreased peak torque from 33.8% to 27.0% (6.8%), from 28.5% to 24.6% (3.9%), from 27.2% to 23.0% (4.2%), and from 29.0% to 23.9% (5.1%) respectively. There were no significant groups by time interactions and no significant differences between the groups (Table 9 & Fig. 5).

TABLE 5

Means, Standard Deviations of Pre-test (T1), and Post-test (T2), Mean Differences (T1-T2), Improvement in Percentage (IMRV. %), and F-ratios for Lean Body Mass (LBM).

	T1 Mean	T1 S.D	T2 Mean	T2 S.D	T1 - T2 (KG)	IMRV. (%)
FW	60.2	9.90	61.4	9.85	1.2	2.0
HF	57.7	9.02	58.4	8.80	0.7	1.2
HFP	55.6	8.32	56.4	8.24	0.8	1.4
FWP	57.8	7.43	59.1	7.20	1.3	2.2

Source of Variation	MS	DF	F	SIG OF F
Between Groups	54.40	3	0.36	0.783
Error	151.73	25		
Between Time	13.78	1	26.31*	0.000
Group by Time	0.29	3	0.56	0.645
Error	0.52	25		

(F* = sig. $p < .05$)

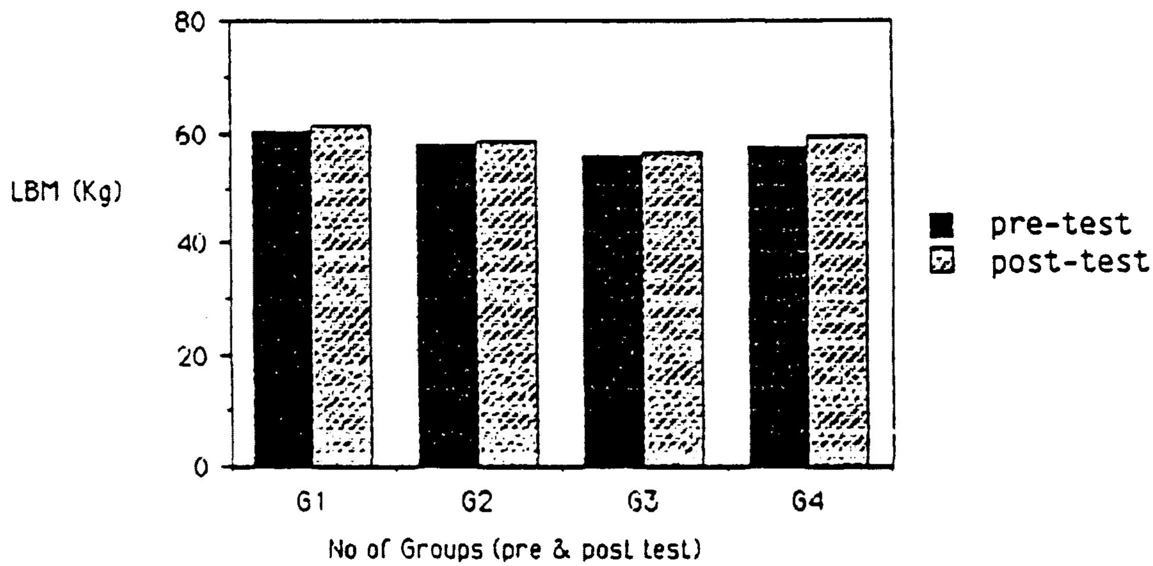

Figure 1.

Lean body mass (Kg).

TABLE 6

Means, Standard Deviations of Pre-test (T1), and Post-test (T2), Mean Differences (T1 - T2), Improvement in Percentage (IMRV. %), and F-ratios for Slow Speed Power (60 degrees / second)

	T1 Mean	T1 S.D	T2 Mean	T2 S.D	T1 - T2 N.m / Kg	IMRV. (%)
FW	3.17	.49	3.48	.29	.31	8.9
HF	2.74	.46	3.00	.26	.26	8.7
HFP	2.96	.33	3.25	.34	.29	8.9
FWP	3.37	.56	3.82	.48	.45	11.8

Source of Variation	MS	DF	F	SIG OF F
Between Groups	1.45	3	3.71	.025
Error	.39	25		
Between Time	1.58	1	42.62*	.000
Group by Time	.02	3	.58	.633
Error	.04	25		

(F* = sig. $p < .05$)

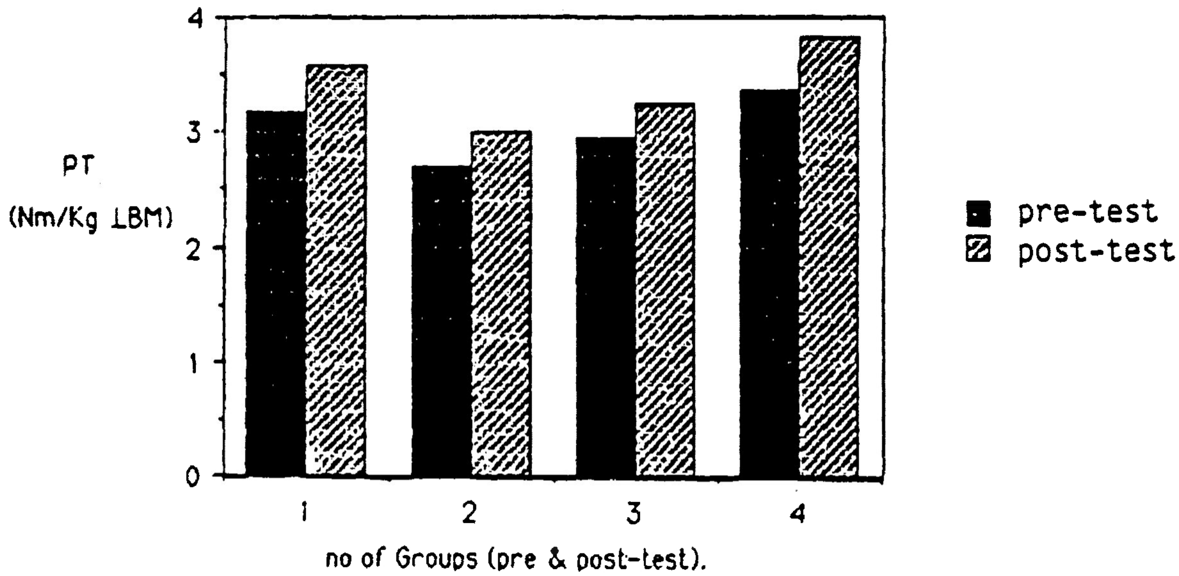

Figure 2.

