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EFFECTS OF DIFFERENT RESISTANCE TRAINING METHODS ON STRENGTH, IMPULSIVE FORCE AND BODY COMPOSITION

by

B.J. OKORO

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ABSTRACT

This study was designed to examine the effectiveness of three resistance training methods on the development of quadriceps strength variables. Also investigated, were the effects of these strength training modes on changes in impulsive force and body composition.

Forty-two healthy male subjects between the age range of 18-28 years (mean 22.5 years) (who were inexperienced in muscle resistance training program) were randomly assigned to one of the four groups. Group 1 (n=11) Isotonic exercise; Group 2 (n=10) Isokinetic exercise and Group 3 (n=10) combined Isotonic and Isokinetic exercises. Group 4 (n=11) control, did all the tests but not the training programs. The exercise groups trained the lower extremity muscles three times a week for a total of 10 weeks. Isotonic group trained by doing 2 sets of 6 repetitions, 80-90% 1RM of concentric contractions and 2 sets of 4 repetitions of 120-130% 1RM for eccentric contractions. The isokinetic group did 4 sets of 6 repetitions for maximal concentric and eccentric contractions while the combined exercise group did half of isotonic and half of isokinetic exercise routines.

During this study, four tests were conducted at the interval of three and half weeks. Before the pretest, all the subjects were exposed to three familiarization sessions to acquaint them with the testing protocol and equipment. At the beginning of the study, there were no significant differences among the groups in all the variables tested. The criterion variables used were maximum isokinetic-concentric and isokinetic-eccentric strength, dynamic strength (1RM), maximum impulsive force of the legs, thigh and calf girths, body fat and lean body mass.

Unique two-way analysis of variance and Greenhouse-Geiser conservative test were applied for the analysis of the data. The results indicated that all the exercise groups improved significantly ($P < .05$) in all strength variables and thigh girth except the isotonic group which did not improve in maximum impulsive force. None of the training programs was effective in significantly altering body fat and lean body mass. The trends however, show that the

isokinetic group led the other groups in maximum isokinetic-concentric strength and isokinetic-eccentric strength; maximum impulsive force, and increase in thigh girth. The combined group only excelled in dynamic strength.

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CHAPTER I

THE PROBLEM

A. Background to the Problem

Physical fitness is required for successful participation in any sporting activity. Strength, power and endurance are some of the components of physical fitness. To excel in sports that involve physical prowess, optimal strength and power are required. In order to acquire these important components, some type of muscle resistance training must be done, otherwise the individual will continue to hover on the edge of mediocrity.

A review of the literature in resistance training reveals that different types of resistance training programs can cause improvement in strength, power and endurance capacity of the muscle or muscle groups trained. The major stimulus for an increase in the force of the voluntary muscle is the production of tension above that previously demanded of the muscle (Hettinger, 1961; Hakkinen, 1985).

The comparative studies which have so far been carried out to determine the relative effectiveness of different training methods for the development of muscular strength have yielded conflicting results. To complicate the problem, researchers have used a variety of training devices and programs which make it virtually impossible to come to any precise conclusions in assessing relative merits and demerits of different training methods. The use of different types of equipment for training and testing in research studies have made it even more difficult to appraise the effectiveness of the training programs because along with the training programs, the effectiveness of the equipment is also being evaluated (Hinson and Rosentwieg, 1973; Pipes, 1978; Sapega et ál., 1982; Jette et al., 1987).

There is no consensus among coaches, athletes and others interested in resistance training as to the best method of training for a specific purpose. Both coaches and athletes have thus to rely on inconclusive research findings when developing their programs, with the result that athletes may perform below their optimal levels either because they acquire more strength than necessary for their events (Ikai, 1973; Danoff, 1978) or the resistance was not stressful enough to elicit the desired effects (Berger, 1962c; O'Shea, 1966; Withers, 1967; Anderson and Kearny, 1982). In addition, some investigators (Pletnev, 1975, 1976; Kakkinen and Komi, 1981) reported that a combination of concentric and eccentric training contractions was more effective for strength development than either concentric or eccentric training done alone.

The argument in favour of isotonic-concentric and eccentric training is that greater strength seems to be gained at the weakest point in the range of movement (Spackman, 1971; Smith and Melton, 1981). Muscle tension also changes due to lever arm (Hinson and Rosentwieg, 1973; Knutten and Kraemer, 1987). The main disadvantage of using this training method is that isotonic exercise is done through a range of joint motion with a set resistance, and because of the biomechanical factors, the strongest points in the range will be working at a lower capacity since a trainee can never lift the weight that would place maximum stress on the strongest points in the range of movement (Sheeran, 1977; Jensen and Jensen, 1978; Smith and Melton, 1981; Hobson, 1983; Bosco, 1985)

Perrine (1968) contended that because the speed of lifting free weights is subject to considerable acceleration, it thus renders the resistance unstable and unpredictable thereby making it difficult for a muscle to develop its maximum strength.

Isometric (static) resistance on the other hand, is particulary useful where movement is contraindicated. The weakness with this type of method is that gains in strength are quite specific to the angle at which the training is done (Doss & Karpovich, 1965; Pipes, 1977). Isometric exercise occurs against a load which prevents visible shortening of the muscle. Although isometric exercise does not result in mechanical work, Duchateau and Hainaut (1984) found in their study that isometric training increased the speed of movement with heavier loads.

The isokinetic training method attempts to overcome the limitation of both isometric and isotonic methods by allowing a dynamically contracting muscle to be loaded maximally through a full range of motion. The proponents of isokinetic exercise (Thistle et al., 1967; Perrine, 1968; Moffroid et al., 1969) argue that it develops strength over a full range of movement because the apparatus used for this type of training prevents the increased velocity of muscle shortening more than the set speed of the apparatus regardless of the force exerted.

The disadvantage of isokinetic method like any other machine type of training is the limited degree of specificity to most athletic movements as precise fast explosive full-range multiple body joint action is not mechanically possible (Garhammer, 1978; O'Shea, 1979). This method of training also precludes dynamic balance (Everson, 1983) an important factor which requires muscles to operate in more complex synergistic patterns therefore stimulating total muscle strength and power development to a greater degree. Darden (1977) contended that isokinetic exercise does not provide the stretching of the joints and pre-stretching of the muscles which are not only prerequisities for forceful contractions, but have an important effect on motor nerves.

Since the introduction of the isokinetic training method, many studies have been done to determine its efficacy in the development of both strength and power and to compare it with other muscle resistance training regimes. Some studies indicated that isokinetic exercise was superior to the conventional modes of weight training (Thistle et al., 1967; Hinson and Rosentwieg, 1972; Pipes, 1977). Others (Delateur et al. 1972, Okoro, 1979) however, found that isokinetic training was as effective as isotonic training method in strength development.

In eccentric exercise, more tension is developed than in concentric or isometric contraction as the muscle is forced to lengthen during contraction (Doss and Karpovich, 1965; Rogers and Berger, 1974; Singh and Danielson, 1975). The findings of Johnson (1972) and Ferris (1977) indicated that eccentric method was not superior to other methods of strength training. Although highest tension is developed in eccentric contraction, conditioning the muscle with repetititon of this type of contraction has not been thoroughly investigated.

One of the problems of using this method solely for strength development, may be due to the muscle soreness associated with it (Friden et al., 1983; Newhan et al, 1983; Cieslik, 1986). Also it is extremely difficult to compare eccentric and concentric training workloads because to have the desirable effects with eccentric training, a workload corresponding to 100-130% 1RM should be employed (Johnson, 1976; Hakkinen et al., 1981). Whereas, in concentric exercise, in which free weights are employed, 80-90% of 1RM is optimal for strength development (Berger, 1962c; Hakkinen Johnson et al., 1976; Hakkinen and Komi, 1981).

Heavy resistance training has been shown to result not only in increase in lean body weight which translates into increased force generation by the muscle, but also decrease in body fat. Some studies (Pipes and Wilmore, 1975; Bishop, 1983; Brazell, 1986) have been able to demonstrate these positive changes while others (Hurley et al., 1984; Katch and Drumm, 1986; Jette et al., 1987) could not. The nature of various training programs employed and the subject pools used rendered comparative analyses of studies and generalization of findings more difficult.

No reported study has used optimal combined training contractions to investigate changes in body composition. The combination of eccentric and concentric training methods has been reported to be more effective for strength and power development than either concentric and eccentric training done alone (Pletnev, 1975, 1976; Hakkinen and Komi, 1981; Hakkinen et al., 1981). These investigators did not however, examine the effects of such training regimen on body composition. Similarly, not many comparative studies of resistance training modes on changes in body composition and anthropometric variables have been reported.

The Purpose of the Study

The findings of various studies in the area of strength development have produced a broad range of training concepts which are conflicting or inconclusive. Very few investigations have been reported in the literature that used different combinations of training contractions for the development of strength.

Based on research findings, Pletnev (1976), Hakkinen and Komi (1981), and Telle and Gorman (1985) postulated that gains in strength are more if the muscle is exposed to combined training regimes compared to training with one method alone. Research work on the effects of heavy resistance training on body composition is still in its infancy as there is paucity of knowledge in this area.

The investigator therefore, embarked on this study to determine the most effective muscle resistance training method for the development of strength variables. Also investigated, were the effects of these training modes on changes in body composition.

The Objectives of the Study

The objectives of this study were as follows:

1. To assess the effects of isotonic-concentric and eccentric, isokinetic-concentric and eccentric and a combination of these two training methods on muscular strength.
2. To determine the change in maximum impulsive force of the legs with training.
3. To investigate which method induces the greatest hypertrophy of the muscles trained.
4. To determine the rate of increase in strength over a 10-week period of heavy resistance training.
5. To determine which of the training methods is the most effective in reducing body fat and increasing lean body mass.

Hypotheses

The following hypotheses were tested:

1. After 30 training sessions spread over 10 weeks, there would be no significant differences among the exercise groups for each of the variables under study:-
   i) Maximum isotonic-concentric strength
   ii) Maximum isokinetic-concentric strength
   iii) Maximim isokinetic-eccentric strength
   iv) Maximum leg impulsive force
   v) Percent body fat and lean body mass
   vi) Girth of leg extensors and plantar flexors.
2. At the end of this study, the control group would not show any significant change in the dependent variables under study.

3. At posttest, the increases achieved by the exercise groups in all the variables under study would not be significantly different from the gains made by the control group.

Operational Definition of Terms

As used in this study, these terms have been defined as follows:

1. Strength: is defined as the maximum effective force or tension a group of muscles can exert in a single maximal voluntary contraction at a given angle or through a range of movement.
2. Impulsive force: Force developed at the time of take-off from the force platform.
3. Isotonic-concentric Exercise: An activity in which the muscle contracts and shortens, resulting in the development of tension and movement.
4. Isotonic-eccentric Exercise: An activity in which a contracting muscle is forced to lengthen by an external load thereby resulting in the development of tension in the muscle.
5. Isokinetic-eccentric Exercise: An activity which allows a contracting muscle to develop tension or force while being compelled to lengthen by an external load that is moving at a constant velocity.
6. Isokinetic-concentric Exercise: An activity that allows a dynamically contracting muscle to shorten at a constant velocity while being loaded maximally through a full range of movement.
7. Isometric (Static) Exercise: An activity in which the muscles contract without visible shortening in length, but tension is continuously generated.
8. Repetition Maximum (RM): Maximum weight that can be lifted a specific number of times without a rest period (e.g. 6-RM means the maximum weight that can be lifted only six times and not more without a rest period).
9. Repetition: The number of times a dynamic or static contraction is repeated in a given exercise program.
10. Set: One series of repetitions without an intervening rest period in a given number of

times.

11. Resistance Training: Training that is reflective of all types of exercises which are possible using devices that provide resistance to the muscle.

Abbreviations

The following abbreviations are used in this study:

1.	T1	Test 1 - Pretest
2.	T2	Test 2
3.	T3	Test 3
4.	T4	Test 4 - Posttest
5.	LBM	Lean Body Mass
6.	Isotonic-Con.	Isotonic-concentric
7.	Isotonic-Ecct.	Isotonic-eccentric
8.	Isokinetic-Con.	Isokinetic-concentric
9.	Isokinetic-Ecct.	Isokinetic-eccentric
10.	Max. Isok. Con.	Maximum Isokinetic-concentric
11.	Max. Isok. Ecct.	Maximum Isokinetic-eccentric

Limitations of the Study

The limitations of this study were as follows:

1. Extraneous variables like the height, weight, somatotypes and outside activities of the subjects (i.e. all the physical activities or work performed by the subjects apart from those of this study), were beyond the investigator's control. These extraneous variables might have some effect on the results.
2. Due to the difficulty in obtaining subjects to participate in this type of training study, volunteers were asked to participate thereby precluding random selection of subjects from the target population.
3. The wide individual differences in physiological and psychological adaptability to muscle

resistance training may be responsible for the observed qualitative and quantitative strength gains of the subjects.

4. Attrition: Due to personal reasons, some subjects dropped out during the course of this study. The remaining number of subjects that completed the study may have effect on statistical power.
5. Accuracy of the measuring instruments and or intra-tester variability during the series of measurements conducted.
6. Due to neural factors in 'motor learning', repeated strength tests may increase the test scores without evidence of measurable muscular hypertrophy. This may have an effect on the control group's scores (Moritani and DeVries, 1979).
7. The training equipment may have a bearing on the test results.
8. Residual volume which is an integral part of the determination of body density was not directly measured.

Delimitations of the Study

The delimitations of this study were:

1. This study was delimited to 60 healhty males between the age range of 18-28 years who were inexperienced in resistance training.
2. Due to the transient nature of students that formed the bulk of the subjects, this research study was restricted to 11 weeks (ten weeks for training and one week for testing).
3. Training was done three times a week; each session being at least 48 hours apart.
4. Measurement criteria were restricted to the muscles of lower extremity which were trained in this study.
5. Measurement of skinfold thicknesses was done on the dominant side of the body except the abdomen and was restricted to seven sites namely; triceps, subscapular, suprailiac, abdomen, front and back thigh and calf.
6. Independent and dependent variables selected for research.

(i) **Independent Variables**

(a) Training workloads in kilograms and centimeters per second.

(ii) Dependent Variables

(a) Maximum leg impulsive force

(b) Girth of the flexors and extensors of the knee and plantarflexor muscles in centimeters

(c) Lean body mass and body fat

(d) Maximum dynamic strength (1RM)

(e) Maximum isokinetic-concentric strength

(f) Maximum isokinetic-eccentric strength

7. Equipment utilized for training and testing were:

(a) Electric leg dynamometer

(b) Automated free weights apparatus

(c) Force platform

(d) Harpenden caliper

(e) A 3-meter steel tape.

CHAPTER II

REVIEW OF LITERATURE

A. INTRODUCTION

In line with the general principle of adaptation for living organisms, a human skeletal muscle improves its strength by working against a greater than normal resistance which provides the training stimulus. Although there is limited knowledge about the changes underlying the improvement of the functional capacity of the muscle, it has been known for over a century that a muscle will develop strength if the training stimulus is higher than the familiar levels of stimulus the muscle has been previously exposed to (Hinson and Rosentwieg, 1972; Johnson and Adamczyk, 1976; Friden et al., 1983; Hakkinen, 1985).

Muscle fibers increase in size as a result of the persistent tension developed in them. This increase in size is due to the hypertrophy and or hyperplasia of the muscle which accounts for the corresponding increase in strength and power (Clarke, 1973; Edgerton, 1976; Darden, 1977; Gonyea, 1980; MacDougall, 1986)

Steinhaus (1950) in his review of the research on strength development over half a century,stated that:

> "Only when a muscle performs with the greatest power; i.e. through the overcoming of greater resistance in a unit of time than before would its functional cross section need to increase. If however, the muscle performance is increased merely by working against the same resistance as before for a longer time, no increase in its contractile substance is necessary. Hypertrophy is seen only in muscles that must perform a great amount of work in a unit of time. The greater the intensity, the greater the hypertrophy."

In his contribution, Muller (1962) stated:

> "The stimulus necessary for an increase in muscle strength is an increase in the tension over previously exerted. The threshold of training rises steeper than the maximum strength during training. A more intensive training causes a more intensive increase in strength. The gain in muscle strength gets smaller and smaller in the course of training until it finally ceases."

There is general consensus in the literature that strength induced by isometric training method is restricted to the angle at which the training contraction occurs (Bender and Kaplan, 1963; Gardner, 1963; DeVries, 1974) and that there is less transferability of the strength gained to dynamic motor performance (Berger, 1963; Ball et al., 1964). The reason behind this phenomenon is that isometric contraction is static in nature whereas most performance tasks are dynamic. By specifically strengthening a limb while no movement occurs, one tends to reduce the limb's ability to contract at high speed which are common to athletic performance (Pipes and Wilmore, 1975).

There is no controversy regarding the fact that training over certain intensity level causes an increase in muscular strength and power. What is subject to debate is the training method that will produce the greatest increase in the strength and power of the skeletal muscle over a given period of time. This problem has stimulated many interested researchers to compare concentric, eccentric and isometric exercises in the development of strength and power. Although their findings have provided guidelines for strength training programs, they were inconsistent, conflicting and inconclusive. This was partially due to the lack of uniformity in experimental designs and also to the fact that muscular strength is general because many factors are involved in its training and development. Factors like different training programs, equipment used for training and testing, different subjects and the groups of muscles trained, measurement criteria and protocol, and the experience of the investigator could singly or in combination have significant effects on the findings.

The literature relating to strength training will be reviewed under the following sub-headings:- Isotonic-concentric and eccentric training, Isokinetic-concentric training; comparison between isotonic-concentric and eccentric with sokinetic-concentric training modes; eccentric training; comparision between concentric and eccentric training modes and strength tests.

B. ISOTONIC-CONCENTRIC AND ECCENTRIC TRAINING

Isotonic-concentric & eccentric (hereinafter referred to as isotonic) training which involves the lifting of free weights, has been the most conventional method of training that many people interested in developing strength and power have been using. Isotonic is a word that had been wrongly implied to mean a contraction that provides constant tension when lifting free weights. Although free weights provide constant resistance, they do not produce constant tension. Instead, the tension varies as the resistance is moved through a range of movement (Berger, 1972; Ariel, 1976; Pipes, 1977; Garhammer, 1986). Singh (1984) described the contraction as "Hetro-Tonic-Metric" because it does not provide constant tension through a full range of movement due to the modifying effects of the lever system of the body. The relationship between the joints and the points to which the muscles are attached across the joint largely determines the load that can be lifted during training (Berger, 1972). The amount of load that can be handled effectively is limited to the weakest point in the range (Sheeran, 1977; Bosco, 1985) which results in the muscle working less than maximum at a point in a range of movement. Therefore, the total work done is less than maximum (Ariel, 1976; Hobson, 1983).

There is no consensus of opinion among various investigators with regards to the sets and repetitions to be done with this method for strength deveopment. While Delorme (1945) who popularized this isotonic training method postulated 7-10 sets of 10 RM, others (Berger, 1962; O'Shea, 1966; Withers, 1967) countered with the results of their research that 3 sets of 4-8 RM were optimal for maximum strength development.

Delorme, (1945) as a result of his experience with his patients stated that low resistance with high repetition exercise built endurance while high resistance with low repetition exercise conditioned the muscle to become powerful. His rationale for making this assertion was that when using heavy resistance for training, it calls forth the maximal inherent strength of the muscle and since the rate and extent of muscle hypertrophy is usually proportional to the resistance the muscle must overcome, improvement in strength occurs faster than in the low resistance exercise. This concept has formed the basis for strength training till today.

But later Delorme and Watkins (1948) modified Delorme's (1945) earlier technique of using heavy resistance throughout the training program to a more acceptable and easily applied program which they called "Progressive Resistance Exercise". This method makes it possible to do progressive exercise through a full range of motion by extremely weak muscles.

This was a substantial improvement over the method previously described - that of overloading weak muscles through a limited range of motion. This training mode became known as Delorme-Watkins' method which advocated 3 training sets of 10 repetitions at 50% of 10-RM; 10 repetitions at 75% 10-RM and 10 repetitions at 100% 10-RM.

In explaining their rationale for designing this type of training program, they stated;

> "By the use of small muscle loads initially, and then increasing them after each set of 10 repetitions, the muscle is warmed up preparatory to exerting its maximum power for 10 repetitions."

On the basis of their postulate, several investigations were carried out to determine the efficacy of this training program as such warming up phase might have trophic effect on motor units recruitment.

After trying Delorme and Watkins' program in his clinic, Zinovieff (1951) believed it was too fatiguing and too great a strain was placed on the muscles. He stated:

> "At each exercise session, whilst building up to the 10RM, the quadriceps became so fatigued that the last quarter of the session became very exhuasting to the patient.. In addition, the quality of the performance fell off to such an extent that full active extension of the knee was by then rarely possible thus detracting from the value of the session and preventing the performance of the exact technique."

As a result of the fault which he found with the Delorme-Watkins' technique, he developed what he called the "Oxford technique". The Oxford technique retained the principle of heavy resistance-low repetition, but reversed the former procedure by starting with the heaviest weight first and progressively decreasing the load.

The only reported study using both Delorme-Watkins' and Oxford techniques was done by McMorris and Elkins (1954). They found that the Oxford technique produced a 5.5% greater increase in strength. They asserted however, that a series of experiments was necessary before it could be concluded that these techniques produce consistently different results. So far, no study has yet been reported that substantiates their findings.