Slow speed power at 60 d/s (N.m/Kg-LBM).

TABLE 7

Means, Standard Deviations of Pre-test (T1), and Post-test (T2), Mean Differences (T1 - T2), Improvement in Percentage (IMRV. %), and F-ratios for Fast Speed Power (180 degrees / second).

	T1 Mean	T1 S.D	T2 Mean	T2 S.D	T1 - T2 N.m / Kg	IMRV. (%)
FW	2.20	.25	2.56	.51	.36	14.1
HF	1.92	.26	2.13	.24	.21	9.9
HFP	2.16	.22	2.49	.37	.33	13.3
FWP	2.21	.16	2.57	.27	.36	14.0

Source of Variation	MS	DF	F	SIG OF F
Between Groups	.46	3	3.16	.042
Error	.15	25		
Between Time	1.42	1	36.52*	.000
Group by Time	.02	3	.52	.673
Error	.04	25		

(F* = sig, p < .05)

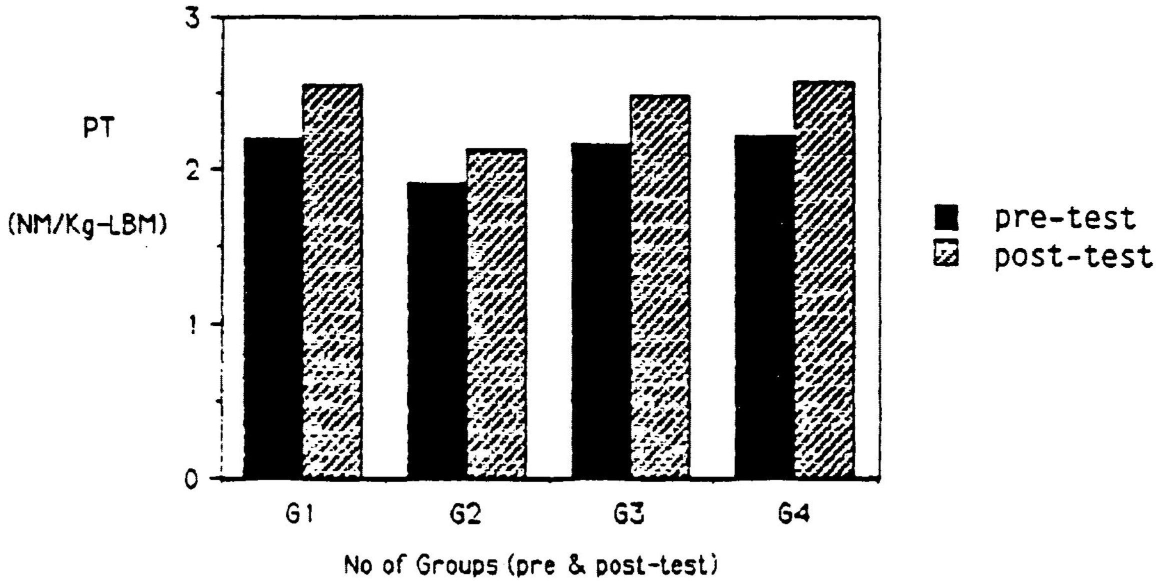

Figure 3.

Fast speed power at 180 d/s (N.m/Kg-LBM).

TABLE 8

Means, Standard Deviations of Pre-test (T1), and Post-test (T2), Mean Differences (T1 - T2), Improvement in Percentage (IMRV. %), and F-ratios for Vertical Jump.

	T1 Mean	T1 S.D	T2 Mean	T2 S.D	T1 - T2 Cm / Kg	IMRV. (%)
FW	.84	.09	.91	.13	.07	7.7
HF	.82	.09	.88	.13	.06	6.8
HFP	.92	.18	1.00	.17	.08	8.0
FWP	.89	.15	.97	.16	.08	8.2

Source of Variation	MS	DF	F	SIG OF F
Between Groups	.04	3	1.12	.359
Error	.04	25		
Between Time	.08	1	55.57*	.000
Group by Time	.00	3	.55	.653
Error	.00	25		

(F* = sig, p < .05)