In one of his many studies on strength and power development, Berger, (1962c) did a study to determine the optimum number of repetitions with which to train for rapid strength development. Using the bench press lift as the training exercise, nine groups consisting of a total of 199 male college students were tested before and after 12 weeks of progressive resistance exercise. Each group trained with different repetitions per set three times a week. The resistances they trained with were 2RM, 4RM, 6RM, 8RM, 10RM and 12RM. In his results, he found that the optimal number of repetitions per set to improve strength were from four to eight.

In another study, Berger (1962b) investigated the effects of varied weight training programs on strength. He compared nine different weight training programs to determine which were more effective in improving strength. 20 university male students trained thrice weekly for 12 weeks in each weight training program using the bench press lift as the training exercise. The training programs were, 1 set of 2 repetitions; 1 set of 6 repetitions, 1 set of 10 repetitions; 2 sets of 2 repetitions; 2 sets of 6 repetitions,; 2 sets of 10 repetitions; 3 sets of 2 repetitions; 3 sets of 6 repeptitions and 3 sets of 10 repetitions. The strength evaluation was the maximum weight the subject could press once.

His findings indicated that 3 sets of 6 repetitions were most effective in improving strength. This result was in agreement with his last reported study in which he found that 3 sets of 4-8 repetitions were optimal for developing strength.

The findings of O'Shea (1966) were at variance with those earlier reported by Berger (1962b, 1962c). In a study to determine the effects of six-week progressive weight training program on the development of strength and hypertrophy using the deep knee bend exercise routine, he divided 30 students into three experimental groups. Group A did 3 sets of 9-10RM; Group B exercised with 3 sets of 5-6RM while Group C trained with 3 sets of 2-3RM. The effectiveness of the training program was determined by three measurements:- thigh girth, dynamic strength (as measured by 1RM on the deep knee bend) and static strength (as measured on the dynamometer). His results showed that no significant differences were found between the three systems of training.

In a study similar to that of O'Shea (1966), Withers (1967) investigated the effects of varied loads on the strength of university freshmen. 55 randomly selected subjects were randomly assigned to one of the three training regimes in which they performed two workouts per week over a nine-week period using exercise routines of the curl, bench press and squat.

Group A trained with 3 sets of 7RM while Group B did 4 sets of 5RM. Group C employed 5 sets of 3RM for its training.

The findings showed that the weight training schedule resulted in statistically significant increases in strength and that beginners increased in strength more rapidly when training with 4 sets of 5RM than with either 3 sets of 7RM or 5 sets of 3RM. This result appeared to agree with that of Berger (1962b, 1962c) that 3 sets of 5-6RM were optimal for the rapid development of dynamic strength.

In a more recent investigation, Anderson and Kearney (1982) compared the effects of three resistance training programs on muscular strength and on absolute and relative muscular endurance. They randomly assigned 43 male college students to three training protocols of bench press, thrice weekly for a total of nine weeks. Group 1 performed 3 sets of 6-8RM while Group 2 trained with 2 sets of 30-40RM. Group 3 utilized 1 set of 100-150RM for its training program.

In conformity with what has been established, they found that Group 1 improved most by 20% while groups 2 and 3 improved by 8 and 5% respectively in strength. The significant increase of 28% by Group 3 in relative endurance was more than 22% of Group 2 and also of Group 1 which decreased by 7%. Their results supported the original observations of Delorme (1945) as they have shown that low-intensity long duration training increases the activities of aerobic enzymes whereas high intensity-short duration training increases the activities of the anaerobic enzymes which are needed in activities that require power (Gonyea, 1980; MacDonagh and Davies, 1984; Howard, 1985).

Berger (1962b) demonstrated with the findings of his study that training with submaximal loads of 90% was just as effective for improving strength as training with maximum loads. It was however, not explained how he equated the training stimulus as one group trained with 90% of 10RM twice a week and with the 10RM once a week while the other experimental group trained with 10RM thrice a week.

In order to determine how frequent a strength training program should be done to get the desired results, Corbett (1969) examined the effects of three different frequencies of weight training on muscular strength development using isotonic training techniques. 20 high school boys were assigned to one of the three exercise groups. Group 1 trained twice daliy, five days a week; Group 2 trained once daily, five days a week while Group 3 trained thrice weekly. The training program consisted of 3 sets of 4-8 repetitions per set. All three experimental groups experienced significant increase in elbow flexor and extensor strength over the six-week training period but no significant difference was evident between groups.

Summary

From the foregoing review, it is apparent that to train for rapid increase in dynamic strength, near maximum or maximum loads should be employed in every repetition. It has been demonstrated that 3 sets of 4-8 repetitions are optimal for the rapid development of muscular strength.

C. ISOKINETIC CONCENTRIC TRAINING

Isokinetic system of training is the newest form of resistance training to be introduced. Since its inception in the late sixties, it has been the subject of many general and specific research projects. It has the advantages of isotonic and isometric methods in addition to overcoming the inherent weaknesses of these two methods (Hislop & Perrine, 1967).

Isokinetic exercise occurs against a load which allows movement at a mechanically fixed speed and offers resistance inherently proportional to the muscle's maximal force developing capacity at every point (Thistle et al., 1967; Perrine, 1968; Moffroid, et al., 1969) throughout the range of movement.

Thistle et al, (1967) stated:

> "In isokinetic exercise system, the speed of motion, no longer an uncontrollable variable may be pre-set according to the specific activity for which the muscle is being trained."

Perrine (1968) explained the mechanism involved in the isokinetic exercise system:

> "When an individual applies maximum affort to an isokinetic exerciser which consists of a unique speed controlling mechanism that operates as a speed-governor on a dynamic exercise motion, it will instantly accelerate to its set speed. By preventing any further acceleration above that speed, it will load the

> dynamic "harnessed" muscle exactly proportional to its maximum dynamic tension capacity through a full range at that speed."

Chu and Smith (1971) have this to say:

> "In isokinetic exercise, more energy may be absorbed by muscular exertion because acceleration is controlled mechanically by the device. Therefore, energy is not wasted in speed control and may be concentrated on developing force. With the use of an isokinetic device, the muscle is able to maintain a state of maximum contraction through its full range of motion and thereby a maximum demand is required on the work capacity of the muscles."

Jensen and Jensen (1978) in their contribution, stated:

> "Isokinetic exercise devices have variable adjustments so that exercise can be done at slow, intermediate or fast speeds."

Isokinetic-concentric exercise does not cause muscle soreness as other methods of training do (Perrine, 1968; Pipes, 1977; Counsilman, 1971; Mini Gym, 1979). The rationale for their assertion was that muscles relax momentarily between repetitions in isokinetic exercise. This gives the blood time to remove the lactic acid from the exercising muscles, thus enabling the muscles to work maximally apparently without suffering the results of waste product accumulation. In constrast, during isotonic exercise, the muscles do not relax sufficiently between repetitions because the weight must return (eccentric contraction) and this muscle contraction continues to restrict the flow of blood and the natural cleaning process.

Antagonists (O'Shea, 1966; Jones, 1974; Ariel, 1976; Garhammer, 1986) of isokinetic exercise being the best, contended that isokinetic and other types of machine training may be theoretically sound for the development of isolated muscle groups, but fast, explosive and full-range multiple body joint action is not mechanically or physically possible.

Other disadvantages inherent in this form of training as highlighted by Darden (1977), Hobson (1983) Stone (1982) and Sale and Macdougall (1981) are:-

1. There is less resistance at either end of the movement which means that the muscle does not contract maximally through a full range of movement.
2. It is unproductive to use isokinetic exercises which control the speed of movement to duplicate neuromuscular system as most sports involve ballistic movements.
3. Since force has been considered an important component of athletic performance,

isokinetic devices inhibit natural patterns of acceleration and deceleration.

4. Isokinetic exercise does not provide the stretching of joints and pre-stretching of the muscles which are not only preresiquites for forceful contraction but have an important effect on motor nerves.

5. Athletic performance requires dynamic balance and concentration which are intergral requirements for success. These qualities cannot be developed when training with a machine like the isokinetic device to which the trainee is strapped.

6. If improvement and better performance in the field of sports is the sole objective of strength training, the exercise should simulate as much as posssible the movement patterns of the intended sports because neural adaptations play an important role in the response to strength training. Simulation of sports patterns that require the use of the total body cannot be achieved with isokinetic training as wide movement variations are not possible.

It is not still clear whether it is more beneficial to train at velocities where maximum torque occurs or at higher velocities which gives rise to maximum power output. In view of this uncertainty, many research studies have been done to determine the optimal sets, repetitions and training speed in developing maximum dynamic strength and power. The generally accepted principle of specificity in strength and power training, suggests that there may be little transfer from slow speed resistance training to the rapid ballistic movements performed in many sports settings. Sale and Macdougall (1981) have reviewed the factors which influence training effects such as movement pattern, contraction type, force and velocity in an attempt to clarify some of the principles of specificity of strength and power training.

The findings of Adeyanju et al. (1983), Pipes and Wilmore (1975), Moffroid and Whipple (1970) and Smith and Melton (1981) indicated that training at high-speed tension would lead to more rapid increases in strength and general work capacity than training with low-speed tension. However, the studies of Kehl (1977) and Lesmes et al. (1978) showed no significant difference between training speeds in strength development. Van Oteghen (1975) found that there was no difference between the two speeds of training on the improvement of vertical jump performance but slow speed tension was more effective in developing strength. Rosentswieg et al. (1975), after making an electromyographic comparison of an isokinetic bench press performed at three speeds, found that muscle action potential for the slowest setting elicited a much greater output than the two faster speeds.

The postulate of Rosentewieg et al. (1975) does not totally agree with the findings of Moffroid and Whipple (1970) who examined the effects of two different training speeds on muscular force and endurance. One group trained at a slow speed of 6 revolutions per minute while the other exercised at a fast speed of 18 revolutions per minute. Both groups trained three times a week for a total of six weeks. They summarized their findings as:

1. Low power (low speed, high resistance) exercise produces greater increases in muscular force only at slow speed.
2. High power (high speed, low resistance) exercise produces increases in muscular force at all speeds of contraction at and below the training speed.
3. High power exercise increases muscular endurance at high speeds more than did low power exercise increase muscular endurance at slow speeds.

In a similar study, Adeyanju et al. (1983) investigated the effects of two speeds of isokinetic training on muscular strength, power and endurance. His experimental subjects trained thrice weekly for a total of seven weeks. Their findings were consistent with those of Moffroid and Whipple (1970) that isokinetic fast speed training is superior to isokinetic slow speed training in the development of muscular force, power and endurance at high performance speed.

The results of the studies conducted by Caiozzo at al. (1980) Coyle et al. (1981) and Pipes and Wilmore (1975) are at variance with the findings of superiority of fast training velocity earlier presented in this review. They found that the gains in muscular strength at slow training speeds were greater than gains achieved at fast training speeds. This position was substantiated by the findings of Kanehisa and Miyashita (1983). They demonstrated that slow speed and intermediate groups showed statistically significant increases in average power at all test speeds while the fast speed group only showed statistically significant increase at faster test speeds of 240^{o} and 300^{o}/sec. These conflicting findings could be partly due to the operational definition of training speeds categorized as slow or fast and the duration of the training programs employed in various studies.

Rozier and Schafer (1981) studied the optimal frequency of training for maximum gains. After training with 3 sets of 8 repetitions per set at 10 rpm for six weeks, they found that there was no difference with regard to strength gains measured by peak force when exercising isokinetically three times per week or exercising daily, for a total of five times a week. However, when strength was measured isometrically, the subjects who exercised five times a week compared less favourably to the subjects who trained three times weekly. The implication of this finding is that daily stimulus of the muscle offered by isokinetic exercise, is not as effective as that provided thrice weekly. Their subjects were female; male subjects may respond differently to the training regime.

Kehl (1977) designed a study to determine the effects of three different repetition frequencies of/parallel-squat exercise performed isokinetically on the performance of the vertical jump. 34 male college students were divided into four groups. One experimental group did 2 sets of 10 repetitions; another did 2 sets of 20 repetitions while the third group trained with 2 sets of 30 repetitions. The control did not train. All the experimental subjects had two-minute rest between sets and they trained at high speed of two feet by second, three times a week using the isokinetic mini gym leaper. His results showed that all the exercise groups improved significantly over the control group. He stated:

> "Vertical jump performance can be improved through isokinetic training at high speed when training three times a week for six weeks using either two sets of 10, 20 or 30 repetitions."

The results of the experiment conducted by Lesmes et al. (1978) agreed with the findings of Kehl (1977). They designed a study in which five healthy subjects participated in a training program to compare strength and power gains achieved as a result of isokinetic strength training lasting six seconds and thirty seconds respectiviely. The subjects trained four times a week for a total of seven weeks. Each training bout consisted of maximum flexion and extension of the knee at constant velocity of 180°/sec. One leg was trained with a six-second work bout while the other leg was trained with a thirty-second work bout.

Their results showed that total work output increased by an average of 30% with either training mode, but no significant difference emerged when tested either at relatively slow (60°/sec.) or fast (180°/sec) velocities.

Counsilman (1976) advanced an explanation for the physiological implications in training with low and high resistance and at fast speeds:

> "Biopsies of athletes on a sprint program and of athletes who do high resistance, low repetition exercise at fast speed on isokinetic equipment show that the white fibers increase in size and the red fibers remain almost unchanged. The advantages are obvious. The white fibers are made stronger and the proportional mass of the white fibers is increased. Each white fiber is able to develop more tension and adapt to the stress of fast, high resistance exercise by becoming not only stronger but faster."

Summary

It is evident from the facts that have emerged from this review that there is no definite training velocity agreed upon in the literature when the objective is to develop muscular strength and power. One important concept that emerged though is that, training at high speed or low speed tension will cause an increase in dynamic strength while training at fast speed which provides low resistance, results in the development of power. This provides a better carry-over to motor performances of fast velocity. Different adaptations occur in the nervous system as well as in the musculature as a result of the different training velocities and thus intensities. These adaptations also affect the in vivo force-velocity relationship of the muscle.

D. COMPARISON BETWEEN ISOTONIC & ISOKINETIC TRAINING MODES

Most athletic movements are ballistic in nature which are preprogrammed in the central mechanisms of the brain and once initiated, cannot be influenced by sensory or environmental information (Ariel, 1976). In order to develop this precise complex neuromuscular action, isotonic exercise routine must be employed to enhance the preciseness in the timing and coordination of both the system of muscle contraction and the segmental sequence of muscular activity involved in these complex tasks (Ariel, 1976; Garhammer, 1978; O'Shea, 1979).

Ariel (1976) argued that it was impossible to use isokinetic exercises, which control the speed of movement to duplicate the neuromuscular system; because adaptations in the contractile and nervous tissues are specific to the type of training done (Sale and MacDougall, 1981). Isokinetic training method has been presented by Pipes and Wilmore (1975) as having a logical advantage over isotonic training method because in isokinetic exercise, the resistance is variable and accommodating, thereby allowing the development of maximum tension and thus strength throughout the full range of motion. To butress their case for isokinetic, they contended that:

> "Matching the speed of training to the speed of performance may be important in light of recent work concerning the specificity of training as isokinetic device has been constructed to allow training speeds to vary from 0^{o} to 200^{o} per second."

However, speed of performances in some sporting activities is as high as 600^{o}-700^{o}/sec.

There are not many comparative studies of isotonic and isokinetic training modes reported in the literature. But early investigations conducted produced conflicting results. The experimental studies of Moffroid et al. (1969), Girardi (1971) Stahali (1974), Titlow (1977) and Okoro (1979) showed that there was no significant difference between isotonic and isokinetic in developing strength and improving work capacity. Delateur et al. (1972) found that both training methods produced about the same results.

However, the study of Thistle et al. (1967) in which they compared isokinetic training with isotonic exercise routines produced different results. After eight weeks of training, the isokinetic group had gained approximately 35% in quadriceps strength as comapared to 27% for the isotonic group.

In their much cited study, Pipes and Wilmore (1975) examined the differences between isotonic and isokinetic strength training and what effects they have on changes of muscle strength, body composition and athletic performace. 36 subjects were assigned to one of four groups. Training was conducted three times a week for a total of eight weeks.

The isotonic group trained initially at 75% of 1RM, 3 sets of 8 repetitions. The isokinetic low speed group trained at 24° of limb movement per second, 3 sets of 8 repetitions and later 3 sets of 15 repetitions. The isokinetic high speed group trained at 136° of limb movement per second, 3 sets of 15 repetitions. The control group did not train. The results demonstrated a clear superiority of the isokinetic training procedures over the isotonic procedures relative to strength, anthropometric measurement and motor performance tasks representative of power. The isokinetic high speed group demonstrated the greatest gain of all.

Smith and Melton (1981) replicated the study of Pipes and Wilmore (1975) and came up with similar results except that their experiment was of six weeks duration and their high speed group gained significantly only when tested in activities requiring fast muscular contractions. Garhammer (1978) questioned the validity of the findings of Pipes and Wilmore (1975) on the ground that:

> "Barbell training was done for 3 sets of 8 to 10 repetitions at 75% of maximum three times a week for eight weeks - not an optimal free weight training regimen to achieve the desired results. No mention was made of how the subjects performed the barbell exercises (explosively vs slowly), a factor which would influence results in the motor performance tasks which were very dependent on explosive strength."

Hinson and Rosentswieg (1973) stated that comparison among different methods of contraction was tenuous because of the difficulty in equating the work and also because any procedure used to evaluate the outcome involved one of the types of contraction and was necessarily biased in that direction. To offset this discrepancy, they employed quantitative electromyographic (EMG) techniques in an effort to examine the differences among isokinetic, isotonic and isometric contraction types in terms of electrical activity elicited by each. Their findings demonstrated that isokinetic contractions elicited greater muscle action potential than either isotonic or isometric contractions.

However, in their second study, Hinson and Rosentswieg (1973) changed their opinion and stated that no single contraction type produced the greatest action potential for all the subjects who exercised with the training modes under study.

Summary

In the light of the facts that have emerged from this review, there is conflict of opinions regarding the superiority of isokinetic exercises over isotonic exercises in the rapid development of dynamic strength and improvement of motor performance.

E. ECCENTRIC TRAINING

An eccentric contraction occurs when the muscle is being lengthened passively by an external force resulting in the development of tension (Kroemer, 1970; Rasch, 1974; Sale and Norman, 1982; Knuttgen and Kroemer, 1987). McMahon (1984) defined it as the work done by the muscle when it is developing an active force at the same time as it is being compelled to lengthen by an outside agency. Rasch (1974) observed that it is much less fatiguing to perform negative work (eccentric contraction) than it is to perform positive [illegible] (concentric contraction). Asmussen (1952) has demonstrated that for fairly rapid movement, the maximum concentric force was only 75 to 80% that of isometric strength, whereas in resisting a movement at the same velocity, 125% to 130% of isometric strength can be produced.

An examination of the force-velocity curve reveals that as velocity of concentric contraction increases, force decreases. Conversely, eccentric force increases (up to a point) as the velocity of lengthening increases (Rasch, 1974; Sale and MacDougall, 1982; McMahon, 1984).

Since the tension exerted by a muscle is the product of the number of fibers activated and the frequency of the neural stimualtion of these fibers, several groups have investigated the degree of motor-unit involvement in muscle contraction. They measured the levels of integrated electromyography (IEMG) in muscle contraction under eccentric and concentric conditions because electrical activity in the muscle is said to have a linear relationship with the amount of tension developed (Bigland and Lippold, 1952; Rogers and Berger, 1974). Asmussen (1952) reported that IEMG was greater during concentric work than eccentric work because in eccentric contraction, as the muscle fibers are forcefully lengthened, relatively fewer fibers are required (as low as 1/3) to hold the load compared to concentric work. This view was supported by Bigland and Lippold (1952) and Basmajian (1967) that for a given submaximal force of contraction, an eccentric contracting muscle uses less oxygen, a smaller amount of ATP and less motor-unit involvement than when the muscle is contracting concentrically. Ashton and Singh (1973) after investigating the relationship between erectores spinae voltage and backlift strength for different contractions, found that the maximal concentric strength voltage per pound force ratio was significantly higher than the ratios for the isometrtic and eccentric strength.

However, the findings of Komi (1973) after investigating the relationship between maximal IEMG and tension development of the elbow flexors at different speeds of concentric and eccentric contractions, were different. His results were substantiated by Rodgers and Bergers (1974) who failed to find any difference in the degree of motor-unit involvement between maximal concentric and eccentric contractions, although the tension developed during eccentric contraction was nearly twice that developed concentrically. This phenomenon could be explained by the postulate of Bosco (1985) that over stretching of the muscle elastic components (i.e. tendons, connective tissue among fibers and fibrils and elastic elements in the sarcolemma) along with the accompanying delay in the recoil would serve as a trophic stimulus to increase the force of muscle contraction. Cavagna et al. (1965) supported this perspective and theorized that such stretching of the muscle at the onset of eccentric contraction, results in the storage of greater amount of energy in the elastic components of the muscle thereby culminating in the generation of much greater force as compared to the force production in a corresponding motor-unit recruitment during concentric contractions. A different view was expressed by Astrand (1977) that greater tension of eccentric contraction compared to concentric contraction might be partly due to the facilitation of motor-unit involvement during imposed stretch and inhibition during shortening.

The interpretation of the findings of Komi (1973) and Rodgers and Bergers (1974) should be done with caution because since their studies were only concerned with a range of motion that did not include the extreme angles at either end of the range of elbow movement, the degree of facilitation would perhaps differ during complete flexion or extension of elbow.

Although it has been established that the force generated during eccentric contraction is greater than that of concentric contraction, (Asmussen, 1952; Bigland and Lippold, 1952; Basmajian, 1967) there are problems associated with training with this method to improve work capacity. Apart from the fact that most of the training devices contructed are biased toward concentric method in various forms, heterogeneity of subjects, muscle groups studies coupled with different training intensities and velocities, mitigated concrete generalization of the findings.

In eccentric training, a relatively greater load is placed upon the elastic components of the muscle resulting in muscle soreness primarily in the tendinosus attachments of the muscle (Johnson, 1972; Friden et al., 1983; Cieslik, 1986) found that following eccentric training, myofribillar damage was pronounced in the Type II fibers and that the Z-band of all the fiber types was damaged as the disorganization of Z-band material occurred.

Downhill running a different form of eccentric training, had been shown by Schwane et al. (1983) to cause delayed-onset muscular soreness and a significant increase in plasma CPK activity (351% at 24 h) due to structural changes in the muscle tissue resulting from eccentric contractions. This delayed onset of muscle soreness (DOMS) associated with eccentric training has been confirmed by Armstrong (1984).

These pains have been known to subside after a period of time (probably 2 weeks) during which time development of maximum strength by the subjects affected decreased as they trained with discomfort (Johnson, 1972; Rasch, 1974). Hence Racsh (1974), and Komi and Buskirk (1972) opined that because of the drop in tension and soreness during early conditioning, eccentric contractions may not provide optimal muscle conditioning in the shortest possible time. This observation was supported by Singh and Danielson (1975) when they did not find any significant change in the eccentrically trained group in the first six weeks of their eight-week training program.

There is no reported study which examined the optimal eccentric training loads, repetitions and sets for the rapid development of muscular strength and power, although most investigators have utilized various training loads ranging from 120 to 130% 1-RM. However, Jones (1973) has suggested that for maximum response to eccentric training, the movement should be slow enough to permit the subject to attempt to stop the external force. Johnson et al. (1976) have advised against using training loads greater than 130% 1-RM as it might increase the potential for damage to the muscles or to other body support structures. Apart from the potential of injury, subjects may not beable to slow down the downward movement of the lenthening force in eccentric exercise which might therefore result in little or no training effect.

Summary

Eccentric contraction produces much greater tension than concentric contraction. Eccentric muscle contraction (negative work) results in lower metabolic cost probably due to a reduction in active muscle mass. The increased tension developed during eccentric work is the result of energy stored in the elastic elements of the msucle as it is forcefully stretched at the onset of contraction. It is not clear whether there is increased IEMG with a corresponding increase in motor-unit involvement in eccentric contraction. Eccentric training causes delayed onset muscle soreness (DOMS) and also myofribillar damage coupled with the disorganization of the Z-band material.

F. COMPARISON BETWEEN CONCENTRIC AND ECCENTRIC METHODS

Research studies that have compared eccentric and concentric modes of strength training using different types of equipment have reported conflicting results. The first comparative study reported was done by Logan (1952) in which he trained 16 subjects matched on the basis of equal leg length and maximal strength of the quadriceps muscles as measured by a tensiometer during seated knee extensions. The training program consisted of slow-leg press on a leg press machine by one subject while his partner took the weight on his feet and lowered it. Gradual increases were made in the weights as the training progressed. The subjects did 30 repetitions thrice weekly for a total of 7 weeks. In his findings, he noted that there was apparently little difference between the effects of exercise under concentric and eccentric conditions and that the little difference that occurred was probably due to the fact that the work done could not be equated exactly.

This observation was confirmed so many years later by Seliger et al. (1968) who trained 15 members of an adult rugby team (8 eccentrically and 7 concentrically) by lifting and lowering dumbells over a two-hour period repeated twice a week for 13 consecutive weeks. They reported that strength gains were identical for both groups but noted eccentric exercise was more efficient as it required less energy expenditure during the exercise.

The results of the investigations (Mannheimer, 1969; Johnson, 1972; Singh and Danielson, 1975; Johnson et al., 1976; Pavone and Moffat, 1985) carried out in later years to determine which training mode was more efficient (eccentric vs concentric) supported the earlier results.

In 1960, Petersen reported a study in which he found different results. He observed after training his subjects with different contractions in 20-36 days that inspite of the higher tension developed during eccentric training, no significant increase in isometric strength was found as a result of 10 maximal daily eccentric contractions. On the other hand, heavy dynamic work increased the isometric strength of the muscles by 12% for the females and 23% for the males.

A clear dissenting view has been expressed by Komi and Buskirk (1972) who employed a special electric dynamometer to condition the forearm flexors of his subjects through a range of 65^{o} - 170^{o} six times in a training session. Following a pretest of maximal isometric strength, 31 subjects were matched and randomly assigned to one of 3 groups eccentric, concentric and control. The exercise groups trained for 7 weeks, 4 times a week on the dynamometer.

His results indicated that eccentric condition caused on the average, a greater improvement in muscle tension than did the concentric conditioning. The difference in the results could be attributed to the different special electric dynamometer employed in their conditioning and testing as compared to the other studies that utilized various types of manually operated equipment for training and testing.

In a departure from the conventional practice of using one type of contraction for muscle conditioning, Hakkinen and Komi (1981) examined the effects of a 12-week progressive strength training program utilizing different combined concentric and eccentric muscle work regimens on maximum leg extension forces and dynamic performance test results. The subjects who trained 4 times a week, were 13 competitive junior weight lifters and 27 non competitive habitually active weight trainers plus 10 controls. They were divided into two main groups (concentric and eccentric) which were further sub-divided. Concentric training was done with 80-100% of 1RM, 1-6 repetitions per set while that of eccentric training was 100-130% of 1RM, 1-3 repetitions per set.

The study demonstrated that the combinations of concentric and eccentric training resulted generally in better increases in muscle force than that of concentric work alone. The authors did not explain however, how eccentric work was done with clean and jerk and snatch exercises.

As a result of the effectiveness of the combined concentric and eccentric training methods on strength development, Hakkinen et al. (1981) did a follow-up study to investigate the effects of a 16-week combined concentric and eccentric strength training program followed by an 8-week detraining program on maximal force and various force-time, anthropometric, muscle fiber and enzyme activity characteristics.

The subjects were 14 males (20-30 years old) accoustomed to weight training in a non-competitive manner and 10 physically active male controls (20-30 years old) with no special experience in weight training. The conditioning exercise was performed three times weekly with a program consisting mainly of dynamic squat exercise of which 75% (80-100% of 1RM) was concentric while 25% (100-120% of 1RM) was eccentric.

Their results indicated that the magnitude of strength gains, improved dynamic motor performance and alterations agreed with the findings of Pletnev (1975, 1976) and Hakkinen and Komi (1981) that the combination of concentric and eccentric training was more effective for strength and power development than either concentric or eccentric training done alone.

It is significant to note however, that a decreased capacity for fast force production (power) was observed during the later part of the training when hypertrophy of both fibers were quite evident. This decrease, they attributed among other adaptations, to the very slow contraction speed employed during eccentric training. This reason is at variance with the stated principle of eccentric training which called for slow-speed contraction in order that the conditioning may be effective (Rasch, 1974; Johnson et al., 1976). At increased speeds of contraction, sustained lengthening may not occur resulting in no desired training effect.

Summary

The reaserch findings are not conclusive but there is considerable evidence in the literature that eccentric work may be more advantageous since comparable strength gains could be achieved at a less expenditure of energy. It is not clear however, which method is superior inspite of the greater tension developed during eccentric contraction. But there is consensus among researchers that a combination of eccentric and concentric training in any form is more effective than either concentric or eccentric training done alone.

G. STRENGTH TESTS

Strength is proportional to the physiological cross-sectional area of the muscle (Hettinger, 1961). Muscle strength is measured by the weight lifted through concentric contractions or the amount of tension a group of muscles exerts against an inmovable object in a static contraction. The magnitude of internally developed force of a muscle cannot be measured directly instead the external effects of the internal muscular effort is measurable as the force exerted at a certain distance from the joint to an outside object (Kroemer, 1970). Berger (1972) asserted that some individuals score higher on strength tests than others because of more favourable leaverage although actual muscle contraction forces are the same.

Hunsickler and Donnelly (1955) referred to De La Hire - a French scientist as the first to publish the results of his investigations in 1699. De La Hire did not use highly scientific devices but merely compared the strength of man in lifting weights and carrying burdens with that of horses. Since his publication, many different pieces of apparatus have been designed to measure the muscular strength of humans. While some have been discarded, others were modified to suit present use. Hunsicker and Donnely (1955) gave a historical picture of the development of these various instruments and the principle of operation upon which the designs were based.

Comparative studies and analyses have been made by various investigators (Clarke, 1954; Hunsickler & Donnelly, 1955; Komi, 1973; Chaffin et al. 1980) and a consensus was not reached as regards the best testing method. It is however, pertinent to mention the observation of Kennedy (1965) that muscle strength tests could be affected by the competence of the tester, force of gravity, joint stability, fulcrum and length of the lever, the apparatus used for the test and according to Darden (1977,) neural factor in performance. Measurement of maximum strength by voluntary maximal contraction of the muscles is not only a technical but a psychological problem (Muller, 1962. Ikai and Steinhaus (1961) discovered from their study that gunshot or screaming during contraction increased the strength of their subjects by 7-12%. and that strength can be altered by hynotic suggestion. It is likely that screaming or gunshot sound at the time of muscular contraction may reduce the neural inhibition on the generation of maximal tension by the muscles.

There is no test in which all or some of the factors mentioned above do not contribute to weaken the validity of strength measurement results. In view of the attenuating factors in strength tests, one may want to question the validity of the results of tests already conducted which have formed the basis of scientific research today.

In recent years, the development of a practical method of objective strength and power testing has been the subject of a great deal of work in the field of Physical Education, Physical Therapy and Physical Rehabilitation. An objective measurement which is independent of the effects of the training program would seem to be required if the contribution of the respective contraction types of strength gain is to be accurately evaluated. Along this line of thought, Ikai and Fukunaga (1966) came up with the idea of measuring the strength of a muscle through the means of ultrasonic photography. They stated:

"By means of ultrasonic photography of the cross-section of the acting muscle bundle, together with the measurement of the strength developed by the subject with maximal effort, the strength per unit area of the muscle (kg/cm) could be calculated."

A different approach was espoused by Singh (1972) who designed an electric dynamometer to test concentric, eccentric and isometric strength. This device can measure concentric and eccentric strength at a pre-fixed constant velocity. Chaffin et al. (1980) described the concept of electromyographic (EMG) amplititude as being a consistent and sensitive measure of motor unit recruitment and that it is effective in determining the actual muscle strength capability of a person.

H. ISOTONIC CONCENTRIC STRENGTH TEST USING 1RM

The one repetition maximum (1RM), which is the heaviest weight that can be lifted once, is the most common measure of concentric strength (1982). Although the protocol involves alternating concentric and eccentric contraction phases, it is always a test of concentric contraction strength. Delorme and Watkins (1948) used 1RM as a maximum dynamic strength of a muscle or muscle groups. Following this protocol, Berger (1962a, 1963); O'Shea (1966), Withers (1967) and some other investigators used similar method to determine the isotonic strength of the muscle groups being tested.

The values obtained from isotonic weight lifting tests are not only for concentric but also eccentric contractions because the subject has to lower the weight (eccentric) from its supports and returns it (concentric) thereby depleting his energy sources intended for the concentric test per se. To overcome this weakness inherent in this test, Sale and Norman (1982) suggested that the test should consist of concentric contraction only by designing a device to lower the weight independent of the subject's effort.

Since the force applied at the onset of the lift to overcome the inertia of the weight is more than that of the weight, Sale and Norman (1982) suggested that a system be devised whereby the initial force developed by the contracting muscle is assessed objectively.

In vivo, a muscle will register its peak torque when its joint angle has optimal mechanical advantage (Berger, 1962a; Lesmes et al., 1978) therefore, it is important that the test protocol is standardized because the position assumed at the time of the test may increase or decrease the weight that can be lifted (Jones, 1974). De Vries (1974) pointed out that one of the weaknesses inherent in this test is the repetition of the test with different loads in order to determine the subject's true 1RM. If all testing is done in one session, the validity of the test may be affected by fatigue.

I. ECCENTRIC STRENGTH TEST

Eccentric strength test is not popular because of its non-applicability to daily activities. Its relevance to some sports like Judo and Wrestling therefore, calls for a more objective method of assessing it. Eccentric strength test could be isotonic or isokinetic depending on the type of equipment used.

Velocity criterion should be set in order to get the correct value in eccentric strength measurement. The study of Asmussen (1952) showed that human muscles can do negative work at 1/3 - 1/9 cost of positive work while working at low and moderate speeds. At high velocity, he observed that the cost of negative work almost equalled zero.

J. ISOKINETIC STRENGTH TEST

One of the newest devices available to physical therapists and researchers for the evaluation of strength is the isokinetic dynamometer (Falkel, 1978; Barbee and Landis, 1984). This isokinetic device can be set at a variety of speeds through a complete range of motion and prints a read-out of the torque exerted by a specific group of muscles. It measures force out-put at pre-selected controlled velocities from isometric contraction (0^{o} per second) to fast functional speed (over 200^{o} per second)

Moffroid et al. (1969) found that test-retest sessions using an isokinetic device for evaluating strength produced a coefficient of reliability of 0.995. Isokinetic devices have gained increasing acceptance in the area of strength evaluation since its inception because calculations in terms of footpounds can be made which reflects such functional ability as strength, power, comparative joint intergrity and actual dynamic performance of the body joint or muscle group being evaluated. Thistle et al. (1967) contended that;

> "Since exercise which involves lifting of weights is difficult to interpret and standardize, it would appear that measurement of torque is the best index of muscular contraction."

Some investigators notably Winter (1981) and Sapega et al. (1982) have criticisized Cybex isokinetic device as not recording the actual torque produced during maximal contractions because it does not account for the force of gravity acting on the limbs. Sapega et al. (1982) were of the opinion that the prominent initial spikes and second oscillations that appear in Cybex torque records do not represent intermittent surges of muscle contractile force but rather the forces associated with the initial deceleration and subsequent velocity fluctations of an initially overspeeding limb-lever system. It is the contention of Osternig (1975) that since the limb has to pass through several degrees of motion before equalling the set speed of the dynamometer, the force developed in the initial part of the movement is not recorded. With all these points marshalled against the commercially available isokinetic testing devices, their effectiveness as strength measuring dynamometer is thus questioned.

K. RESISTANCE TRAINING, BODY FAT & ANTHROPOMETRIC CHANGES

One of the adapative changes that occur in the muscle as a result of high-intensity resistance training is an increase in lean body mass which is responsible for increased force development. There is research evidence that the concomittant effects of strength training includes improvement in other physical and physiological parameters (Katch and Drumm, 1986).

The effect of high resistance training on the reduction of body fat has recently become an issue of great interest to exercise physiologists, physiotherapists, medical doctors and exercise instructors. Although research work is limited in this area, the findings that have been reported are as controversial as the training programs employed.

In a recent review on the effects of resistance training on body composition, Katch and Drumm (1986) presented data for boys and men which showed increases in body weight of .3 to 2.3 kgs in ten studies whereas five studies noted reductions in body weight that ranged from .4 to 1.1kg. Decreases in per cent body fat of .5 to 2.8 were also noted while moderate increases in lean body weight ranged from .9 to 3 kgs. Studies investigating the effect of resistance training on body composition have been limited in scope. Some investigators like Pipes and Wilmore (1975), Stone et al.(1983), Goldberg et al., (1984), and Hunter (1985) reported reduction in percent body fat and an increase in lean body weight, while others (Ward and Fisk, 1964; Hurley et al., 1984; Katch and Drumm, 1986; Jette et al., 1987) found no significant changes in body composition following heavy strength training.

Some of those early investigators who studied the effects of different resistance training programs on body composition were Pipes and Wilmore (1975). After eight weeks of training with isokinetic and isotonic modalities three times a week, they found no meaningful changes in body weight but did find significant changes in lean body weight of 2.3 and 3.9% including fat weight which decreased by 6.9 and 19.4% for the isotonic and isokinetic modes respectively. It is however, worthy of note that their isokinetic high speed group exhibited the greatest loss in percent body fat over the isotonic and isokinetic low speed groups. The implication of their result is that speed of muscle contraction during training is an important factor as regards the reduction of body fat with strength training.

The results of Pipes & Wilmore (1975) corroborated the earlier findings reported by Wilmore (1974) after training 46 women and 26 men with different resistance exercises for both the upper and lower body. The subjects trained thrice weekly for a total of ten weeks with each training session lasting 40 minutes. Body composition of the subjects were assessed by hydrostatic weighing technique and skinfold thicknesses were measured by Harpenden calipers.

He reported significant increase in strength as well as identical changes in body composition as reflected by increase in lean body weight (2.4 & 1.9%) and decrease in absolute body fat (7.5 & 9.3%) for men and women respectively. Body weight remained stable throughout the study.

Stone et al. (1983) conducted investigation into cardiovascular responses to short term Olympic style weight training in young men. Much as positive cardiovascular changes were observed, positive changes in body composition of their nine subjects were also noted.

Their subjects were college age male students who trained three times a week for eight weeks with squats, leg extension, snatch grip pulls, push press exercises and vertical jump. They determined body composition by hydrostatic methods but residual volume was estimated by multiplying vital capacity by .24 (Wilmore, 1969). Body fat was estimated by the equation of Brozek et al. (1963). The practice of using constant value for all the subjects to determine residual volume is questionable. But Wilmore (1969) reported that there were no statistically significant differences between the means for density, percent body fat or lean body weight calculated using the actual residual volume and the means calculated using either the estimated or constant residual volume.

Their results supported those of Pipes and Wilmore (1975) and Wilmore (1974) which were earlier reported. Their subjects exhibited significant increase in lean body weight accompanied by a decrease in percent body fat resulting in a stable body weight.

The study of Golberg et al. (1984) and Hurley et al. (1984) have much significance regarding resistance training and lipid lipoprotein levels of both active and inactive subjects. Hurley et al. (1984) reported that training regimen of bodybuilders is associated with a more favourable lipid profile than the training of powerlifters. The implication of this is that moderate resistance with high repetition (20-30) usually done by bodybuilders is more optimal for fat mobilization compared to powerlifters' training of high resistance, low repetition (1-6). After training for 45-60 minutes per session, three times a week for 16 weeks using universal gym machine for the resistance exercises (3 sets of 3-8 reps), Goldberg et al. (1984) found that not only did their subjects (8 women, average age 27 years and 6 men, average age 37 years) increased significantly their mid-arm circumference by 15 mm and 17 mm respectively, they also demonstrated a significant decrease in their tricep skinfold. These positive morphometric changes were accompanied by significant decrease in cholesterol levels.

They then postulated that weight training exercises could increase high density lipoprotein cholesterol concentrations which might relate to reduction in body fat and increased lean body mass.

The study of Hunter, (1985) supports the idea that training for strength which involves the upper and lower extremities of the body could induce positive changes in body composition. His subjects (22 females and 24 males) trained three or four times a week for seven weeks by doing 3 sets of 3-10 repetitions of bench press, two-arm hand curl, behind the neck pulldown, and knee curls. His results indicated not only an increase in standing long jump, strength and muscular endurance, lean body weight also increased while percent bodyfat of the subjects decreased.

Brazell (1986), demonstrated that 3 times a week heavy resistance training was more effective than 2 times a week at similar workloads in significantly improving body composition. The subjects who trained 3 times a week decreased their skinfold thicknesses by 14% compared to the 2 times a week training which induced a 5% change which was insignificant.

Although the training program employed by Fahey and Browm (1973) involved both lower and upper body, increase in lean body weight and decrease in percent body fat was insignificant. Their 28 subjects trained three times a week for nine weeks doing 5 sets of 5 repetitions of bicep curls, bench press, leg press and latissimus dorsi pull down including dead lift exercises.

Some of the earliest investigators to dispute the positive effect of strength training on body fat reduction were Ward and Fisk (1964). They trained 75 male university students who were divided into two groups using isotonic and isometric exercises thrice a week for 10 weeks. Although increase in strength for the groups was reported, there was no significant increase in the muscle circumference of either the biceps or the quadriceps indicating that increase in strength was independent of the increase in the girth of the muscle.

These findings were surported by the outcome of the study conducted by Ricci et al. (1982). This study, a by-product of the effect of strength training on left ventricular size was of 20 weeks. The 12 college-age male subjects trained thrice weekly with 7 sets of 5-RM doing series of upper body isotonic exercises. Body fat was determined from 10 skinfold thicknesses according to the formula of Allen et al (1956).

The results indicated increase in strength by 39% but no change in percent body fat. This was also confirmed by Hurley et al. (1984) after training 13 sedentary males (average age, 44 years) on the Nautilus gym machines 3-4 times a week for 16 weeks doing 8-12 RM of each of 14 exercises per training session. Fat free weight was reported to have significantly increased ($P < .05$) but no significant change in body weight or percent body fat. The possible reason for the observed insignificant change in body fat could be due to the low relative intensity (45% VO2 max.) elicited by this form of exercise as it had some elements of interval training associated with it.