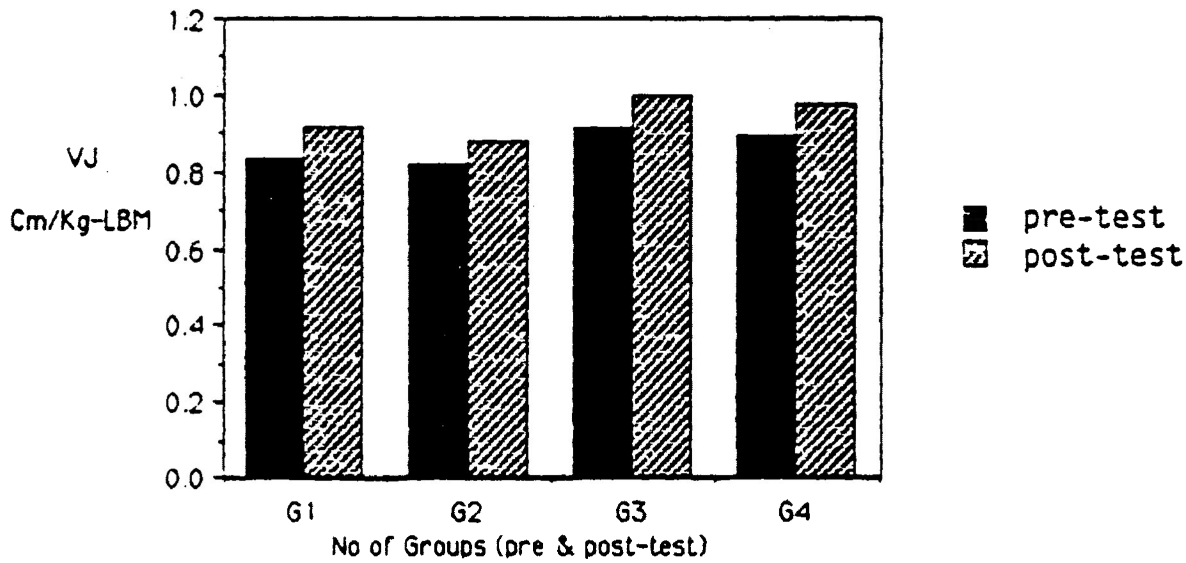

Figure 4.

Vertical jump (Cm/Kg-LBM).

TABLE 9

Means, Standard Deviations of Pre-test (T1), and Post-test (T2), Mean Differences (T1 - T2), and F-ratios for Power-Endurance or Fatigue (180 degrees / second).

	T1 Mean	T1 S.D	T2 Mean	T2 S.D	T1 - T2 Cm / Kg
FW	33.8	8.18	27.0	6.67	6.8
HF	28.5	5.59	24.6	5.63	3.9
HFP	27.2	6.34	23.0	4.09	4.2
FWP	29.0	5.99	23.9	5.63	5.1

Source of Variation	MS	DF	F	SIG OF F
Between Groups	74.33	3	1.19	.332
Error	62.23	25		
Between Time	336.61	1	22.68*	.000
Group by Time	8.63	3	.58	.633
Error	14.84	25		

(F* = sig, $p < .05$)

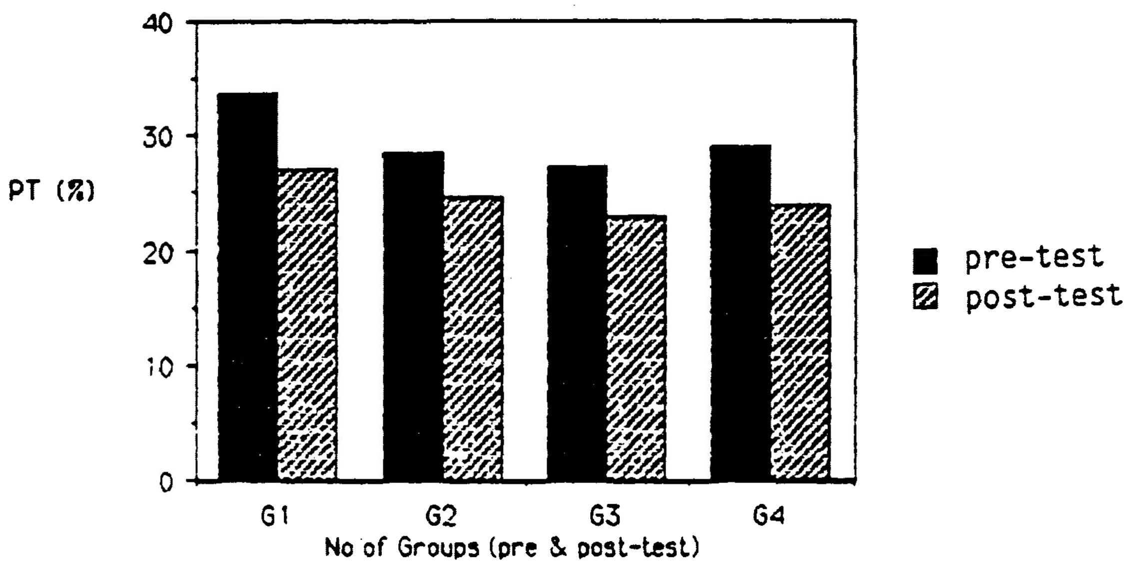

Figure 5.

Power-endurance or fatigue at 180 d/s (%).

Chapter 5

DISCUSSION

Lean Body Mass

Extensive research related to changes of body composition due to weight training, have shown that weight training caused a significant increase in lean body mass which was ranging from 0.9 to 3.1 Kg (Pipes & Wilmore, 1975; Coyle et al., 1981; Gettman et al., 1980; Hetric & Wilmore, 1979; and Wilmore, 1974). Other studies, failed to produce significant changes in body composition (Lesmes et al., 1978; Boileau, Massey, & Misner, 1973; and Tanner, 1952). The present findings revealed that all training groups increased lean body mass and were in agreement with the majority of the literature (Fahey & Brown, 1973; Pipes, 1978; Mathew & Gross, 1974; Wilmore, Parr, Ward, Vodak, Barstow, Pipes, Grimditch, & Leslie, 1977; Wells, Jokl, and Bohanen, 1963). The combined free weights plus plyometrics and the free weight groups exhibited the highest increase in lean body mass by 1.3 Kg or 2.2% and 1.2 Kg or 2.0% while the Hydra-Fitness plus plyometrics, and the Hydra-Fitness groups showed lean body mass gains of 0.8 Kg or 1.4% and 0.7 Kg or 1.2% respectively. The latter two groups had the least initial average values and revealed the least .improvement. There was no significant interaction and therefore no significant difference between the training groups.

The absence of a significant difference between the groups agrees with the findings of O'shea (1966) who reported no significant differences in body composition when he trained thirty individuals for six weeks using progressive resistance of various number of repetitions (2-3, 5-6, and 9-10). Gettman (1978) stated that slow and fast speed isokinetic training caused similar changes in lean body mass but only the former speed training had significant reduction in body fat percentage. A comparison between isotonic versus isokinetic training by Gettman, Cutler, and Strathman (1980) indicated that the two groups did not differ significantly. Both groups increased the lean body mass by 1.9 Kg and 1.6Kg and reduced the body fat by 2.8% and 2.1% respectively. Coyle et al. (1981) comparing slow, fast, and mixed isokinetic velocities found no significant changes in body weight and thigh circumference. Similarly, Pipes and Wilmore (1978) contended that there was no superior weight training program between constant and variable resistance on body composition. These values reflected changes in lean body mass and percent body fat of 2.6 and 3.1 Kg, and 1.6 and 1.5%, respectively. Conversely, Pipes and Wilmore (1975) reported that the isotonic and the fast speed isokinetic training groups exhibited significant changes in lean body mass as oppossed to slow speed isokinetic group.

Researchers have used lean body mass, body fat (%) and anthropometric measurements in order to establish profiles (somatotypes) of succesfull athletes (Nagle, Morgan, Hellickson, & Serfas, 1975). It was found that most successful athletes (such as sprinters, middle, and long distance runners, high, long, and triple jumpers, and volleyball, soccer, and basketball players) were distinguished by low percentage of body fat, and high lean body mass (Withers et al., 1977; Hirata, 1966; and Tanner, 1964). The present results indicated that all training methods increased lean body mass. Lean body mass appear to be an important physiological parameter which enables an athlete to facilitate power and performance.

Muscular Peak Power (60 and 180 degrees/second)

The present findings were in agreement with studies that showed power improvements at slow and fast speed (Barnes, 1981; McKethan & Mathew, 1974; and Coyle et al., 1981). The power test at slow velocity indicated that all groups enhanced power significantly but there were no significant groups by time interactions and no significant differences between the training groups. The free weights plus plyometrics, and the free weights increased power by 11.8% (0.45 N.m/Kg-LBM), and 8.9% (0.31 N.m/Kg-LBM), while the Hydra-Fitness plus plyometrics, and the Hydra-Fitness improved by 8.9% (0.29 N.m/Kg-LBM), and 8.7% (0.26

N.m/Kg-LBM). The free weights plus plyometrics group exhibited the highest power value. Power training with load of 60% (1 RM), 20 seconds duration, and explosive rhythm affected slow speed power (60 degrees/second) positively. Moffroid, Robert, and Whipple, (1970) stated that improvement in muscular force was depended upon the testing equipment used. Subjects who trained isokinetically, performed significantly better in an isokinetic test than in an isotonic test and vice versa. Also, fast speed training resulted in greater muscular force at fast speed and slow speed training caused a greater force at low velocity. However, in the present study the isokinetic test did not favour the Hydra-Fitness training group. Furthermore, fast speed training had a positive transfer affect on slow speed power (Gettman et al., 1980; Thorstensson, 1976).

The fast speed power test showed that all groups improved significantly but there were no significant interactions. The free weights , free weights plus plyometrics, Hydra-Fitness, and Hydra-Fitness plus plyometrics enhanced power by 14.0%, or 0.36 N.m/Kg-LBM, 14.0% or 0.36 N.m/Kg-LBM, 9.9%, or 0.21 N.m/Kg-LBM, and 13.3%, or 0.33 N.m/Kg-LBM. The free weights, and the free weights plus plyometrics showed the highest values. Thus, the plyometrics enhanced power when they were combined with either free weights or Hydra-Fitness devices. Similarly, to present results Shepherd's study (cited in Jensen, & Fisher, 1979) contended that isotonic, isokinetic, and negative resistance training caused significant gains for all groups but no group was found superior to others. In a comparison between isotonic and isokinetic training Thistle et al. (1967) found that after eight weeks of training both isotonic and isokinetic training groups improved by 27.5% and 35% respectively. Fleck (1982) trained 47 college males at velocities of 59, 157 and 212 degrees/second. All training improved significantly at 157 and 212 degrees/second but there were no significant differences between the groups. The author concluded that there was no superior training group. Promoli and Holt (1979) reported no significant differences between fast speed isotonic training and isokinetic (Mini Gym Leaper) resistance. The present results (table 7) were lower than the values of Thistle, Hislop, Moffroid, and Lowman (1967) who reported improvements of 27.5 and 35% for both the isotonic and isokinetic groups respectively. This might have occured because the subjects in the present study were more fit than the subjects reported by Thistle et at. (1967). Conversely, their isotonic results were lower than the isokinetic findings. Berger (1963, 1965) reported higher speed strength improvements due to isotonic training (29 and 21.3%). Smith et al. (1986) indicated that the volleyball players who combined Hydra-Gym training machines with volleyball practice improved their fast speed power (180 degrees/sec), significantly more than the players who were involved only in the volleyball practice. The present results did not support the argument of Pipe's et al. (1975), who claimed that the isokinetic fast speed training was superior to isotonic training.

Since, there was no significant difference between the free weights and the free weights plus plyometrics groups the present results are not in accordance with the findings of Verkoshansky and Tatyan (1983) who reported that depth jumps were superior to strength-speed exercises (barbell on shoulders, hops, and maximal vertical and long jumps). He suggested that depth jumps of 80 cm would enhance optimal speed, while depth jumps of 1.10 cm would increase optimal strength. Moreover, he recommended a combination of free weights with plyometric exercises. In the present study, however, the free weights training program consisted only of half-squats, the height of the plyometric exercises was different, and the duration of each set was longer (twenty seconds). Despite the fact that there is limited information about their methodology, East European investigators (Verhoshansky, 1969, 1973, 1985; Madveyev & Verhoshansky, 1986; Matveyev, 1981 & LevchenKo, 1985) have used athletes as subjects and the duration of their studies were much longer as compared to North American studies. Although, Verhoshansky (1973) recommended that additional weight such as vests or ankle weights should be avoided because they would affect the speed of the muscle contraction from the eccentric to concentric contraction (amortization phase), Polhemus and Burkhardt (1980) found that a combination of depth jumps (45 cm.) with additional vest and ankle weight was superior to a strictly weight training program. This contradiction might have occured due to the difference in intensity and duration of the training programs, the height of the depth jumps, and the fitness level of the participants in each study.