A more recent study by Jette et al. (1987) did not also find significant changes in body composition and anthropometric measurements except an increase in forearm girth of the experimental subjects following heavy resistance training protocols. After 7 weeks of training their 122 college female subjects assigned randomly to three exercise groups, they exhibited significant improvement in upper body strength, but no change in percent body fat.

Summary

Response to resistance training program relative to body composition and anthropometry is due to the intensity rather than the specific method utilized to effect the training stimulus. Research work in this area is limited in scope but the findings so far reported are controversial and inconclusive. The motivation of the subjects during training, the volume and intensity of the exercise performed and the incorporation of aerobic components into the training programs should be considered. All these factors either singly or together will determine whether the subjects will reduce body fat or not as a result of heavy resistance training programs.

There is however, a commonality in the studies that reported reduction in body fat as a result of heavy strength training. This is the involvement of the upper and lower extremities in the training coupled with long duration of training (longer than 10 weeks) as well as 40-60 minutes spent per training session.

CHAPTER III

METHODS AND PROCEDURES

A. SUBJECTS

To recruit subjects, an advertisment was placed in the University of Alberta newspapers - The Gateway and the Folio. The physical activity readiness questionnaire (PAR-Q) (appendix A) was given to the respondents to complete. Sixty healthy males ranging in age between 18-28 years who were inexperienced in resistance training and who did not have contraindications to participate in a strength conditioning program, were randomly selected from those who completed the PAR Q.

The subjects signed the informed consent forms (appendix B) after having been informed of the benefits and possible risks associated with participating in a training study of this nature. They were asked not to engage in any strength conditioning activity outside the training regimes of this study.

In order to motivate the subjects in the control group to abstain from any strength conditioning training throughout the duration of this study, they were promised that they would be given similar training as the training groups (depending on their choice of training regime) at the end of the study.

The rationale for restricting the study to male subjects of 18-28 years was that maximum strength is reached between the ages of 20 to 30 years. After 30 years of age, strength tends to gradually decrease (Astrand and Rodahl, 1977). People of this age group (20 to 30 years) therefore, have high degree of trainability. Changes in strength variables as a result of training can easily be observed and measured.

B. FAMILIARIZATION SESSIONS

Physical fitness tests involve elements of skill which must be mastered by the subjects before tests are administered (Vertex, 1985). In order to ensure maximum performance at the pretest since the subjects were inexperienced and had not used any strength conditioning equipment before, three sessions of familiarization exercise were organized for them.

These familiarization sessions were aimed at acquainting the subjects with the required skills associated with the tests, different testing and training equipment. Therefore, the differences that were observed between the pre and post values were more of the true gains in strength and less likely to be influenced mainly by practice or learning effects.

C. INSTRUMENTATION

Force Platform to Measure Maximum Leg Impulsive force

Vertical jump is an activity in which maximal explosive force can be determined utilizing a force platform (Davies, 1971; Komi, 1979; Caiozzo et al., 1980). The vertical components of the force imparted on the plate are recorded as a function of time.

Force platform is one of the tools used in the study of jumping activities because it provides a direct measure of one of the principal components responsible for a jump to occur - the force (Ramey, 1973). Essentially, the device is an electronic scale which measures the magnitude of the vertical and two horizontal forces.

The force platform (model OR6-3, Advanced Mechanical Technology Incorporated) that was utilized in this study, had a surface which measured approximately 465 mm x 500 mm and was capable of measuring forces up to 5337.6 N.

Signal conditions were achieved using high performance strain guage/RTD conditioners (model 2B30J Analog Devices Incorporated). The conditioned signal was sampled using a Tecmar digital converter interfaced with an IBM micro computer. The sampling frequency was 1 millisecond per sample or 1000 hertz.

The force exerted on the force platform by each subject during takeoff was sampled through the A/D board and stored as force data once converted within a specifically written jump software package. The force data was plotted on a Hewlett Packard 7470A plotter.

Isokinetic-Concentric and Eccentric Leg Dynamometer

This electric leg dynamometer (Singh, 1972) (fig. 1) can measure maximum isokinetic-concentric and eccentric strength at predetermined speeds of flexion and extension. It consisted of an electric motor connected to a double-acting hydraulic cylinder from which a 1,500 kgs capacity cable passed over two ball bearing-pulleys and emerged at a point between the subj[illegible] and in front of him. The cable was connected to a special belt. This belt was further connected to steel bar firmly attached to a four-inch webbed belt (fig. 2). Sewn to the webbed belt was an automobile seat belt with a buckle. By adjusting the buckle, the belt was securely fastened around the subject's waist.

A load cell (BLH Electronics, type U3G1) that had a capacity of 1,400 kilograms was connected to the Honeywell Biomedical System Model 1912 which printed out the force being exerted continuously by the contracting muscles. When the cable was being pulled down at a fixed velocity, the subject was required to resist the pull from a standing position (with a slightly bent knee) to 90^{o} knee flexion. The strength developed by the lower extremity muscles as they were forced to lengthen (eccentric contraction) at a constant velocity was recorded. Similarly, for maximum isokinetic-concentric strength test, as the cable was released, the subject pulled up forcefully from the half squat position (90^{o} knee flexion) with the cable moving at a fixed velocity until full extension was attained. Since the cable was mechanically controlled at fixed speed, the speed of muscle contraction was held constant throughout the range of motion. This dynamometer has previously been used for other studies (Ashton and Singh, 1973; Singh and Danielson, 1975).

Isotonic-Concentric and Eccentric Strength Apparatus

This apparatus (fig. 3) was constructed to eliminate the eccentric contraction phase which is a feature in isotonic strength training or measurement. The apparatus was designed so that it could automatically return the weight to the starting position within a specified time independent of the effort of the subject. If the subject had to do more than one repetition, as soon as the loaded bar was lowered to the predetermined height, he would lift it again with his

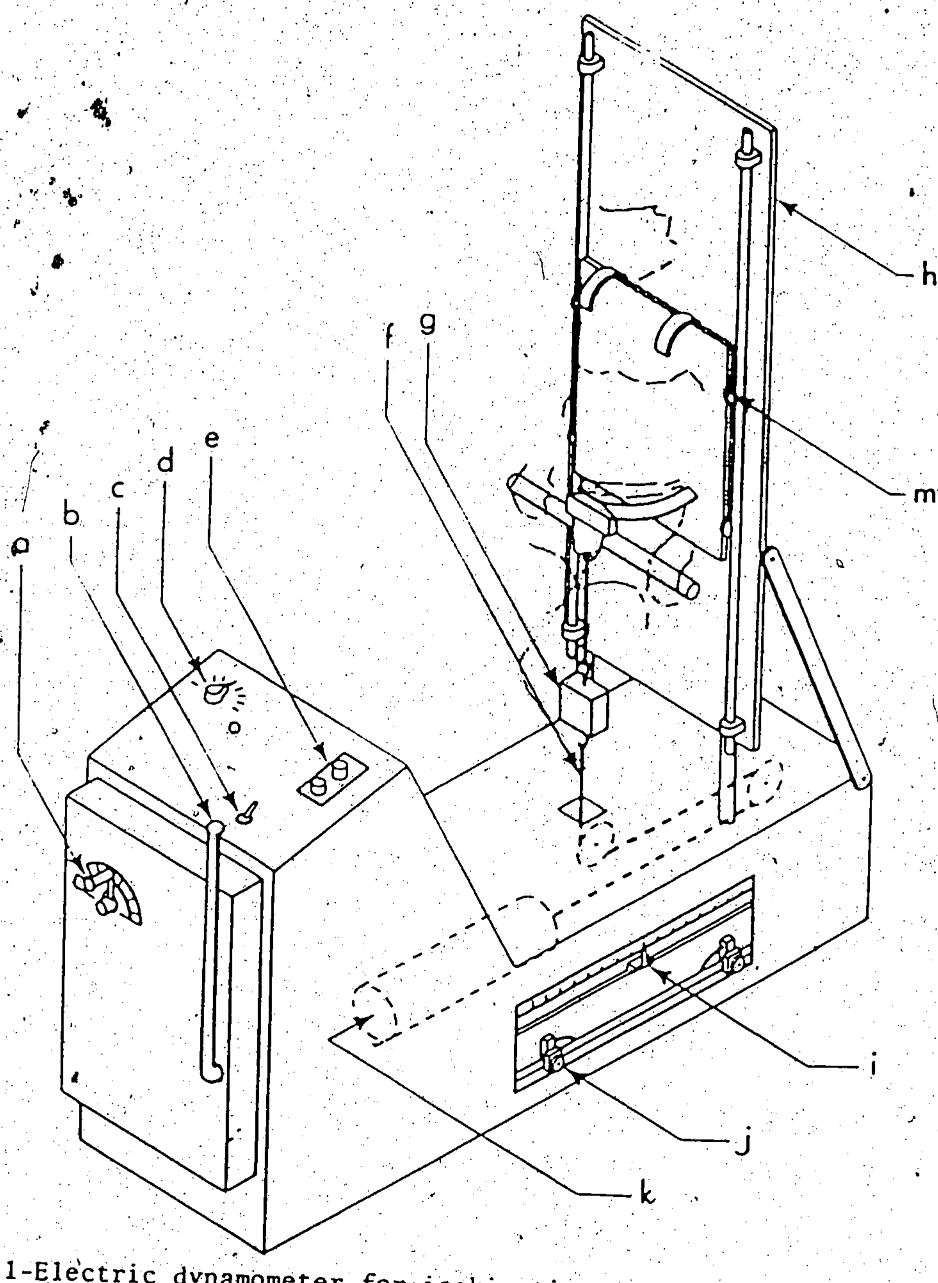

Figure 1-Electric dynamometer for isokinetic testing and training. (a) Flow control valve. (b) Direction control lever. (c) Limit over ride switch. (d) Main flow valve. (e) Start-stop switch. (f) Cable. (g) Load cell. (h) Back support board. (i) Limit switch activator. (j) Limit switch (k) Hydraulic cylinder. (m) Sliding back board.

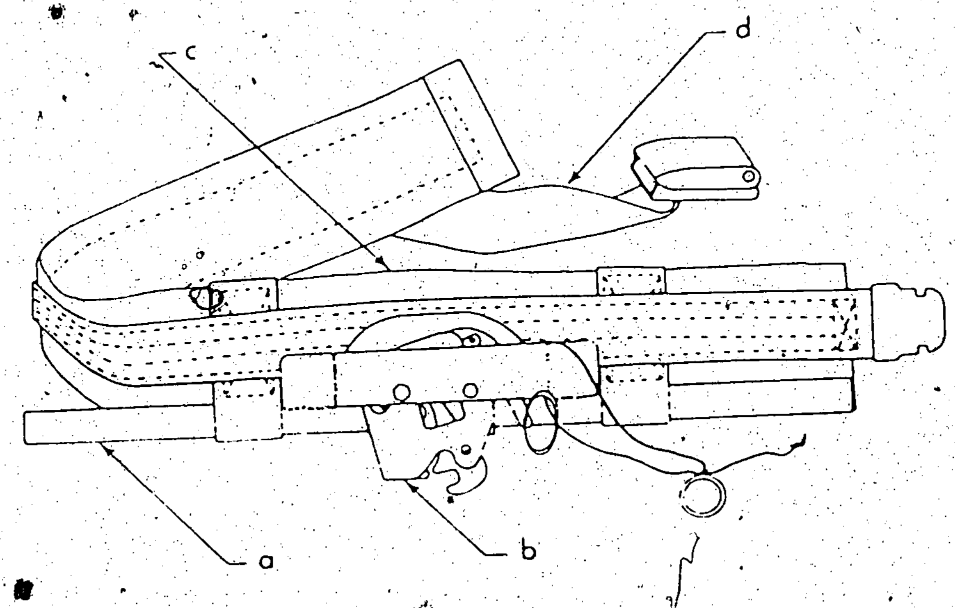

Figure 2-Special belt for the electric dynamometer. (a) Steel bar. (b) Release mechanism. (c) Webbed belt. (d) Automobile seat belt.

shoulders. This cycle continued until the required number of repetitions was completed.

This device consisted of an electric motor with a 1/3 hp connected to a gear box fixed on the wall adjoining the left back upright support (fig. 3). On the top of the upright supports were two 2.5 centimeter diameter steel bars to which 10 mm pitch chains of 2.5 meters long were attached at the ends. These chains were further connected to two 3 mm steel braided cables which were attached to the weight bar at both ends. It was this bar that the weights were loaded. Two suspending counterweights of 10 kilograms each were attached to the rear bar at both ends. The electric motor which had variable speeds, could be adjusted according to the required speed of the training contraction and rest interval.

Depending upon the setting according to the training angle of the subject, on lifting the loaded bar with his shoulders, the micro switch which was fixed on the upper part of the left chain would be disengaged thus activating the electric motor and the gear system. As soon as the subject completed the lift, he relaxed so that the loaded bar could automatically return to the pre-set starting position. If he was unable to complete the lift, the weight would not drop on him. Instead, it would return to the starting position as soon as the subject relaxed underneath the loaded bar. This built-in safety mechanism ensured that nobody could be injured while training or being tested with this apparatus. This special apparatus was mainly designed and built for this study.

Hydrostatic Weighing Equipment

A rectangular tank of water measuring six feet in height, four feet in width and ten feet in length was utilized for hydrostatic weighing of the subjects. An aluminum chair was suspended in the tank from a load cell that had been connected to a Sargent recorder (model SR). For calibration and measurement there was a diver's weight belt weighing 9.5kgs.

Before any measurement was done, the recorder was calibrated and the water temperature was recorded. A six-liter spirometer was used in determining the vital capacity of the subjects. The hydrostatic weighing equipment utilized in this investigation, was the one available in the densitometry laboratory in the Physical Education and Sport Studies

Fig. 3. Isotonic free weights training and testing apparatus

department of the University.

D. DESCRIPTIONS OF TESTING PROTOCOLS

Maximum Isotonic-Concentric Strength Test

The subject stood underneath the bar with his feet placed to correspond with his shoulder width. He flexed his knees to an angle of 90° (fig. 4) (half squat position with the front thigh parallel to the ground) and lifted the loaded bar by extending his knees fully while the back was kept straight. This angle of 90° was determined with a goniometer which was placed on the subject's left knee joint (Ashton and Singh, 1973; Fisher and Ramey, 1977)

If the subject could lift the same load twice, he was asked to stop. The load was then increased by 2.5 or 5 kilograms depending on the capability of the subject being tested. The whole procedure was repeated until his one repetition maximum (1-RM) was established. Rest period between trials was 4 minutes because the substrates (ATP-PC) utilized in this activity can be 100% restored within 3-5 minutes (Fox and Mathew, 1981).

Determination of the subjects' 1-RM especially during the pretest took some time and effort on the part of the subjects and the investigator as 3-4 trials were made before thier true 1-RM could be determined. As for subsequent tests, their previous performance served as a guide. Before the commencement of the testing session, they were asked to warm up by performing 8-10 repetitions with 50-60% of 1-RM.

Maximum Isokinetic-Concentric and Eccentric Strength Test

The electric leg dynamometer (Singh, 1972) was calibrated before the start of every testing session. To calibrate the dynamometer, a 650 kilogram free weight was loaded on a 20 kilogram bar measuring 2.74 meters. The loaded bar was suspended from a load cell (BLH Electronics, type U3G). This loadcell which had been connected to the recording device, had iron hooks at both ends. This enabled it to be hung from the ceiling while from the other end, the loaded bar was suspended. When the Honeywell biomedical system model 1912 - the

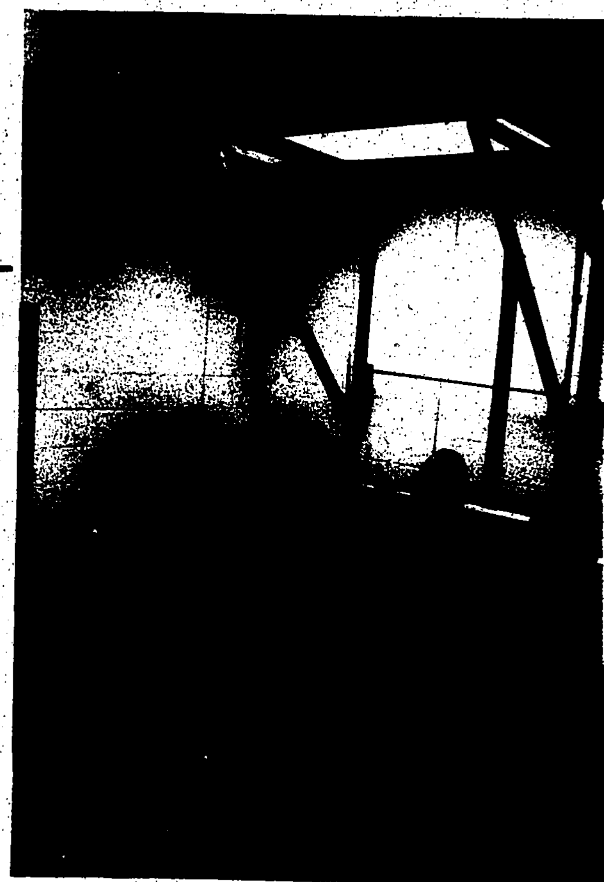

Fig. 4. Initial position for max. dynamic strength (1-RM) test

recording apparatus was turned on, it printed out the amplitude in millivolts corresponding to the weight of the suspended loaded bar. The amplitude which was printed on a Kodak linagraph direct print paper, was then subdivided so that one millimeter represented 8.3 kilograms or 81.34 newtons.

At the start of the test, the subject stood on the dynamometer so that the cable could be adjusted to suit his height and hip angle (fig. 5). The cable was then attached to the load cell. This unit was connected to the webbed belt which had been fastened securely around the subject's waist. He was advised to hold the bar which was attached to the webbed belt with his hands for greater stability.

The speed of the cable was set at 13 centimetrs per second. When the cable was being pulled down, the subject was required to resist the pull from a standing position with a slightly bent knee for safety reason. The torque developed in the lower extremity muscles as they were forced to lengthen (eccentric contraction) was recorded by the recording device. Similarly, for maximum isokinetic-concentric strength test, as the cable was released, the subject pulled up forcefully from the half squat position (90^{0} knee flexion) until full extension was attained (fig. 6).

Maximum Impulsive Force Test

Vertical jump is a test of the body's ability to develop impulsive force in relation to weight. Force platform has been used by several investigators notably Davies (1971) and Ramey (1973) to assess the force development of the legs.

The subject stood on the force platform with his two feet placed 20 centimeters apart. In order to eliminate the added force contributed by the upward swing of the arms and to minimize horizontal and lateral displacement during the test, he was required to place his hands on his hips (Bosco et al., 1986). In this position, the subject flexed his knees close to 90^{0} to assume a static position (fig. 7) and jumped as high as possible (fig. 8). The force exerted by the legs at the time of take-off was detected by the force platform which was then recorded in newtons by the recording device. His best score out of three trials was used for

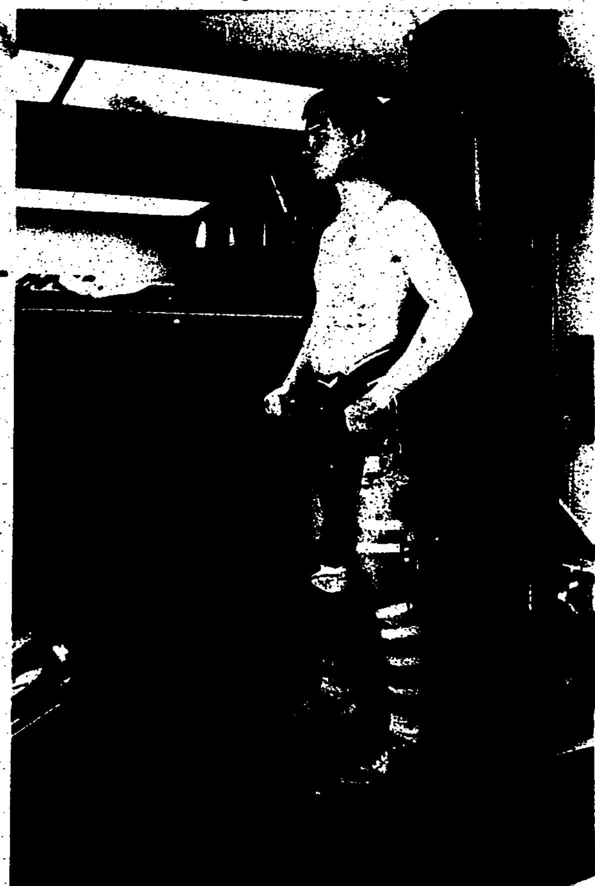

Fig. 5. Starting position for max. isok. ecct. strength test

Fig. 6. Max. isok. ecct. strength test in progress

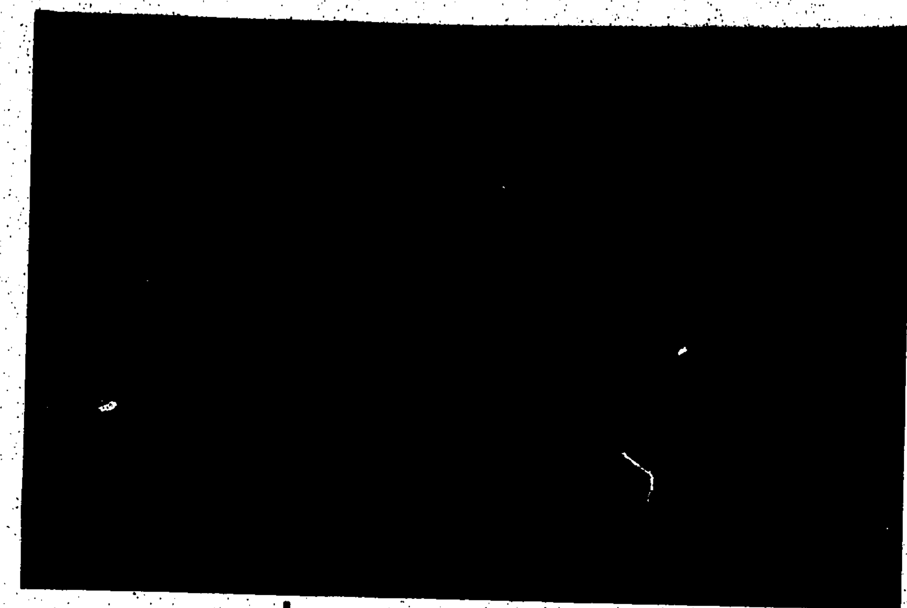

Fig. 7. Starting position for max. impulsive force test.

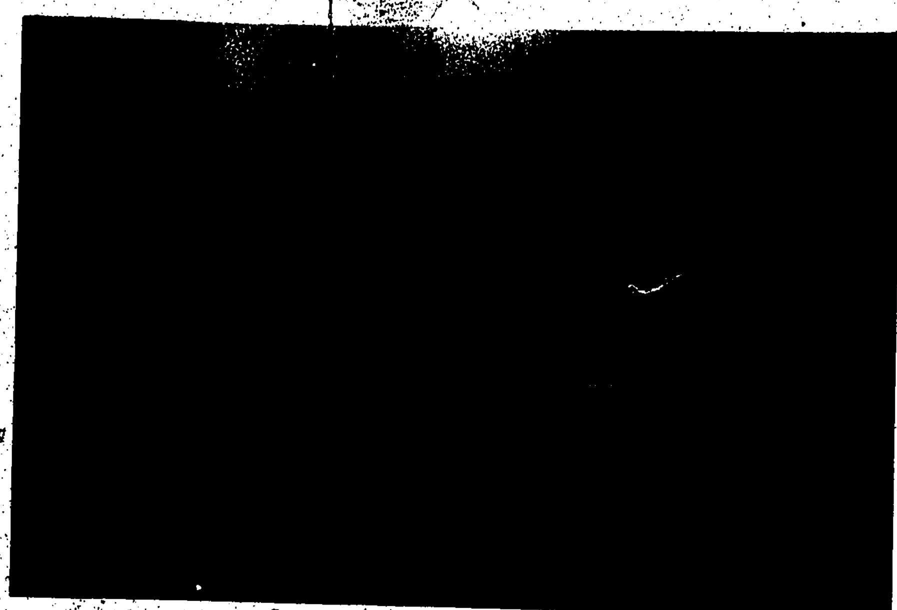

Fig. 8. Max. impulsive force test with the subject jumping off the force platform.

analysis. Appendix C-1 presents a sample of the calculation of the maximum impulsive force scores of the subjects.

Measurement of the Girth of Thigh and Calf Muscles

In order to determine the extent of the hypertrophy of the muscles, a measurement of the girth of the thigh and calf muscles of both legs was carried out with a steel tape (Ross, 1982; Katch and McArdle 1983). By taking measurements at both legs, it might be possible to determine whether differential hypertrophy had occurred in these muscles. Measurement of the thigh was done just below the gluteal fold while the subject was standing (fig. 9) (Behnke and Wilmore 1974, Katch and Drumm, 1986) and that of the calf was taken at the widest circumference . (Fig. 10) (Katch and Drumm, 1986). Appendix C-2 presents the data sheet for this variable.

Skinfold Thicknesses Measurement

Resistance training has been reported to reduce body fat and increase muscle mass (Pipes and Wilmore, 1975; Pipes, 1978; Bishop, 1983; Brazell, 1986). By making an objective evaluation through the measurement of skinfold thicknesses, one would be able to assess with relative accuracy the effect of high resistance training on body fat reduction. Since the girth of a limb segment may be unduly affected by the thickness of skin and subcutaneous fat (Moritani and DeVries, 1979), these changes may not be noticed unless measurement of the skinfold thicknesses is done (Pipes, 1977). It has been reported that half of the body's fat content is located in the tissues beneath the skin (Katch and McArdle, 1983).

In this respect, skinfold thicknesses were assessed in this study with a Harpenden caliper. This instrument was designed to provide a constant tension of 10.00g. mm^{-2} of the caliper face at all thicknesses. The dial was calibrated in 0.2 mm increments. Measurements were read to the nearest 0.1 mm (Ross, 1982). Appendix C-3 presents the data collection sheet for this variable.

Fig. 9. Measurement of thigh girth.

Fig. 10. Measurement of calf girth.

Two measurements were made on the dominant side of the body (except the abdomen) at the following sites; triceps, subscapular, suprailiac, abdomen, front and back thigh and calf. If the two measures differed by 1 mm, a third measure was taken (Pipes and Wilmore, 1975). The purpose of taking measurements at seven sites instead of two - (thigh & calf) which were required for the determination of changes in the girth of the aforementioned muscles, was to dispute or confirm the claim of some investigators (Pipes and Wilmore, 1975; Stone et al., 1983; Hunter, 1985) that strength training has a concomitant effect of reducing body fat.

The values of the various measurements were added as unweighted raw scores (Jackson et al. 1978) which were taken as an indication of the relative degree of fatness among the subjects. Any change in these unweighted scores reflected a change in body fat.

Hydrostatic Weighing Protocol

To conduct hydrostatic weighing of the subjects, the following protocol in a sequential order was utilized according to the method described by Behnke and Wilmore (1974):

1. The temperature of the water was recorded after which the water density was determined from the density chart.
2. The dry weight of the subject was determined with the subject wearing swim trunks.
3. After taking a shower bath, he descended into the tank and seated on the aluminum chair with his head above the water.
4. The diver's weight belt was placed on his thighs.
5. After maximally inflating his lungs, vital capacity was measured with the spirometer as the subject was seated with the water at his neck level. The largest volume of three trials was taken to be the best estimate of vital capacity.
6. The subject then submerged his head to briefly wet his hair. Air bubbles were rubbed off the subject's hair and body after which he resumed his seating position again.
7. With lungs maximally inflated and the nasal passage closed with his thumb and index finger, he leaned forward gently in the chair until completely submerged.

8. After about 5 seconds following the relatively stationary position of the recording pen, the side of the tank was hit three times by the investigator to signal the subject to rise. Throughout the weighing procedure, the subject was entirely supported by the chair and was instructed to remain motionless as much as possible. This procedure was rep[illegible]e times and the mean of the chart recording was used for calculation to determine his body density which was used in estimating his percent body fat according to the equation of Brozek et al. (1963).

Residual volume was determined by calculating 25% of the subjects' vital capacity (Appendix C-4). The rationale for this was based on the findings of Comroe (1974) that residual volume is a function of age.

E. TESTS

Four tests were conducted during the course of this study. They are Pretest (Test 1); midtest 1 (Test 2); midtest 2 (Test 3) and postest (Test 4). The tests were done at the interval of 10 training sessions. During the period of testing which lasted for two days, there was no training for all the exercise groups.

The subjects were advised against special diets or drugs before the tests and during the period of the study. In order to minimize intra-individual variability which is inherent in performance of strength, efforts were made to ensure that the subjects were tested about the same time of the day as the previous tests.

Due to the neuromuscular adaptive response reflecting the specificity effects of the strength training done, changes in muscular strength and force were determined by four tests: maximum isokinetic-concentric; maximum isokinetic-eccentric; 1 RM of half squat and maximum impulsive force of the legs. The last test was independent of any of the training methods.

Pretest, Test 1

Three days after the end of the familiarization training, a pretest was conducted over a period of two days. A delay in testing following the familiarization exercise was necessary in order to allow the subjects to recover fully so that they could perform maximally at the pretest. The tests were conducted in this order:

Day One

1. Measurement of the girth of the thigh and calf muscles.
2. Skinfold thicknesses measurement.
3. Maximum leg impulsive force.
4. Maximum Isokinetic-concentric strength.
5. Maximum Isokinetic-eccentric strength.

Day Two

6. Maximum Dynamic Strength (1RM).
7. Hydrostatic weighing to determine body density.

Test 2

After the tenth training session, a test was conducted to determine the rate and magnitude of the increase in training adaptations. The order of testing was randomized for all the groups so as to hold constant any learning or conditioning effect that may occur or other factors that could have a cumulative effect on the outcome (Chaffin, 1980).

Test 3

At the end of 20 training sessions, another test was conducted. It followed the same pattern as the previous tests.

Posttest, Test 4

At the end of 30 training sessions which was spread over 10 weeks, a posttest was conducted in order to determine the overall effects of the experimental treatments.

F. RELIABILITY

In order to determine the internal consistency or stability of the test measures over time, a coefficient of reliability (test-retest) was done (Borg and Gall 1983) for all the test measurements.

Three days after the pretest, 12 randomly selected subjects (3 from each group) participated in a retest exercise. A correlation coefficient was then computed between their two sets of scores. Efforts were made as much as possible to standardize the test protocols in order to ensure a high reliability coefficients between the tests. In conducting a test of reliablity, it should be noted that many small variations are likely to occur in the testing situations (Ott, 1977; Borg and Gall 1983). Appendix D contains a table of the reliability coefficients.

G. TRAINING AND CONTROL GROUPS

With the aid of a table of random numbers, the subjects were randomly assigned to the exercise and control groups of 15 each. Out of the 60 subjects that originally embarked on this study, 14 failed to attend all the training sessions while four from the control group withdrew at various times during the study due to other commitments or injuries unconnected with this experiment. Henceforth, reference will only be made to the 42 subjects (Group 1, 11; Group 2, 10; Group 3, 10 & Group 4, 11) who successfully fulfilled all the requirements of the study. The physical characteristics of the subjects are listed in Table 1.

Table 1-Physical Characteristics of the Subjects

	Ht. m.	Wt. kgs.	Age yrs.	VC. l
Group1:	1.76±.06	77.6±13.7	22.5±3.4	5.1±.8
Group2:	1.79±.16	76.5±5.0	21.3±3.1	5.3±.5
Group3:	1.75±.09	75.4±13.3	23.8±4.0	5.0±1.1
Group4:	1.75±.06	75.0±8.6	22.4±3.2	5.2±.9

Note: Values are means plus or minus standard deviations.

H. TRAINING PROGRAMS

Isotonic-Concentric and Eccentric Training

The subjects in this group trained with the specially constructed free weight apparatus (Fig. 3). This electrically controlled apparatus was designed to eliminate the eccentric contraction phase which is inherent in this training method.

For concentric contraction, the subjects trained with a workload of 80-90% 1-RM, 2 sets of 6 repetitions with rest interval between sets being 2-3 minutes. To start the training contraction the subject assumed a half squat position (90^{o} knee flexion which was verified by a goniometer (Ashton and Singh 1973), and lifted the loaded bar with his shoulders by extending his knees fully. At full extension of the knees, he relaxed by bending his knees to allow the loaded bar to automatically return to the starting position for him to repeat the lift. This process was repeated until the desired number of repetitions was completed. Each repetition was three seconds. Rest period between repetitions was also three seconds.

As for the eccentric training contraction, with the loaded bar of 120-130% 1RM on his shoulders (fig. 11), the subject lowered the weight by flexing his knees to half squat position (fig. 12) from full extension thereby generating tension in the lower extremity muscles. At the

Fig. 11. Starti[illegible]ition for isotonic-ecct. training.

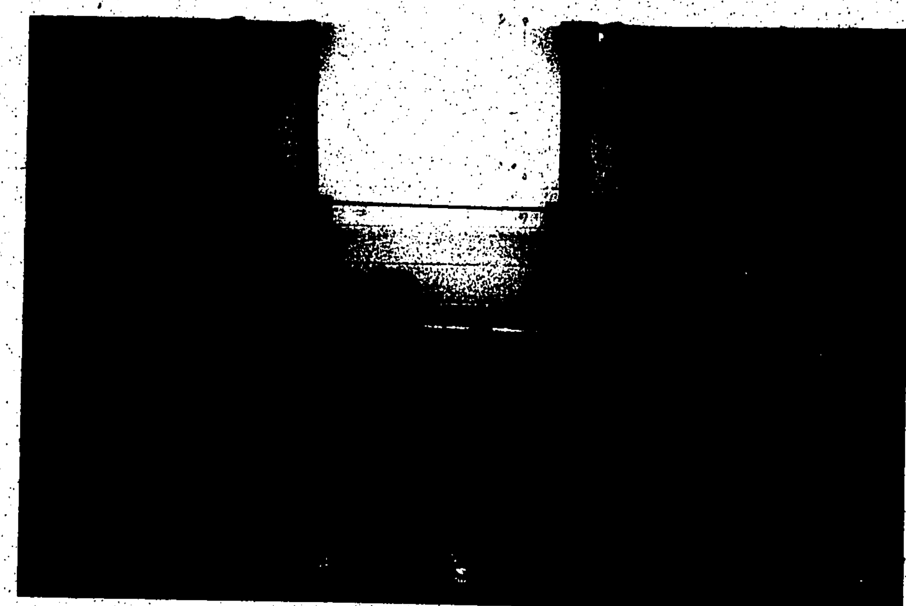

Fig. 12. Final position for ecct. training. Weight about to be returned to the starting position by the trainers.

end of the contraction, the investigator and a helping hand lifted the weight back to the starting position to enable the subject to start again. He did two sets of four repetitions and each repetition was 4.5 seconds in duration. The rest interval between repetitons was 3 seconds while rest period between sets was 2-3 minutes.

Maximal strength (1-RM) of the subjects was determined at the beginning of each week in order to adjust the training workload.

Isokinetic-Concentric and Eccentric Training

The procedure was the same as in the test except that the load cell was disconnected from the cable and the cable attached directly to the webbed belt on the subject's waist. The speed of the moving cable was set at 13 centimeters per second. Komi and Buskirk (1972) who used similar electric dynamometer for their study set their training speed at relatively slow 2.5 centimeters per second while Kehl (1977) trained his subjects on the isokinetic mini gym leaper for parallel squat at a speed of 6 centimeters per second. In another study (Okoro and Singh, 1987 submitted for publication) a slower speed of 4.3 cm/sec., was used. The rationale for choosing a training speed of 13 cm/sec. in this study was to equate it with the contraction speed employed in isotonic training method. It took approximately three seconds to extend from 90^{0} knee flexion to 180^{0} full extension in this study while Singh and Danielson (1975) employed a speed of 6 seconds per repetition. Because the speed of the cable had been mechanically fixed, the subjects could not accelerate the cable more than the set speed, irrespective of the force applied. They did 2 sets of 6 repetitions. Rest period between repetitions was 3 seconds and for sets, 2-3 minutes. For warm-up, they did 4 submaximal repetitions before the commencement of the training regime. Initially, a goniometer was fixed to the knee joint to determine the final squating position.

The procedure for Isokinetic-eccentric training contraction was the same as in the Isokinetic-concentric training except that when the cable was being pulled down at a fixed velocity of 13 centimetrs per second, the subject attempted to stop the moving cable but could not and thus resulting in an eccentric contraction. The exercise started from full extension to

90^{0} knee flexion. The regime for this training mode was 2 sets of 6 repetitions per training session and rest interval between repetitions was 3 seconds and for sets, 2-3 minutes.

Isotonic-Con. and Ecct. with Isokinetic-Con. and Ecct. Training

The subjects in this group did a combination of all the training contractions of the other groups in this study. The training program consisted of the following:-

1. Isotonic-concentric: 1 set of 6 repetitions; workload at 80-90% 1-RM.
2. Isotonic-eccentric: 1 set of 4 repetitions; workload at 120-130% 1-RM.
3. Isokinetic-concentric: 1 set of 6 repetitions; speed at 13 centimeters/second.
4. Isokinetic-eccentric: 1 set of 6 repetitions; speed at 13 centimetrs/second.

The training contraction occured over the range of 90^{0} knee flexion to 180^{0} full extension or vice versa. Rest interval was 2-3 minutes between sets.

The groups were designated as follows:- Group 1, Isotonic-con. and ecct. contractions; Group 2, Isokinetic-con. and ecct. contractions; Group 3, Isotonic-con. and ecct. with isokinetic-con. and ecct. contractions. Group 4, control - did not participate in any of the training programs.

The training contraction time for all the exercise groups was 72 seconds per training session which lasted about 15 minutes. Records were kept for every training session in order to keep track of the improvement made by the subjects. This was especially important for those who trained with free weights. The subjects were under constant supervision by the investigator to ensure that correct training procedures were strictly adhered to.

I. EXPERIMENTAL DESIGN AND STATISTICAL ANALYSIS

The design corresponded to a two-way factorial experiment with repeated measures on the last factor (tests). Factor one was the Groups with four levels while factor two was the tests with four levels namely; pretest-Test 1, Test 2, Test 3, and posttest-Test 4.

1. The Pearson Product Moment corrrelation was done on the pretest and retest scores of 12 randomly selected subjects to determine the reliability (Appendix D) of the test

measures (Borg and Gall, 1983).

2. ANOVA was used to determine the similarity of the groups prior to treatment. This test procedure was to determine categorically whether any of the groups differed on any of the dependent variables that were studied since random assignment does not ensure initial equivalence among the groups. It only ensures absence of systematic bias in groups' composition (Ott, 1977; Borg and Gall, 1983).
3. Greenhouse-Geiser conservative test was done to confirm significant changes in the variables from pre to posttest. Appendix 'E' presents the summary of F-ratios and probability for Unique Analysis of Variance and Greenhouse-Geiser Conservative test.
4. Values were considered to be significant at the .05 level of significance for all the test procedures.
5. Multiple correlation was done to determine the relationship between the variables under study through pre to posttest. (Appendix F).
6. Where there was significant main effects or statistical interaction (Groups X Tests interaction) Scheffe post hoc test was done to determine where the difference was.

CHAPTER IV

RESULTS AND DISCUSSION

The following chapter has been divided into sections the purpose of simplifying the presentation of results and discussions. Section A deals with test-retest reliability coefficients for all the variables tested. The subsequent sections present the results of all the variables followed by tables and figures from pretest to posttest. Concluding the results of each variable for the groups is discussion of the implications specific to that variable.

The last section contains the general discussion. This section deals with all the variables in this study and how they relate to each other as a result of the various training modes.

The probability levels of the main effects and interaction indicated in these tables are those obtained using the degrees of freedom on the basis of unique analysis of variance and not the Greenhouse-Geiser conservative test. The purpose of doing the Greenhouse-Geiser conservative test was to adjust for the violations that might have occurred in the repeated measures ([illegible]ken and Johnson, 1974). However, there was no difference in the results of the statistical analysis done between the Unique Analysis of Variance and the Greenhouse-Geiser conservative test. Appendix E contains the summary of F-ratios for both tests.

The percentages stated are of the group means of percent individual differences and not the percent of the differences of the group means. The former is more accurate and reflective of the magnitude of the actual changes that have occurred in the groups. These were the values that were used in plotting the bar graphs of percent changes of the groups through the periodic tests that were conducted.

A. RELIABILITY COEFFICIENTS

Reliability coefficients calculated for 12 randomly selected subjects on test-retest situations ranged from .96 to .99 for strength variables. For body composition and anthropometric measurements, they were .99 and .98 respectively.

See appendix D for the table of the reliability coefficients.

Discussion

There has not been any study done to determine the reliability of the electric leg dynamometer as a strength measuring device. The investigator therefore, decided to ascertain the consistency of the measuring device to ensure the validity of the results because unreliability of pre-treatment scores impairs the validity of any demonstrated statistically significant differences (Kroll, 1963).

Komi and Buskirk (1972) who employed a similar electric dynamometer for a comparative study of concentric and eccentric contraction at a fixed speed reported a reliability coefficient ranging from .91 to .99 for all the variables tested. The Pearson product-moment coefficients for the calculated scores of 12 randomly selected subjects in this study showed .98 for max. isokinetic-concentric strength and .99 for max. isokinetic-eccentric strength. These coefficients are in agreement with those reported by Komi and Buskirk (1972) and Moffroid et al. (1969) who observed a coefficient of reliability of 0.995 following a retest session using isokinetic device for evaluating muscle strength.

Pipes and Wilmore (1975) who also used isokinetic testing apparatus whose working mechanism was similar to that of Moffroid et al. (1969), reported reliability coefficients that ranged from .92 to .99 for a number of their measures. It should be noted that although the working mechanism of the isokinetic apparatus used in this study which was controlled by an electric motor was different from those used by some of the aformentioned investigators (Moffroid et al., 1969; Pipes and Wilmore, 1975), but the principle of their operation was similar.

The reliability coefficient of dynamic strength (1-RM) as determined by half squat exercise in this study was .96. This was in agreement with the findings of Kroll (1963) who reported a correlation of .91 to .99 in test-retest conditions of wrist flexors using a cable tensiometer and that of Pipes (1978) who observed a r=.96 in a retest condition in which he used constant resistance similar to the one used in this study. In an attempt to give reasons for the observed variability, Kroll (1963) remarked that measurement schedules could affect strength development per se as well as motor learning in a retest situation. This ties in with the remark of Ott (1977) and Borg and Gall (1983) that small variations are likey to occur in a retest situations compared to the first test hence a perfect correlation is not possible in any reliability coefficient determination.