The results indicated that all the training groups increased both slow and fast speed power significantly. There were no significant differences between the training groups. Plyometric exercises are effective when they are combined with either free weights or Hydra-Fitness resistance exercises. Athletes who compete in explosive events involving lower extremity, may train with free weights, free weights plus plyometrics, Hydra-Fitness plus plyometrics to enhance power in the lower extremity.

Vertical Jump

The present findings revealed that all groups improved the vertical jump significantly over the training period. Previous research which compared free weights , plyometric exercises and depth jumps of various heights indicated improvements in the vertical jump after training (Marteen et al., 1987; Verhoshansky & Tatyan, 1983; Polhemus, Burkhardt, Osina, & Patterson, 1980;

Bosco & Komi, 1979; Cavagna, 1970; Dursenev & Raeysky, 1979; Asmusen & Bonde-Peterson, 1974; Gambeta, 1981; and Bosco et al., 1976). The free weights plus plyometrics, and the Hydra-Fitness plus plyometrics groups exhibited greatest improvements of 8.2%, and 8.0% respectively, while the free weights, and the Hydra-Fitness group improved by 7.7%, and 6.8%. However, there was no significant difference between the groups, and no groups by time interaction was detected. These results are in accordance to findings reported by Clutch et al. (1983) who contended that, maximal vertical jumps from a stationary position versus depth jumps of 30, 75, and 110 cm height, resulted in similar improvements (8.4 cm). Resistance training of dead lifts, half squats and bench press were incorporated in each group's training program. The author stated that inividuals such as weight lifters who were not involved in jumping activities increased their vertical jump when they combined weight training with depth jumps. In a subsequent experiment Clutch et al. (1983) found volleyball players who were actively involved in jumping training and depth jumps versus volleyball players who trained only with free weights, enhanced their vertical jump but without any significant difference. The author concluded that depth jumps were effective only to athletes who are not using jumping training. In a comparison between isokinetic (leaper) versus depth jumps (86 cm) training Blattner and Noble (1979) found that both groups enhanced the vertical jump by 4.9 cm and 5.2 cm but neither training program was superior than its counterpart. Similarly, Van Oteghan (1975) reported that both slow and fast isokinetic training enhnced the vertical jump but there was no significant difference between the groups.

Contrary to these results, Verhoshansky and Tatyan (1983) found the plyometric training superior to the resistance training. Polhemus and Burkhardt (1980) contended, that plyometric exercises combined with additional ankle weight increased the vertical jump, standing long jump, and forty yards dash significantly more than a strictly resistance training. Smith et al. (1986) reported that the volleyball players who trained with plyometric exercises enhanced the block jump significantly more than the players who train with no plyometrics.

The present results indicated that all training programs increased the vertical jump. Plyometric exercises combined with either free weights or Hydra-Fitness resistance improved the vertical jump but no significant differences between the groups were detected. The combined groups exhibited higher values than the free weights, and Hydra-Fitness groups. Since plyometrics combined with free weights or hydraulic resistance appear to have a positive effect on the vertical jump, and because plyometrics are very inexpensive they should be combined with resistance training.

Power-Endurance (fatigue)

The power-endurance or fatigue test revealed that all the groups fatigued significantly less, or the peak torque (%) decreased less after training. There were no significant differences between groups (Table 9, Fig. 5).

The decline in peak torque was similar to the findings reported by Barnes (1981) who found that ten maximal isokinetic contractions at velocities of 60, 120, 150, and 300 degrees/second decreased peak torque by 27.1%, 29.6%, 23.6% and 33.6% respectively. In both power-endurance tests the peak torque declined after twenty seconds of maximum effort. However, in the second test (after training) the decrease in peak torque (%) was less as compared to the first test. Therefore, the efficiency of the subjects to perform the test was improved and they fatigued less (PT% = highest PT - lowest PT / highest PT times 100). The difference between the two tests (T1-T2) of the declined peak torque (%) for the free weights, free weights plus plyometrics, Hydra-Fitness, and Hydra-Fitness plus plyometrics was 6.8% (from T1 = 33.8% to T2 = 27.0%), 5.1% (from T1 = 29.0% to T2 = 23.9%), 3.9% (from T1 = 28.5% to T2 = 24.6%), and 4.2% (from T1 = 27.2% to T2 = 23.0%),respectively. The free weights, and the free weights plus plyometrics groups had the highest initial peak torques (PT%) decrease or they fatigued more (T1) and therefore they showed higher improvement values (T2) than the Hydra-fitness and Hydra-Fitness plus plyometrics groups. Imwold, Rider, Haymes, and Green(1983) found no significant difference between sprinters and basketball players in a fatigue isokinetic test.

Nilsson, Tesch, and Thorstensson (1977) tested twelve healthy male subjects who executed one hundred maximal voluntary contractions (180 degrees/second) at a rate of 50 contractions per minute. The author found that the peak torque started to decline rapidly after few seconds until the forty-fifth contraction, and thereafter reached a plateau. In the present study the force (peak torque) started to decrease approximately at the fifth and sixth contraction. The lowest and highest values of the declined force for the training groups ranged from 33.8% to 23.0% (table 9). Similarly, Stephens and Taylor (1972) using a cable tensiometer speculated that the smoothed EMG started to fall after few seconds of maximal voluntary contractions (MVC). The EMG declined by 50% and 25% after one and two minutes of maximum voluntary contractions respectively.