The correlation between test and retest scores of maximum impulsive force of the legs as determined on the force platform, yielded a coefficient of .98. Like the other values obtained, this is equally high thus reflecting the consistency of this device and the testing protocol.

The reliability coefficient for the test-retest scores for skinfold thickness measurement was .97. This agrees with the observation of Shaw (1986) who reported a correlation of .95 to .98 for skinfold measurements conducted by experienced testers. This observation came out of a study to determine the accuracy of two training methods on skinfold assessment.

Behnke and Wilmore (1974) reported a test-retest reliability estimates for selected skinfold and circumference measurements of .94 to .95 for adult men. In this study, the reliability coefficients for thigh girth measurement ranged from .97 to .98 while those of the calves were .99. These high correlations generally reflect the consistency of the testing protocols and instruments.

Body density reliablity coefficient as determined by the hydrostatic weighing method produced a correlation of .97. This shows that the two tests have 94% of their variance in common (Borg and Gall, 1983) thus indicating no significant difference between them. This correlation was in agreement with that of .97 reported by Bouchard (1985). Body density values were used for the estimation of percent body fat and LBM according to the equation of Brozek et al. (1963). These observed correlation coefficients are by all standards, very high which gave credibility to the testing procedures.

B. Maximum Isokinetic-Eccentric Strength

Pretest scores in this variable revealed no significant difference among the groups. Table 2 shows the ANOVA done to compare the similarity of the groups at the pretest. Table 43 presents the descriptive statistics for all the groups in this variable for all the four tests.

Since some subjects dropped out during the course of this study, the sample sizes of the groups became unequal. Unique analysis of variance (Milken and Johnson, 1984) was then utilized to determine the changes that occurred to the groups at different tests periods.

After 7 weeks of training (20 training sessions), Groups 2&3 had a significant increase of 31.7 and 25.4% respectively over their gains at Test 2 (3 1/2 weeks of training) (fig. 13). The increase of 27.8% achieved by Group 1 at Test 3 was also significant while the control group (Group 4) had a 3.3% insignificant [illegible] same test period. At posttest however, only Groups 2&3 demonstrated signifi[illegible] the control group whose overall increase of 4.4% was not significant. T[illegible]ws the Group means and the differences for all the groups from pre to posttest.

All the exercise groups exhibited significant gains but Scheffe post hoc analysis revealed that there were no significant differences among them. Table 4 shows the summary of F-ratios for maximum isokinetic-eccentric strength posttest scores.

Table 2-Summary of F-ratios for Pretest Scores of Max. Isokinetic-Eccentric Strength

Source	DF	SS	MS	F-RATIO	F-PROB.
B. Groups	3	1081916.5	360638.8	.565	.64 NS
W. Groups	38	24264762.7	638546.4		
Total	41	25346679.1			

NS. Denotes not significant.

Table 3-Group Means and Differences for Max. Isokinetic-Eccentric Strength

	1 Isotonic	2 Isokinetic	3 Combined	4 Control
Initial scores	2765.5 N	2731.1 N	2917.5 N	3133.3 N
Final scores	4114.1	4988.8	4931.3	3218.8
Difference	1348.6	2257.7	2013.8	85.5
% Change	59.7*	91.6*	75.1*	4.4 NS
Std. Error	14.3	15.9	12.9	3.9

* Denotes significance at $P < .05$ level.

NS. Denotes not significant at $P < .05$ level.

N = Newtons.

Table 4-Summary of F-ratios for Pre Vs Posttest Max. Isokinetic-Eccentric Strength Scores

Source	SS	MS	DF	F-ratio
B. Groups	15678400	5226130	3	2.92*
Error (a)	68082200	1791630	38	
W. Groups	53369400	17789800	3	121.86**
Groups X Tests	17906600	1989620	9	13.68**
Error (b)	16642600	145988.2	114	

* Denotes significance at $P < .05$ level.

** Denotes significance at $P < .01$ level.

Table 5-Results of the Post Hoc Analysis for Max. Isok.-Ecct. Strength

Group	T1	T2	T3	T4
Isotonic	2765.5	2948.0	3770.0[a]	4114.2[a]
Isokinetic	2731.1	3296.7	4344.9[a,b]	4988.8[a,1]
Combined	2917.5	3372.4	4230.7[a,b]	4931.3[a,1]
Control	3133.4	3054.0	3154.3	3218.8

a = significantly different from T1.

b = significantly different form T2.

1 = significantly different from Group 4.

Discussion

It was no surprise that Group 2 exhibited the highest gain in maximum isokinetic eccentric strength, although not significant. The subjects in this group trained with the contraction and dynamometer that was used during the tests. The significant improvement of this group (91.6%) and Group 3 (75.1) which trained partly with the isokinetic dynamometer shows that adaptation of the neuromuscular system which controls motor functions is highly specific to the demands made on it (Sale and McDougall, 1981; Gonyea and Sale, 1982).

Group 1 which trained with free weights also exhibited significant gains of 59.7%. The significant improvement of Group 1 in this variable could be related to the nature of its training vis-a-vis the test criterion. The 120-130% of 1RM utilized by this group for eccentric contraction could have not only conditioned the neuromuscular system but also induced some structural changes in the muscle that could be beneficial for maximum isokinetic-eccentric contraction. Heavy strength training has been shown to reduce neural inhibition on the ability of the muscle to generate maximum tension (Astrand and Rodahl, 1977; Brooks and Fahey, 1983). This may have been achieved by the exercise groups through the different training methods.

This result is supported by the findings of Hagan and Sale (1986) who reported that training with free weights or isokinetic device produced similar results since the subjects who trained with free weights or isokinetically improved significantly when tested with isokinetic device. Very few studies have been done which employed the combination of isokinetic-concentric and eccentric contractions for training. Therefore, comparison with the findings of other studies is limited.

The results of this variable indicated that although the exercise groups exhibited relative improvements from Test 3 to Test 4 (posttest), these changes were not significant. This phenomenon apparently has to do with the training stimulus and increase in strength. Muller (1962) has stated that the threshold of training stimulus rises with increasing strength to a point where the stimulus becomes ineffective. This view was supported by Hakkinen and Komi (1982) who added that after strength gains have plateaued, additional gains would only be possible if the training resistance of the movement pattern of the weight lifting exercise were altered. In this study however, the movement pattern during training was the same but the resistance especially in Group 1 was increased every week.

The data collected in this study showed that at the end training, all the exercise groups were not significantly different from each other while Groups 2&3 were significantly different from the control group. The outcome of this study indicated that 'maximum' isokinetic strength of inexperienced males of the age group involved in this investigation could be improved with training on the electric leg dynamometer as well as lifting free weights.

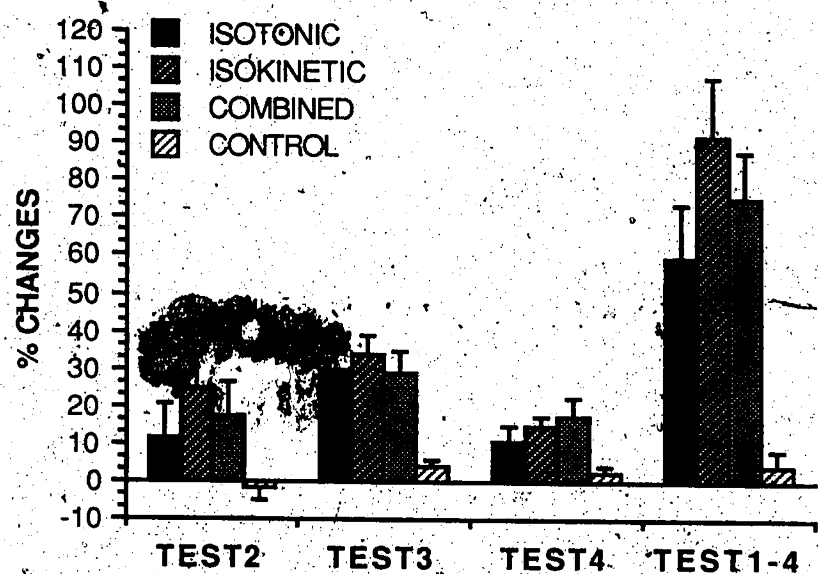

FIGURE 13. Maximum isokinetic-eccentric strength: percent changes of group means (±SEM).

C. MAXIMUM ISOKINETIC-CONCENTRIC STRENGTH

Analysis of variance of pretest scores for maximum isokinetic-concentric strength (Table 6) showed that there was no significant difference among the groups. Table 44 contained the descriptive statistics of maximum isokinetic-concentric strength for all the groups from pre to posttest.

Posttest scores indicate that all the exercise groups significantly increased their strength over that of the control group whose 9.4% increase above the pretraining level was statistically insignificant. After seven weeks of training, all the exercise groups had increases which were significantly greater than their pretest scsores. Like in isokinetic-eccentric strength, Group 2 demonstrated the highest gain of 163.0% followed by Group 3 with 125.0% over the pretraining level (Table 7). The Groups X Tests interaction was significant (Table 8) but further analysis with Scheffe procedure revealed no significant differences among the exercise groups in this variable except that all the gains achieved by the exercise groups were significantly greater than that of the control group (Table 9).

Table 6-Summary of F-ratios for Pretest Scores of Max. Isokinetic-Concentric Strength

Source	DF	SS	MS	F-RATIO	F-PROB.
B. Groups	3	1607505.7	535835.2	1.95	.14 NS
W. Groups	38	10445459.2	274880.5		
Total	41	12052964.98			

NS. Denotes not significant.

Table 7-Group Means and Differences for Max. Isokinetic-Concentric Strength.

	1 Isotonic	2 Isokinetic	3 Combined	4 Control
Initial scores	1727.0 N	1688.0 N	2191.0 N	1910.0 N
Final scores	3381.0	4309.0	4416.0	2089.0
Difference	1654.0	2621.0	2225.0	179.0
% Change	[illegible]	163.0*	125.0*	9.4 NS
Std. Error	[illegible]	16.1	28.1	4.3

* Denotes significance at P< .05 level.

NS. Denotes not significant at P< .05 level.

N = Newtons.

Table 8-Summary of F-ratios for Pre Vs Posttest Isokinetic-Concentric Strength Scores

Source	SS	MS	DF	F-ratio
B. Groups	31476600	10492200	3	10.99*
Error (a)	36272400	954537.38	38	
W. Groups	68809900	22936600	3	214.57**
Groups X Tests	20488200	2276470	9	21.30**
Error (b)	12185900	106893.94	114	

* Denotes significance at P< .05 level.

** Denotes significance at P< .01 level.

Table 9-Results of the Post Hoc Analysis for Max. Isok.-Con. Strength

Group	T1	T2	T3	T4
Isotonic	1726.5	1772.4	2521.2[a,b]	3381.1[a,b,c,1]
Isokinetic	1687.6	2321.6	3079.8[a,b]	4308.9[a,b,c,1]
Combined	2191.3	2573.5	3096.9[a]	4416.2[a,b,c,1]
Control	1910.0	1840.6	1996.5	2089.1

a = significantly different from T1.

b = significantly different form T2.

c = significantly different from T3.

1 = significantly different from Group 4.

Discussion

Rasch and Morehouse (1957) have postulated that scores in strength tests resulting from exercise programs reflected largely the acquisition of skill involved in the exercise. This probably explains the huge increase in concentric strength demonstrated by Group 2 which trained with the dynamometer used for the test. Group 3 which had the second highest gain also partly trained with the procedure used for the test. There are however, other factors in-conjunction with induced tension that are critical in strength development. Delorme (1945) and Hakkinen (1985) suggested development of complex neuromotor patterns being a prerequisite, if not a large factor while Moritani and DeVries (1979) and Sale (1986) identified one of these factors as neural adaptation. The tremendous improvement exhibited by Groups 2&3 is an evidence that gains in voluntary strength with training are largely due to the specific type of contractions espoused in training.

Group 1 which trained with free weights had a significant 105.9% increase over its pretraining value. This supports the view that any strength training, as long as the critical threshold for improvement is surpassed, would result in the desired effects. The high score achieved by Group 1 in this variable could be due to the test position which was similar to the range of movement (90^{o}-180^{o} knee extension) that the subjects in this group were exposed to in training.

One of the adaptations that occur as a result of strength training is the increase in the firing threshold of the golgi tendon organ, a receptor found mainly adjacent to the junction of tendons and muscles (Bosco, 1985). Eccentric training in this study most likely put a stretch load on the muscle which probably was optimal for altering the homeostasis of golgi tendon organ. With the increase in the firing threshold of this organ, more tension could be generated by the muscle without its inhibitory influence. It has been postulated by Muller and Rohmert (1963) that overstretching of muscle elastic components (tendons, connective tissue among fibers and elastic elements in the sarcolemma) along with the accompanying delay in the recoil would serve as a trophic stimulus to increase the force of muscle contraction. It seems reasonable therefore, to state that the eccentric training done was more accountable for the gains in maximum isokinetic-concentric strength achieved by the exercise groups.

The significant gains achieved by the exercise groups compared to that of the control group at the end of the study did not occur by mere chance. The significant Group X Test interaction (Table 8) demonstrated that the training regimes of the exercise groups were effective for increasing isokinetic-concentric strength. If not for the experimental treatment of the exercise groups, they would have behaved as the control group at the end of the study, since they were initially the same in this variable.

At T3 Groups 1&2 had gains which were significantly greater than their scores at T2 (Table 9). These improvements were however, not significantly different from the change demonstrated by Group 3 which was not significantly greater than its score at T2. The effectiveness of the different training methods in this variable became apparent at T3 (after seven weeks of training).

This result did not support the findings of Pipes and Wilmore (1975) who reported the superiority of isokinetic training procedure over the more traditional isotonic training method for affecting changes in concentric strength. It is also at variance with the outcome of the study conducted by Smith and Melton (1981) who proclaimed the superiority of isokinetic high speed training over the isotonic training procedures. This result however, has the support of Wathen et al. (1982) who reported that training with free weights (parallel squats) is equally as effective as isokinetic squatting exercise in bringing about improvement in isokinetic strength. Delateur et al. (1972) had earlier confirmed this while Hágan and Sale's (1986) findings are in agreement with the results of this study that isokinetic and free weights training produce similar effects.

Caution must however, be exercised in making comparison between the outcome of this study and others. While the lever arm of the apparatus used by Pipes and Wilmore (1975) and Smith and Melton (1982) was dependent on the efforts of the subjects, the dynamometer used in this study was independent of the subjects' efforts as it oper[illegible] on electricity. The apparatus used during training affected the rate and amount of [illegible] generated by the muscle which determined its adaptive response.

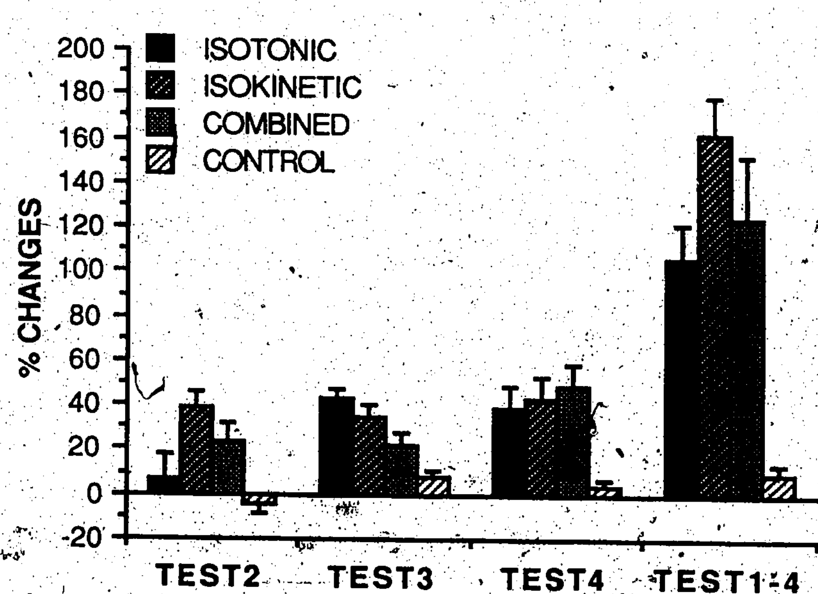

FIGURE 14. Maximum isokinetic-concentric strength: percent changes of group means (±SEM).

D. MAXIMUM DYNAMIC STRENGTH: 1-RM

At the beginning of the experimental study, all the groups were not significantly different from each other in this variable (Table 10). Table 45 presents the descriptive statistics of maximum dynamic strength (1-RM) for all the groups in all the tests conducted.

At the end of the study, postest scores revealed that Group 3 with an increase of 53 kilograms (43.3%) was the most improved out of all the exercise groups. This was followed by Group 1 which had a gain of 46 kilograms (37.3%). Group 2 which trained with a different type of contraction, had an increase of 28 kilograms (22.9%) (Fig. 14). All these increases were statistically significant compared to their pretest scores (Table 11). The control group's increase of 10 kgs (8.6%) was insignificant. Groups X Test interaction was significant (Table 12). On further analysis with Scheffe post hoc procedure, Groups 1&3 were significantly different from the control group (Table 13). Trend analysis showed that the three exercise groups improved significantly from T1 to T2 (after 3 1/2 weeks of training). They failed to show significant increase in T2 to T3 and T3 to T4. But a longitudinal look across the periodic tests showed that the exercise groups' gains in dynamic strength were significant ($P < .01$) from T1 to T3 (after 7 weeks) and T1 to T4. Only Groups 1&3 showed significant increase from T2 to T4 (fig. 15).

Table 10-Summary of F-ratios for Pretest Scores of Max. Dynamic Strength

Source	D.F.	SS	MS	F-RATIO	F-PROB.
B. Groups	3	58.9	19.6	.049	.985 NS
W. Groups	38	15233.2	400.9		
Total	41	15292.1			

NS: Denotes not significant.

Table 11-Group Means and Differences for Max. Dynamic strength (1-RM)

	1 Isotonic	2 Isokinetic	3 Combined	4 Control
Initial scores	124 kgs	125 kgs	127 kgs	123 kgs
Final scores	170	153	179	133
Difference	46	28	53	10.0
% Change	37.3*	22.9*	43.3*	8.6 NS
Std. Error	3.1	1.9	5.3	1.8

* Denotes significance at P< .05 level.

NS. Denotes not significant at P< .05 level.

kgs = Kilograms

Table 12-Summary of F-ratios for Pre Vs Posttest Max. Dynamic Strength (1RM) Scores

Source	SS	MS	DF	F-ratio
B. Groups	19589.73	6529.91	3	3.83*
Error (a)	64707.30	1702.82	38	
W. Groups	28448.81	9482.93	3	234.63**
Groups X Tests	6627.4	736.38	9	18.61**
Error (b)	4511.26	39.57	114	

* Denotes significance at P< .05 level.

** Denotes significance at P< .01 level.

Table 13-Results of Post Hoc Analysis for Max. Dynamic Strength (1-RM)

Group	T1	T2	T3	T4
Isotonic	124.4	149.0[a]	160.4[a]	169.8[a,b,1]
Isokinetic	124.5	144.0[a]	154.0[a]	152.8[a]
Combined	126.5	157.0[a]	169.5[a]	170.5[a,b,1]
Control	123.2	128.6	130.9	133.4

a = significantly different from T1.

b = significantly different form T2.

1 = significantly different from Group 1.

Discussion

Pipes and Wilmore (1975) have stated that:

> The concept of specificity of training suggests that the improvement should be greatest when tested with a device or procedure that approximates the training procedure.

Following this principle, Groups 1&3 which had the experience of free weights training exhibited the highest gains of 37.3% and 43.3 % respectively. Group 2 trained with the isokinetic procedure had an increase of 22.9% (Table 11). The differential increase observed, could be attributable to the different training methods employed since all the groups were not initially different from each other.

It is of interest to note that significant increase was demonstrated by all the exercise groups after 3 1/2 weeks of training. This increase could not be due to hypertrophic factors because there had not been any noticeable change in the girth of the leg extensors of the subjects. It could be attributed to neurological adaptation. This is in line with the observations of Moritani and DeVries (1979), Sale (1985) and Hakkinen (1985) that increase in strength that occurs in initial stages without increase in muscle size is due to increased motor unit activation mediated by the central nervous system.

It has been postulated that gains in strength are greater if the muscle is exposed to combined training regimes compared to training with one method alone (Pletnev, 1976; Hakkinen and Komi, 1981; Telle and Gorman, 1985). Group 3's highest increase in dynamic strength, is a further demonstration of the efficacy of combined training contractions and is in total agreement with the findings of Hakkinen and Komi (1981) and Telle and Gorman (1985).

What might be responsible for the unique effectiveness of this combined training methods lies in the nature of the resistance provided by the training apparatus. Free weights provide negative resistance (Telle and Gorman, 1985) which keeps tension on the muscle because during the first stage of the maneuver, a greater force than the weight must be gen[illegible] before the weight's inertia can be overcome. With the isokinetic device, maximal [illegible]ed in the muscle throughout the muscle's length. Since the number of motor [illegible]hin a muscle is proportional to the effort exerted (Edgerton, 1985), the [illegible] by a muscle group therefore, is simply the summation of the tension [illegible] motor units that are activated. It is possible that combined training [illegible] greater tension in the muscle than any single training method.

[illegible] result of this study is similar to the one reported earlier (Okoro and Singh, 1987) in which the isokinetic-eccentric and concentric training group significantly increased its maximum dynamic strength by 44% while the control group had 8% increase which was also significant. In this study, the 8.3% gain of the control group was not significant. This relatively small improvement shown by the control group in this variable could be due to the "learning effect" which is possible in the maximum tests employed. The subjects had 3 to 5 trials in every test condition before their 1RM could be determined.

The findings of this study do not confirm the results of Pipes and Wilmore (1975) and Melton and Smith (1982) that isokinetic method is superior to the more conventional free weights training. This could be due to the differences in the experimental designs of the studies. Pipes and Wilmore used an isokinetic device whose operation depended upon the efforts of the subjects for training and testing while in this study, the operation of the isokinetic dynamometer utilized was independent of the efforts of the subjects. These results however, confirm the work of Delateur.et al. (1972) and Shephard (1975) that free weights and isokinetc training modes are equally effective in developing dynamic strength. The results of this study are also in agreement with those reported by Wathen and Shuttes (1982) that free weights squatting exercise is preferable to a program of isokinetic squatting exercise in bringing about improvement in dynamic strength of college males.

Trend analysis indicated that within the limits of the sample used for this study, all the three exercise groups exhibited significant changes with Group 3 showing the highest gain. But at T2 to T4, Groups 1&3 were significantly different from Group 2. This is not a surprising result considering the specificity factor involved in the training contraction vis-a-vis the strength test.

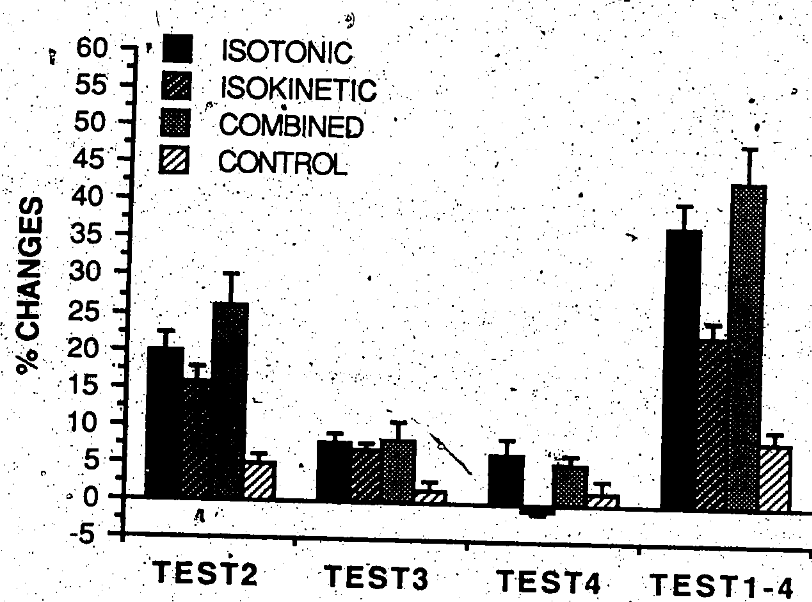

FIGURE 15. Maximum dynamic strength (1-RM): percent changes of group means (±SEM).

E. MAXIMUM IMPULSIVE FORCE

At the beginning of the study, all the groups were similar in this variable (Table 14). Table 46 presents the descriptive statistics of all the tests done in this variable for all the groups.

At the end of the study, Group 2 had the highest gain of 12.7% followed by Group 3 with 11.6% increase while Group 1 had a modest but not significant increase of 2.9%. The control group increased by 1.6% (Table 15). Although Group 2 had the highest overall gain, it had 2.2% insignificant gain after seven weeks of training compared to Group 3 which improved significantly by 5.9% at the same period.

Statistical analysis of the posttest scores of the groups did not show significant differences in this variable (Table 16). Further examination of the scores, since the Groups X Tests interaction was significant, revealed that the gains achieved by Groups 2&3 at T4 were significantly higher than their pretest scores (Table 17). It was only Group 3 that exhibited significant improvement at T3 (after seven weeks of training).

Table 14-Summary of F-ratios for Pretest Scores of Max. Impulsive Force

Source	D.F.	SS	MS	F-RATIO	F-PROB.
B. Groups	3	117102.3	39034.1	.663	.58 NS
W. Groups	38	2236876.67	58865.17		
Total	41	2353978.98			

NS. Denotes not significant.

Table 15-Group Means and Differences for Max. Impulsive Force

	1 Isotonic	2 Isokinetic	3 Combined	4 Control
Initial scores	1721.1 N	1743.5 N	1797.1 N	1650.2 N
Final scores	1763.1	1959.4	1991.2	1672.0
Difference	42.0	215.9	194.1	21.8
% Change	2.9 NS	12.7*	11.6*	1.6 NS
Std. Error	2.6	2.0	3.7	2.0

* Denotes significance at P< .05 level.

NS. Denotes not significant at P< .05 level.

N = Newtons.

Table 16-Summary of F-ratios for Pre Vs Posttest Max. Impulsive Force Scores

Source	SS	MS	DF	F-ratio
B. Groups	1555680	518562.77	3	2.19 NS
Error (a)	8985230	236453.5	38	
W. Groups	374331.53	124777.1	3	19.11**
Groups X Tests	228209.1	25356.6	9	3.88**
Error (b)	744493.4	25356.56	114	

** Denotes significance at P< .01 level.

NS. Denotes not significant at P< .05 level.

Table 17-Results of the Post Hoc Analysis for Max. Impulsive Force

Group	T1	T2	T3	T4
Isotonic	1721.2	1742.3	1790.2	1763.2
Isokinetic	1743.[illegible]	1810.5	1851.6	1959.4[a]
Combined	1797.1	1905.5	2019.2[a]	1991.2[a]
Control	1650.2	1674.0	1683.9	1672.0

a = significantly different from T1.

Discussion

Vertical jump is a test of the body's ability to develop impulsive force in relation to body weight (Bangerter, 1965) For increase in impulsive force of the legs to occur, there has to be a change in the histochemical and biochemical composition of the muscle fibers and the ability of the individual fibers to contract rapidly due to increased firing and stimulation by motor neurons (Goldberg et al., 1975). In this study, the influence of skill inherent in any of the training procedures was most likely eliminated with the introduction of this test criterion. Maximum impulsive force as used in this study is similar to a vertical jump without the contributive effects of the upward swing of the arms (Bosco et al., 1986). Any jumping activity has an element of power. It therefore, follows that any training regime that has components of power in its design and execution will improve the functional capacity of the muscles involved in jumping. In this study however, the training regimes were designed to improve strength and not power per se. As evidenced by the data collected, some adaptations have occurred in the trained muscles which are suitable for motor performance requiring power. This has been confirmed by the significant improvement of Groups 2&3 over their pretest values.

What may have accounted for the translation of this acquired strength to performance of a task that required power resides in the nature of their training programs. The development of explosive force associated with training with heavy resistance may have conditioned the neuromuscular system to express itself in a very explosive action like in vertical jumping. It is surprising that the subjects in Group 1 did not show any significant increase over their pretest scores (fig. 16) despite their heavy training schedule. Their failure to demonstrate any significant increase may be due to the postulate of Goldberg et al. (1975) that with hypertrophy of the muscle, contractility and speed of contraction decrease as a result of increased collagen and water content of the enlarged fibers. Bosco (1985) theorized that the gain achieved by the fast twitch fibers as a result of heavy resistance training is neutralized by the slowly contracting hypertrophied slow twitch fibers; hence after long heavy strength conditioning (greater than 8 weeks), the time of shortening of the muscle is increased. This observation could only be made in respect of Group 1 since the other exercise groups improved significantly in this variable. Since jumping is a function of the number of fast motor units recruited and the rapidity with which they are recruited, isokinetic training could be more effective in influencing these adaptations. McDonagh and Davies (1984) have confirmed in their review that the effect of strength training on the speed of muscle contraction depends on the detailed nature of the training regime. It could be that the resistance offered by the isokinetic device has a greater effect on the knee and hip extensors which play a major role in vertical jump (Bangerter, 1964) compared to that offered by free weights.

No study has been reported that investigated the effects of various training modes on maximum impulsive force. However, in equating vertical jump with maximum impulsive force of the legs, the outcome of this study supports the work of Pipes and Wilmore (1975) and Smith and Melton (1981) that isokinetic training method is superior to isotonic training procedure in increasing performance in maximum impulsive force (vertical jump). It however, failed to confirm the report of Wathen and Schuttes (1982) that free weight training is preferable to isokinetic training to improve vertical jumping ability. Okoro (1979) has earlier reported no significant difference between free weights and isokinetic training methods for the improvement of vertical jump. This has been substantiated by this study.

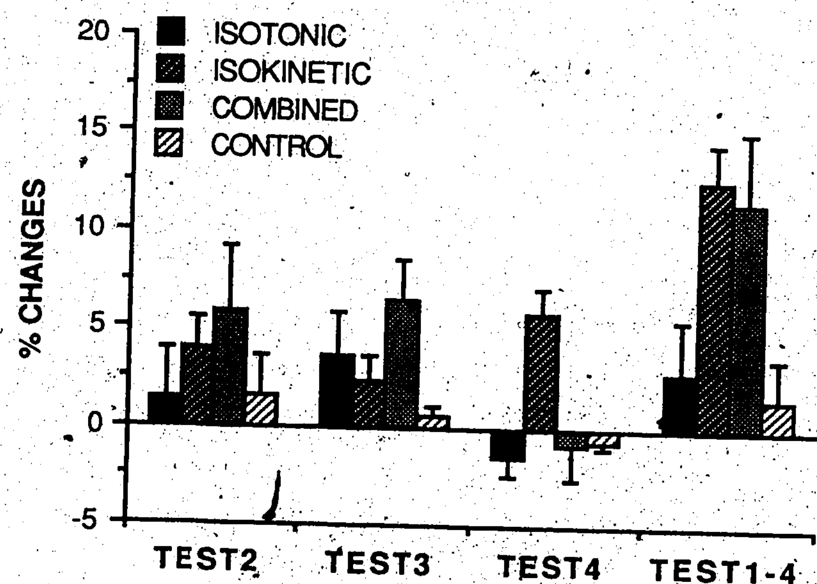

FIGURE 16. Maximum impulsive force: percent changes of group means (±SEM).

F. LEAN BODY MASS

Analysis of pretest scores (Table 18) indicated that all the groups were not significantly different from each other in this variable. Table 47 presents the descriptive statistics of the scores in this variable for all the groups from pretest to posttest.

At the end of the study, all the groups demonstrated non signficant increase in lean body mass with Group 2 having the highest gain of 3.8% (2.5kgs) followed by Group 3, 2.5% (1.5kgs); Group 1, 2.0% (1.3kgs) and the control group with .8% (.5kg) (Table 19). Between groups comparison did not show any significant difference in the gains achieved. The Groups X Tests interaction was also not significant (Table 20). Since the main effects and Group X Tests interaction were not significant, post hoc analysis was not conducted (Thomas and Nelson, 1985).

Table 18-Summary of F-ratios for Pretest Scores of Lean Body Mass

Source	D.F.	SS	MS	F-RATIO	F-PROB.
B. Groups	3	442.2	147.4	1.78	.16 NS
W. Groups	38	3151.6	82.9		
Total	41	3593.9			

NS. Denotes not significant.

Table 19-Group Means and Differences for Lean Body Mass

	1 Isotonic	2 Isokinetic	3 Combined	4 Control
Initial scores	65.5 kgs	67.3 kgs	65.2 kgs	58.8 kgs
Final scores	66.8	69.8	66.7	59.3
Difference	1.3	2.5	1.5	0.5
% Change	3.4 NS	3.8 NS	2.5 NS	.8 NS
Std. Error	1.4	1.2	.6	1.0

NS. Denotes not significant at P< .05 level.

kgs = Kilograms.

Table 20-Summary of F-ratios for Pre Vs Posttest Lean Body Mass Scores

Source	SS	MS	DF	F-ratio
B. Groups	2349.35	783.12	3	2.29 NS
Error (a)	13002.21	342.16	38	
W. Groups	52.74	17.58	3	6.46**
Groups X Tests	22.68	2.52	9	0.93 NS
Error (b)	310.25	2.72	114.0	

** Denotes significance at P< .01.

NS: Denotes not Significant at P< . 05 level.

G. Discussion

Increase in lean body mass is a function of increased protein synthesis and decreased degradation of protein (Goldgerg et al., 1975; Goldspink, 1985; MacDougall, 1986). This could be achieved through a well designed training program in which tension is continuously generated in the muscle. The adaptations that result are more actin and myosin filaments, more capillaries, ATP-PC and connective tissues (Westcott, 1985; MacDougall, 1985). It might also be possible as a result of heavy resistance training over a long period of time for the number of muscle fibers to increase (hyperplasia) through longitudinal splitting of the fibers or development of satellite cells (Gonyea et al. 1986; Larsson and Tesch, 1986). Research evidence in this direction however, is still controversial.

Although the mechanism for this adaptive response is not well understood, there is consensus in the literature that sequel to heavy resistance training, there is increased concentration of calcium (Golberg et al., 1984; Howard, 1985) to stimulate the synthesis of RNA and protein which are essential in the hypertrophic process following the uptake of amino acid by the exercised muscle.

In this experimental study, although all the exercise groups significantly increased in quadriceps strength variables (Tables 3,7,10) increase in lean body mass (LBM) for all the groups was not significant (Fig. 17). Higher-volume training (8-12 reps/set) has been shown to produce positive changes in body composition (Stone et al., 1983). The training regimes employed in this study could not be considered to be of very high volume although the intensity was high because of the time frame of the training contraction which altogether did not exceed 72 seconds. Most studies that reported increased LBM and reduction of body fat as a result of heavy resistance training, employed training regimes that involved the whole body and exercised for 45 to 60 minutes per session (Goldberg et al., 1984; Hunter, 1985). In this study, the training was limited only to the lower extremity of the body hence significant increase was observed in the girth of the leg extensors (Tables 33&34) of the subjects in the exercise groups. Since hydrostatic weighing method measures total body density for the estimation of percent body fat, it could not uncover in isolation the increase in the size of the muscles trained. The increase in LBM above the pretraining level exhibited by exercise groups more than the control group is a demonstraion of the effect (though not pronounced) of strength training on body composition. In the absence of this training, the increase observed in the exercise groups would have been the same as the control's.

From the data collected, the trends showed that the isokinetic training procedure provided the greatest stimulus to elicit changes in body composition. This was evidenced by the highest nonsignificant gain of 3.8% experienced by Group 2 followed by Group 3 with 2.5%. It will be recalled that Group 3 also had as part of the combined training regimen, isokinetic training. Surprisingly, free weights training utilized by Group 1 was least effective as it trailed with 2.0% increase.

Although strength is proportional to the cross-sectional area of the muscle (Hettinger, 1961; Ikai and Fukunaga, 1963), increase in strength is not due to increase in muscle size alone. Neural adaptation has been implicated as playing a significant role (Moritani and DeVries, 1979; Sale, 1986) because the magnitude of the increase in voluntary strength of beginners is considerably higher than the increase in muscle size (Moratini and DeVries, 1979; Sale, 1986). This seemed to be what had happened in this study as insignificant increase in LBM has been observed despite significant increase in quadriceps strength variables for the exercise groups.

The method espoused for the determination of LBM may not be sensitive enough to detect significant differences. Constant age related values were used in estimating residual volume for the calculation of body density. This might be a potential source of error (Hachney and Deutsch, 1985) since the accuracy of the residual volume measure can possibly influence seriously the validity of the subsequent calculation of body density (Wilmore, 1969). In the absence of direct measurement of residual volume, Wilmore (1969) as a result of the findings of his investigation, stated that it made no difference whether residual volume is estimated from vital capacity or whether a constant average value is used. He found no signficant difference between actual measuremnt of residual volume and estimated residual volume in determining body density.

Compared to other studies (Wilmore, 1974; Pipes and Wilmore, 1975; Stone et al., 1983; Goldberg et al, 1984; Hunter, 1985) which reported significant increase in strength and LBM, the increase in LBM in this investigation was not significant. In their studies, training involved the upper and lower parts of the body and a training session lasted between 40 to 60 minutes. In this investigation, only the quadriceps were trained and a training session did not exceed 20 minutes.

The results of this experiment however, support the work of Ward and Kisk (1964), Sanders (1975) and Jette et al. (1987) who reported that increase in strength was not accompanied by significant increase in LBM of their subjects.

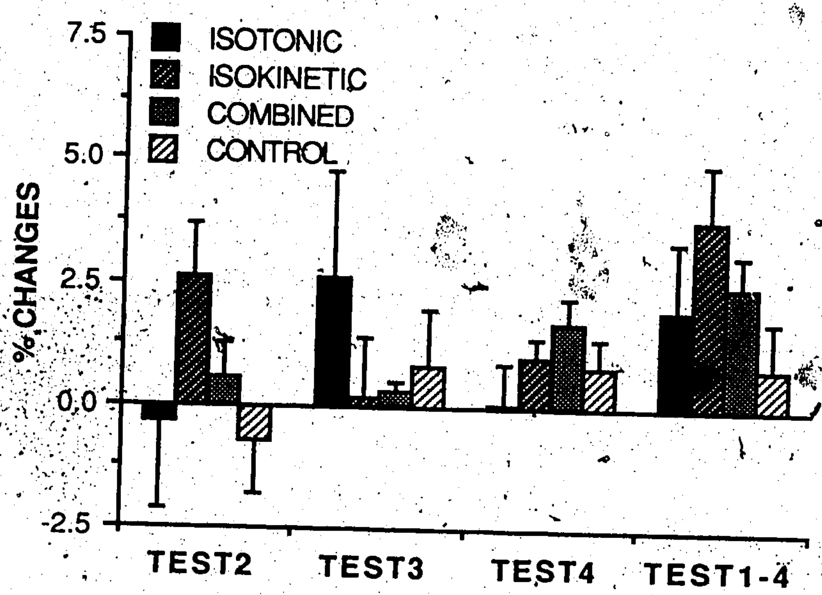

FIGURE 17. Lean body mass: percent changes of group means (±SEM).

H. SKINFOLD THICKNESS AND PERCENT BODY FAT

These two variables will be treated under the same section as they are interrelated. At the start of the study, all the groups were the same in both skinfold thickness and percent body fat (Tables 21&22). Tables 48 and 49 present the descriptive statistics for these variables. Table 23 shows the reduction in this variable achieved by Group 1 which was 2.4 mm (-2.0%); Group 2, 2.5 mm(-2.9%) and Group 3 with .3 mm (-.5%). The exercise groups were however, not significantly different form each other with regard to the reduction exhibited.

Table 24 shows the group means and differences for the skinfold thickness of the front and back thigh. Interest in this variable arose out of a desire to determine the effects of the various training methods on the skinfold thickness of the quadriceps as they were the target muscles of treatment in this study.

In percent body fat, at the end of the study, none of the groups demonstrated significant reduction to distinguish it from the other groups (Table 25). Further analysis of Groups X Tests interaction which was significant (Table 26), showed that the control group behaved differently from the exercise groups in skinfold thickness as it increased significantly by 11.8% (Table 27). Among the exercise groups, Group 1 had the highest decrease of 14.7% in body fat followed by Group 2 with 5.6% and Group 3, 4.3%. The control group with a decrease of 1.3% was surprisingly not different from Group 1 that had a reduction of 14.7% (Table 25). But within group changes showed significance at P< .01 level (Table 28).

Table 21-Summary of F-ratios for Pretest Scores of Skinfold Thickness

Source	D.F.	SS	MS	F-RATIO	F-PROB.
B. Groups	3	2266.1	755.4	.5172	.673 NS
W. Groups	38	55497.8	1460.5		
Total	41	57763.9			

NS. Denotes not significant at P< .05

Table 22-Summary of F-ratios for Pretest Scores of Percent Body fat

Source	D.F.	SS	MS	F-RATIO	F-PROB.
B. Groups	3	101.1	33.9	1.4	.26 NS
W. Groups	38	908.5	23.9		
Total	41	1009.6			

NS. Denotes not significant at P< .05

Table 23-Group Means and Differences for Skinfold Thickness

	1 Isotonic	2 Isokinetic	3 Combined	4 Control
Initial scores	104.0 mm	86.9 mm	90.4 mm	86.1 mm
Final scores	101.6	84.4	90.1	96.0
Difference	2.4	2.5	.3	9.9
% Change	-2.0 NS	-2.9 NS	-.5 NS	+11.8*
Std. Error	1.5	2.2	2.3	3.5

* Denotes significance at P< .05 level.

NS. Denotes not significant at P< .05 level.

mm = Millimeters.

Table 24-Group Means and Differences for Front and Back Thigh Skinfold Thickness

	1 Isotonic.	2 Isokinetic	3 Combined	4 Control
Initial scores	30.2 mm	29.1 mm	31.6 mm	26.7 mm
Final scores	28.9	27.9	30.5	28.1
Difference	1.3	1.2	1.1	1.4
% Change	-4.3 NS	-4.1 NS	-3.5 NS	+5.2 NS

NS. Denotes not significant at P< .05 level.

mm = Millimeters.