Athough the present study did not examine accumulated lactic acid, buffer capacity, or fiber types, it is suggested that the force declines probably due to the fatigue of the neuromuscular junction. Also, the exhaustion of the muscle's elastic component, and metabolite accummulation, such as lactic acid concentrations are other possible causes of muscular failure (Tesch, 1980; Nilsson et al., 1977; and Stephens & Taylor, 1972). Jacobs et al. (1983b) reported that lactic acid accumulated after a few seconds of maximal exercises. The present improvements in peak torque after training might have been caused as the subjects enhanced their buffer capacity. Shahlin and Henriksson (1983) found that athletes had a significantly higher buffer capacity than sedentary individuals and therefore lactic acid could escape into the bloodstream. The same author condented that athletes can tolerate higher levels of lactic acid accumulation and a lower intracellular acidosis than inactive subjects (Brooks & Fahey, 1984). Tesch, (1980) found that fast twitch fibers fatigued faster, and produced more lactic acid than slow twitch fibers (Thorstensson & Karlsson, 1976). Thus, individual differences due to fast and slow twitch fibers, plus high and low threshold motor units are important parameters which may relate to the subjects power-endurance or fatigue in the present study.

Power -Endurance or fatigue is very important to sports in which the energy demands and the accumulated lactic acid is high.

The 20 seconds training improved all training groups and it would be appropriate for anaerobic events (such as sprinting, and jumping) or team sports (such as soccer, basketball, volleyball, hockey, football and rugby). However, the training should meet the requirements of each sport.

In conclusion, the present results indicated that lean body mass, vertical jump, power, and power-endurance increase after training but there were no significant differences between the four experimental training groups. Therefore, an application of these training methods will enhance power. Plyometrics combined with free weights or Hydra-Fitness resistance have a positive effect on lean body mass, muscular power, vertical jump power, and power-endurance.

Chapter 6

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Summary

This study investigated the training effects of four experimental groups including free weights, Hydra-Fitness, free weights plus pyometrics, and Hydra-Fitness plus plyometrics. Pre and post-tests measured lean body mass, muscular peak power (60, and 180 degrees/sec), vertical jump power, and power-endurance or fatigue in the lower extremity. Forty Physical Education students were trained on four combinations of resistance training programs over seven weeks. A 4 (groups) by 2 (tests) ANOVA with repeated measures was employed. All training groups increased lean body mass, power, power-endurance, and the vertical jump but without any significant differences between the groups.

Conclusions

Free weights, Hydra-Fitness, free weights plus plyometrics, and Hydra-Fitness plus plyometrics, improved lean body mass, vertical jump, muscular power, and power- endurance for all groups. There were no significant differences between the training groups. The results indicate that plyometrics have a positive training effect, when they are combined with either free weights, or Hydra-Fitness over a 7 weeks training period.

Recommendations

The purpose of scientific training research is to provide coaches and trainers with training information which will assist athletes in maximizing their performance. Based on the training program results, design, and protocol of the present study the following recommendations are suggested:

1. It is recommended that all training methods increase lean body mass, muscular power,power-endurance, and vertical jump.

2. Different testing devices or tests (Wingate lactic, and alactic power test, 60 yard-dash, and standing long and triple jump) which do not involve isokinetic resistance are recommended for future studies. The isokinetic (Cybex II) device favours only the isokinetic trained groups. The Cybex II machine is capable of measuring only one joint while in sports there is multilateral joint involvement which produces higher power values. Correction for gravity should also be included when testing takes place in a sitting position and the testing device does not record the true peak torque during leg extension of the knee (MacDougall et al, 1982).

3. Percentage of body fat, and lean body mass should be measured employing the hydrostatic procedure which is more accurate than the skinfold measurements, using callipers (Brooks & Fahey, 1984; Wilmore, 1969).

4. Training of the lower extremity using prospective athletes as subjects is recommended to examine the effectiveness of training programs on performance. Results, however, may indicate lower improvements in lean body mass, muscular power, power-endurance, and vertical jump power due to the level of training.

5. It is suggested that future studies train the upper body to measure the effectiveness of upper body plyometrics, free weights, Hydra-Fitness, and combined plyometrics plus free weights or Hydra-Fitness training on power for explosive events (throwing and sprinting).

6. Future research should attempt to periodize training programs into a yearly training plan. Power training always follows the strength training. Since, plyometric exercises are very demanding and possible injuries may occur, strength training is compulsory. If a sport requires power-endurance this type of training follows power training. Athletes are training for power and power-endurance before the competitive phase or during the specific preparatory phase (power or power-endurance training). The training period for strength, power, and to power-endurance depends on the requirements of each sport (Verhoshanski, 1985; and Bompa, 1983).

7. Further training research using a larger number of subjects, a longer period of training, higher intensity, and

frequency, different heights for plyometric exercises, and variable free weight loads or hydralic resistance is recommended.

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APPENDIX A

Weight Circuit Orientation Program

In the 1st week each subject will perform the circuit twice through and in the 2nd week each subject will go through the circuit 3 times. The circuit is to be performed 3 times/week.
Perform each exercise for a 20 sec. period.

EXERCISES #	WEIGHT TO USE	WT.	# OF REPS IN LAST SET					
		LBS.	DAY 1	2	3	4	5	6
1. Bench press	½ body wt.							
2. Squat	½ body wt.							
3. Lat. Pulls	1/3 body wt.							
4. * Sit Ups								
5. Dead lift	½ body wt.							
6. Leg Press	3/4 body wt.							
7. Bicep curl	1/5 body wt.							
8.** Quad ext.	ham curl ¼ body wt.							
9. Sit ups								
10. Military press	¼ body wt.							
. Toe raises	3/4 or full body wt.							
. Hip Flexor	½ body wt.							
. Sit ups								

* As many sit ups in 20 sec. as possible

* Perform quad extensions one session: then hamstring curls in next session.

APPENDIX B

Training Programs

Group 1 (FW) / Group 2 (HF)

Week	#Of Sets	Load	Duration	Rest	Rhythm
1	4	60%	20 SEC.	3-5min	Explosive
2	4				
3	5				
4	5				
5	6				
6	6				
7	7				

The free weights (FW) group trained with free weights. The Hydra-Fitness (HF) group trained with a hydraulic squat (Leaper) machine thoughout the 3 sessions.

Group 3 (HFP) / Group 4 (FWP)

Week	# Of Sets		Load		Rhythm
	FW/HF	PLYOM.EX.	FW/HF	PLYOM.EX.	
1	4	A - B	60% & Maximum		Explosive
2	4	A - B		Effort	
3	5	A - B			
4	5	C - D			
5	6	C - D			
6	6	C - D			
7	7	C - D- E			

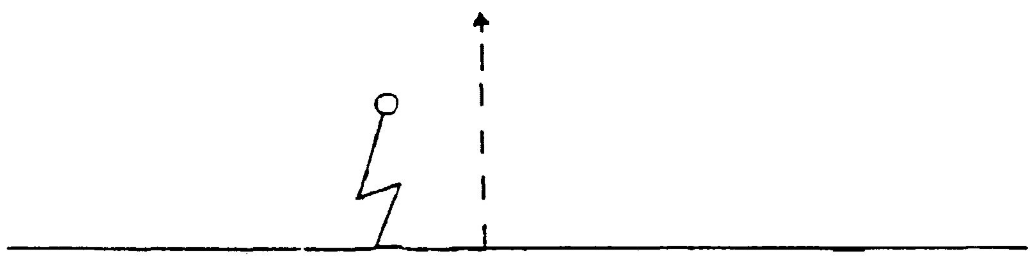
Training Sessions

First Session:	FW OR HF
Second Session:	Plyometrics
Third Session:	50% FW OR HF & 50% Plyometrics

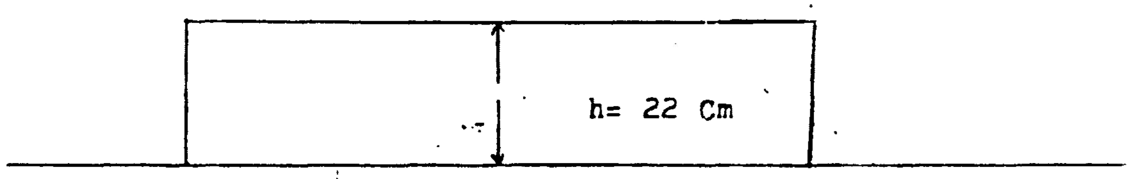
APPENDIX C

Plyometric Exercises

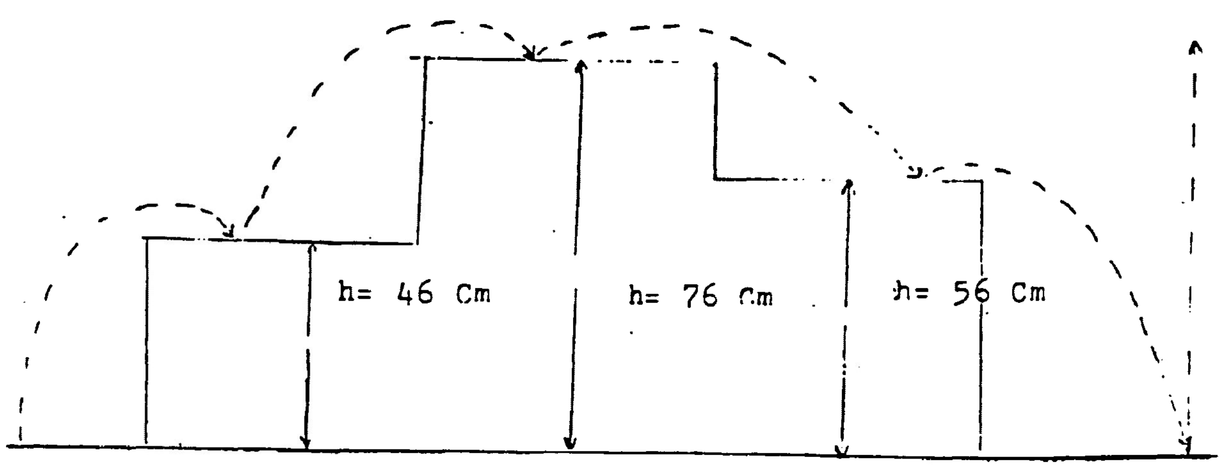
EXERCISE A). 3/4 JUMP SQUATS



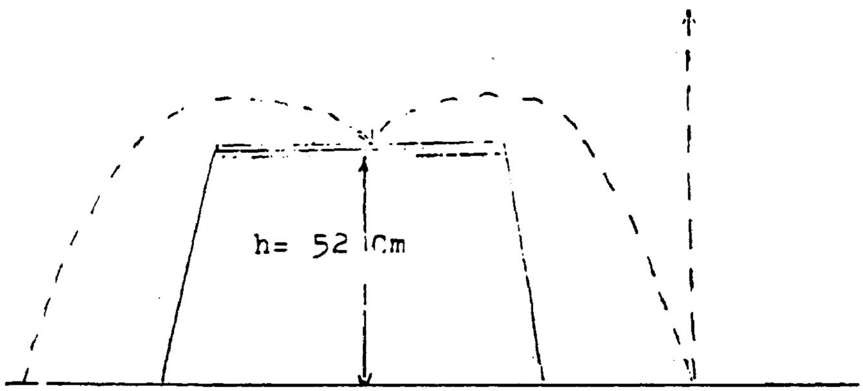
EXERCISE B). BENCH HOPS



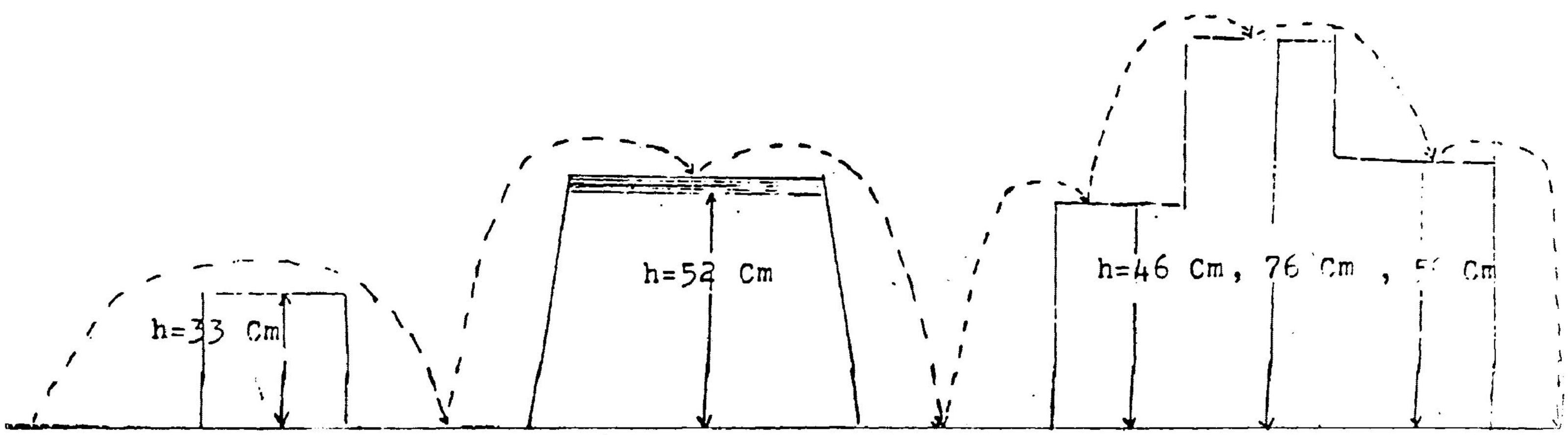
EXERCISE C).



EXERCISE D).



EXERCISE E).



APPENDIX D

Raw Data of Subjects

G#	(n)	Pre-test					Post-test				
FW											
1	1	69.6	2.47	2.23	24.6	0.76	69.2	3.23	2.91	23.1	0.80
1	2	68.1	3.63	2.21	38.3	0.95	72.1	3.72	3.36	23.8	1.10
1	3	60.3	3.13	2.06	40.2	0.81	60.1	3.62	2.10	20.1	0.83
1	4	66.2	3.68	2.38	37.2	0.74	67.1	3.71	2.87	31.7	0.85
1	5	66.8	3.22	2.28	41.1	0.82	66.4	3.54	2.36	34.9	0.95
1	6	60.3	3.20	2.21	22.4	1.00	62.8	3.59	2.51	19.6	1.10
1	7	45.4	3.61	2.55	41.1	0.83	47.6	3.55	2.63	36.9	0.88
1	8	44.8	2.43	1.70	25.2	0.78	45.5	2.87	1.71	25.9	0.80
HF											
2	1	71.6	3.26	2.05	26.9	0.70	71.7	3.31	2.33	26.8	0.72
2	2	56.1	2.43	1.75	19.4	0.91	56.2	2.83	2.12	17.1	1.00
2	3	61.5	2.65	1.77	22.0	0.86	62.3	2.92	2.25	21.2	0.91
2	4	64.2	3.39	2.20	31.5	0.86	65.5	3.49	2.24	25.9	0.90
2	5	62.8	2.43	2.38	29.1	0.84	62.8	2.84	2.48	20.0	0.86
2	6	51.7	2.15	1.66	29.3	0.74	52.9	2.82	1.85	27.7	0.74
2	7	49.0	2.69	1.72	32.3	0.73	50.8	2.82	1.85	27.7	0.78
2	8	44.3	2.92	1.84	36.6	0.92	44.7	2.98	1.92	35.1	1.10
HFP											
3	1	65.0	3.14	2.38	26.3	0.80	66.2	3.45	2.96	17.3	0.88
3	2	62.6	3.06	1.91	25.0	0.82	63.5	3.15	2.67	21.6	0.87
3	3	58.5	3.03	2.46	22.8	0.80	57.9	3.38	2.70	22.6	1.00
3	4	55.8	2.43	2.05	21.4	1.10	56.9	3.11	2.06	21.0	1.10
3	5	47.8	3.36	2.16	28.9	0.79	48.6	3.70	2.51	28.8	0.92
3	6	43.8	2.73	1.99	39.0	1.20	45.0	2.72	2.05	26.4	1.30
FWP											
4	1	62.3	2.97	1.96	19.1	0.98	63.9	3.66	2.30	18.5	1.00
4	2	55.5	3.11	2.28	27.3	0.99	56.9	3.21	2.50	19.4	1.10
4	3	56.8	3.45	2.29	33.3	1.10	58.8	3.75	2.40	17.4	1.20
4	4	71.5	4.00	2.34	33.2	0.87	72.2	4.52	3.05	32.5	1.00
4	5	51.8	4.46	2.37	26.5	0.89	53.7	4.64	2.78	24.1	0.98
4	6	48.8	3.43	2.21	26.7	0.78	50.1	3.81	2.65	25.7	0.82
4	7	57.8	2.16	2.02	37.2	0.66	57.9	3.13	2.34	30.0	0.71