Table 25-Group Means and Differences for Percent Body fat

	1 Isotonic	2 Isokinetic	3 Combined	4 Control
Initial scores	15.0%	11.0%	13.6%	11.7%
Final scores	12.7	10.3	12.8	11.4
Difference	2.3	.7	.8	.3
% Change	-14.7 NS	-5.6 NS	-4.3 NS	-1.3 NS
Std. Error	2.9	3.7	3.2	5.5

NS. Denotes not significant at P< .05 level.

Table 26-Summary of F-ratios for Pre Vs Posttest Skinfold Scores

Source	SS	MS	DF	F-ratio
B. Groups	7217.5	2405.8	3	.42 NS
Error (a)	217017.4	5711.0	38	
W. Groups	51.62	17.21	3	1.17 NS
Groups X Tests	655.9	72.88	9	4.95**
Error (b)	1679.0	14.73	114.0	

** Denotes significance at P< .01 level.

NS. Denotes not Significant at P< .05 level.

Table 27-Results of the Post Hoc Analysis for Skinfold Thickness

Group	T1	T2	T3	T4
Isotonic	104.0	104.6	103.3	101.6
Isokinetic	86.9	87.8	85.6	84.4
combined	90.4	88.2	88.7	90.1
Control	86.2	92.8	92.5	96.0.[a]

a = significantly different from T1.

Table 28-Summary of F-ratios for Pre Vs Posttest Percent Body Fat Scores

Source	SS	MS	DF	F-ratio
B. Groups	257.1	85.69	3	1.07 NS
Error (a)	3032.45	70.80	38	
W. Groups	21.39	7.13	3	5.04**
Groups X Tests	16.22	1.8	9	1.27 NS
Error (b)	161.3	1.41	114.0	

** Denotes significance at $P < .01$ level.

NS. Denotes not Significant at $P < .05$ level.

Discussion

Mobilization of free fatty acids occurs from the fat depots throughout the body and the area of greatest fat storage probably supplies greatest amount of energy (Katch and McArdle, 1983). It is therefore apparent that every thing being equal, the rate of fat reduction as a result of any exercise over time is dependent upon the initial level of fat in the individual. More obese individuals tend to lose fat more readily than their nonobese or lean counterparts (Katch and Drumm, 1986). The decrease of 14.7% demonstrated by Group 1 was not only a function of training done but also due to the high initial level of fat in this group (Table 19). It had the highest skinfold score of 104.0 and 14.7% body fat initially as determined by hydrostatic weighing method.

It could be deduced from the literature dealing with strength training that most of those who reduced body fat as a result of heavy resistance training employed exercises that involved both lower and upper parts of the body and for 40-60 minutes per training session (Wilmore, 1974; Pipes and Wilmore, 1975; Stone et al., 1983; Goldgerg et al., 1984; Hunter, 1985). In this study, Group 1 trained with free weights-half squats, a multi-segment exercise known to stress erector spinae, gluteus, abdominals and lower extremity muscles (O'Shea, 1984). It is no surprise therefore, that Group 1 achieved the highest percent reduction in body fat because Katch and McArdle (1983) have opined that exercises that engage large muscles of the trunk and extremities produce the highest energy requirements if continued for a prolonged period of time. The time spent during a training session in this study could not be regarded as long as it did not exceed 15-20 minutes; the actual time of training contraction being 72 seconds.

Isokinetic training as used in this study may not be very effective in reducing body fat because not only its effect was restricted to the target muscles (quadriceps), the exercise produced minimal expenditure of calories. To induce weight loss, calories in the range of 5.9 kcal/min should be burnt for 30-45 minutes during exercise (Katch and Drumm, 1986). The findings of this present study have support in the postulate of Hurley et al. (1984a) that the lack of a potentially beneficial effect of heavy strength training on lipoprotein profiles could be related to the anaerobic nature of the training program and low VO2 max. achieved during training. This is also in agreement with the observation of Hurley et al. (1984b) who did not find significant changes in body fat of their subjects because of low relative (45% VO2 max.) stimulus elicited by the high intensity strength training. But in another study, Hurley et al. (1984a) found that the subjects who trained with moderate resistance high repetition (10-20) exercise with short intervals of rest have lipoprotein lipid profiles that could be potentially protective against coronary heart disease.

The data collected in this study did not substantiate the results of Goldberg et al. (1984) who after 16 weeks of heavy weight training found a significant reduction in body fat and 16.5% decrease of low density lipoprotein cholesterol in their subjects. Nor does it support the work of Stone et al. (1983) and Hunter (1985) who found significant reduction of body fat in their study. The differences in the results could be attributable to the nature of the studies referred to as they might have had some elements of aerobic training in their experimental designs which favoured the expenditure of fatty acids. In this investigation, there was a close correlation of r=.72 between the skinfold thickness measurement and percent body fat as determined by hydrostatic weighing.

Skinfold thickness changes as measured by Harpenden calipers in this study showed that Group 2 had the highest decrease of 2.9% while it had the second highest reduction of 5.6% in body fat as determined by hydrostatic weighing. Wilmore (1970) has contended that skinfold changes have been found to be an unreliable indicator of changes in body composition while Katch and McArdle (1983) were of the opinion that hydrostatic weighing is one of the most accurate indirect methods currently available to assess body fat content. Following this line of argument therefore, one is apt to rely more on the body fat changes as determined by hydrostatic weighing method. However, when the two measurements are combined, the observed trend indicated that body fat was reduced (Figs. 18&19) but the reduction was not significant.

On the basis of the findings in this investigation with particular reference to the effects of resistance training on reduction of body fat, no method of training has been found to be very effective. The trend showed however, that because free weights training (isotonic) as used in this study involved more muscle groups compared to isokinetic training method, training by free weight is preferable for fat reduction.

In view of the fact that the exercise groups did not experience significant reduction in body fat compared to that of the control group after 10 weeks of heavy resistance training, the third original null hypothesis was therefore not rejected.

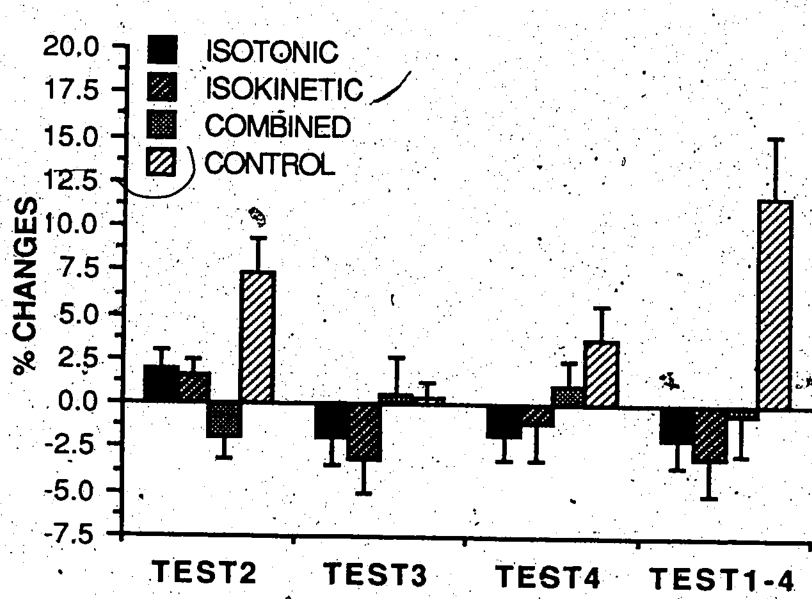

FIGURE 18. Skinfold thickness: percent changes of group means (±SEM).

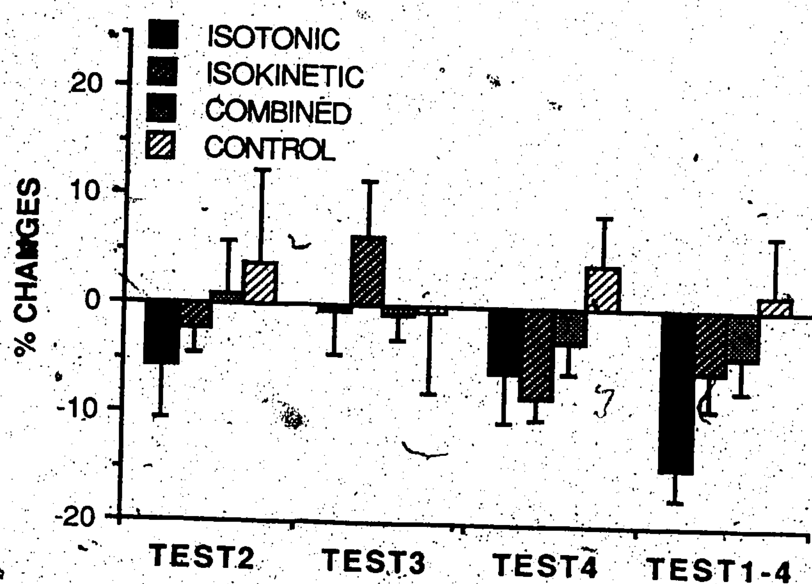

FIGURE 19. Body fat: percent changes of group means (±SEM).

I. THIGH AND CALF GIRTH

All the girth measurements taken will be treated together under this section as they relate to each other. As indicated in Tables 29-32 all the groups were not disimilar for these variables at the start of the study. Tables 50-53 present the descriptive statistics for the groups in all the tests.

Posttest scores indicated that the significant increases in right thigh girth of all the exercise groups were matched by the increases exhibited by the left thigh girth which were also significant at $P < .01$ (Tables 33&34). Between groups increases did not show any significant difference (Tables 37&39). Groups 2&3 with 3.7% and 3.5% increase for left thigh girth plus 3.6% and 3.9% increase for right thigh girth respectively (fig. 20-21) were more than the 2.8% gain achieved by Group 1 in both thighs. Of the total gain exhibited by Groups 2&3, about 75% of it was achieved after three weeks of training which was significantly greater than their pretest scores (Tables 38 & 40). Group 1's increase of .7% for both thighs in the same period was not significant. The increases of .3% (.18 cm) for the right thigh and .4% (.24 cm) for the left thigh of the control group were not significant (Tables 33-34).

As for the left calf girth values, posttest increase of Group 3 was the highest with 2.2% (.8 cm) followed by Group 2, 1.7% (.6 cm) and Group 1 with .8% (.2 cm). The control group decreased by .1% (-.1 cm). The right calf posttest scores followed the same pattern as the left. Both Groups 2&3 ended up with 2.2% (.8 cm) followed by Group 1 with 1.5% (.5 cm). The control group made a gain of .4% (.1 cm) (Tables 35-36). The increases achieved by all the the groups were however, not significantly higher than their pretest scores. The Groups X Tests interaction revealed significant difference among the groups in the pattern of their response to the tests as a function of time (Tables 41-42).

Table 29-Summary of F-ratios for Pretest Scores of Right Thigh Girth

Source	D.F.	SS	MS	F-RATIO	F-PROB.
B. Groups	3	48.8	16.3	.821	.49 NS
W. Groups	38	751.9	19.8		
Total	41	800.7			

NS. Denotes not significant at $P < .05$ level.

Table 30-Summary of F-ratios for Pretest Scores of Left Thigh Girth

Source	D.F.	SS	MS	F-RATIO	F-PROB.
B. Groups	3	30.7	10.2	.48	.699 NS
W. Groups	38	813.9	21.4		
Total	41	844.6			

NS. Denotes not significant at $P < .05$ level.

Table 31-Summary of F-ratios for Pretest Scores of Right Calf girth

Source	D.F.	SS	MS	F-RATIO	F-PROB.
B. Groups	3	6.0	2.0	.284	.837 NS
W. Groups	38	269.0	7.0		
Total	41	275.0			

NS. Denotes not significant at $P < .05$ level.

Table 32-Summary of F-ratios for Pretest Scores of Left Calf girth

Source	D.F.	SS	MS	F-RATIO	F-PROB.
B. Groups	3	5.5	1.8	.249	.861 NS
W. Groups	38	277.0	7.3		
Total	41	282.5			

NS. Denotes not significant at $P < .05$ level.

Table 33-Group Means and Differences for Right Thigh Girth

	1 Isotonic	2 Isokinetic	3 Combined	4 Control
Initial scores	56.9 cm	56.8 cm	56.4 cm	55.8 cm
Final scores	58.5	58.8	58.4	56.0
Difference	1.6	2.0	2.0	.2
% Change	2.7*	3.6*	3.9*	.3
Std. Error	.3	.5	.5	.4

* Denotes significance at $P < .05$ level.

cm = Centimeters

Table 34-Group Means and Differences for Left Thigh Girth

	1 Isotonic	2 Isokinetic	3 Combined	4 Control
Initial scores	56.4 cm	56.5 cm	56.4 cm	56.0 cm
Final scores	58.0	58.6	58.3	56.2
Difference	1.6	2.1	1.9	.2
% Change	2.9*	3.7*	3.5*	.4 NS
Std Error	.3	.5	.6	.3

* Denotes significance at P< .05 level.

NS. Denotes not significant at P< .05 level.

cm = Centimeters

Table 35-Group Means and Differences for Right Calf Girth

	1 Isotonic	2 Isokinetic	3 Combined	4 Control
Initial scores	37.1 cm	37.3 cm	37.7 cm	37.3 cm
Final scores	37.6	38.1	38.5	37.4
Difference	.5	.8	.8	.1
% Change	1.5 NS	2.2 NS	2.2 NS	1.0 NS
Std. Error	.5	.4	.4	.6

NS. Denotes not significant at P< .05 level.

cm = Centimeters

Table 36-Group Means and Differences for Left Calf Girth

	1 Isotonic	2 Isokinetic	3 Combined	4 Control
Initial scores	37.2 cm	37.5 cm	37.7 cm	37.4 cm
Final scores	37.4	38.1	38.5	37.3
Difference	.2	.6	.8	-.1
% Change	.8 NS	1.7 NS	2.8 NS	-.1 NS
Std. Error	.5	.7	.6	.8

NS. Denotes not significant at $P < .05$ level.

cm = Centimeters

Table 37-Summary of F-ratios for Pre Vs Posttest Right Thigh Girth Scores

Source	SS	MS	DF	F-ratio
B. Groups	123.34	41.11	3	.53 NS
Error (a)	2975.19	78.29	38	
W. Groups	53.95	17.98	3	88.42**
Groups X Tests	20.39	2.27	9	11.14**
Error (b)	23.19	.20	114.0	

** Denotes significance at $P < .01$ level.

NS. Denotes not significant at $P < .05$ level.

Table 38-Results of the Post Hoc Analysis for Right Thigh Girth

Group	T1	T2	T3	T4
Isotonic	57.0	57.2	58.4[a,b]	58.5[a,b]
Isokinetic	56.8	58.3[a]	58.4[a]	58.8[a]
Combined	56.4	57.8[a]	58.3[a]	58.6[a]
Control	55.8	55.0	55.9	56.0

a = significantly different from T1.

b = significantly different from T2.

Table 39-Summary of F-ratios for Pre Vs Posttest Left Thigh Girth Scores

Source	SS	MS	DF	F-ratio
B. Groups	77.37	25.79	3	.30 NS
Error (a)	3239.68	85.25	38	
W. Groups	52.01	17.34	3	73.59**
Groups X Tests	16.58	1.84	9	7.82**
Error (b)	26.86	.24	114.0	

** Denotes significance at $P < .01$ level.

NS. Denotes not significant at $P < .05$ level.

Table 40-Results of Post Hoc Analysis for Left Thigh Girth

Group	T1	T2	T3	T4
Isotonic	56.4	56.9	57.8[a]	58.0[a,b]
Isokinetic	56.5	58.0[a]	58.3[a]	58.6[a]
Combined	56.4	57.7[a]	58.0[a]	58.3[a]
Control	56.0	56.1	56.1	56.2

a = significantly different from T1.

b = significantly different from T2.

Table 41-Summary of F-ratios for Pre Vs Posttest Right Calf Girth Scores

Source	SS	MS	DF	F-ratio
B. Groups	19.49	6.5	3	.22 NS
Error (a)	1147.01	30.18	38	
W. Groups	7.94	2.65	3	19.95**
Groups X Tests	3.12	0.35	9	2.65**
Error (b)	15.12	.13	114.0	

** Denotes significance at $P < .01$ level.

NS. Denotes not significant at $P < .05$ level.

Table 42-Summary of F-ratios for Pre Vs Posttest Left Calf Girth Scores

Source	SS	MS	DF	F-ratio
B. Groups	21.81	7.27	3	.24 NS
Error (a)	1159.67	30.52	38	
W. Groups	4.26	1.42	3	7.74**
Groups X Tests	3.85	0.43	9	2.33*
Error (b)	20.91	.18	114.0	

* Denotes significance at P< .05 level.

** Denotes significance at P< .01 level.

NS. Denotes not significant at P< .05 level.

Discussion

An exercise that involves the stretching of the muscles increases the membrane transport of amino acid which then stimulates protein synthesis (Goldgerg et al, 1975; MacDougall, 1986). Stretch is also known to increase the concentration of calcium which promotes the build-up of RNA and protein (Howard, 1985). In this study, isokinetic training procedures offered maximal stretch during eccentric contraction to the leg extensors of the subjects as their muscles were forcefully stretched from 180^{0} to 90^{0} knee flexion (half squat). This could be the stimulus for the early hypertrophy observed.

The data showed that after three weeks of training, Groups 2&3 which were exposed to isokinetic training, achieved 75% of their gains in thigh girth which were significantly greater than their pretest scores. This huge early significant increase in thigh girth by these two groups is hard to explain considering the time course of hypertrophic process in skeletal muscle due to heavy resistance training. Moritani and DeVries (1979) have postulated that hypertrophy of the muscle could become a dominant factor in strength development after 3-5 weeks. In the present study, both neural and hypertrophic factors could have accounted for the early increase in quadriceps strength as the increase in thigh girth observed correlated with the early increase in dynamic strength (1RM) demonstrated by Groups 2&3.

The early hypertrophy of the thigh muscles observed in this study was unique only to the electric dynamometer which provided isokinetic training contractions. Training by free weights (isotonic) as done by Group 1 was only effective in significantly inducing hypertrophy after seven weeks of training. Although all the exercise groups achieved significant increases at posttest at $P < .05$ level (Tables 33-34), they were not significantly different from the control group that had a nonsignificant increase of .3 to .4% for right and left thigh girth respectively.

Comparatively, studies that did not find early increase (after three weeks of training) in hypertrophy of the quadriceps have either used free weights or other conventional mechanical apparatus for training studies. The data of the present study corroborated that of Singh and Danielson (1975). After using the same dynamometer (Singh, 1972) for a training study, they reported a significant increase in the girth of leg extensors after eight weeks of training college males but none of their training methods was superior in eliciting greater gains in quadriceps girth. Contrary to the reported significance in lean body mass as a result of significant increase in the girth of different muscle groups reported by Pipes and Wilmore (1975), increase in lean body mass in this study was not significant. This could be due to the localized effect of the training program compared to that of Pipes and Wilmore (1975) that trained several major upper and lower muscle groups of the body.

All the exercise groups in this study demonstrated nonsignificant increases in the girth of the calf of both legs. similarly, these increases were not significantly different from the scores achieved by the control group. As could be observed for the training regimes of the exercise groups, the target muscles of the training stimulus were the quadriceps which demonstrated significant increase in girth. To involve the calf muscles more physically in the training contraction, would have introduced a new dimension into the training regimens. Heel raise exercises with weights would have effectively stressed these muscles to induce any noticeable hypertrophy.

On the basis of these findings, the original hypothesis that there would not be any significant differences among the exercise groups in muscle girth after the study, was upheld. Similarly, the girth increases achieved by the exercise groups were not significantly greater than that of the control group therefore, the null hypothesis was not rejected.

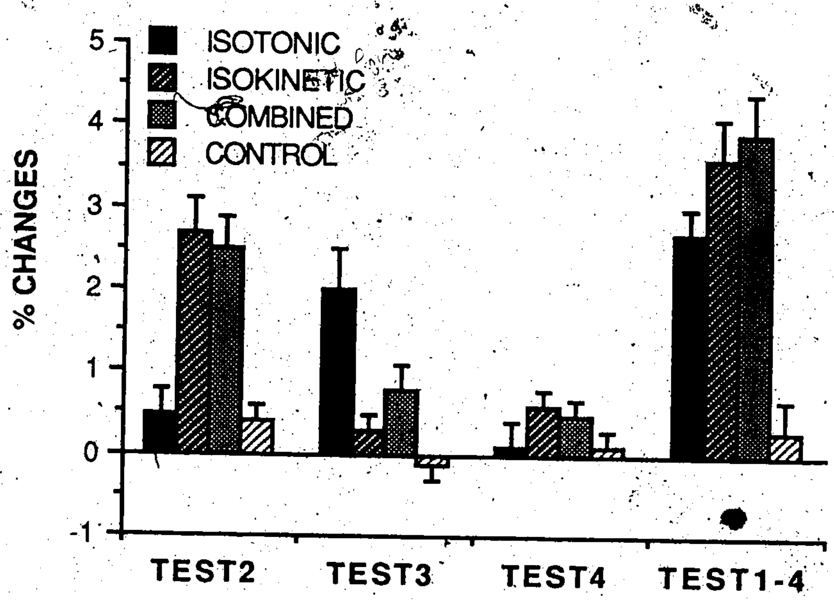

FIGURE 20. Right thigh girth: percent changes of group means (±SEM).

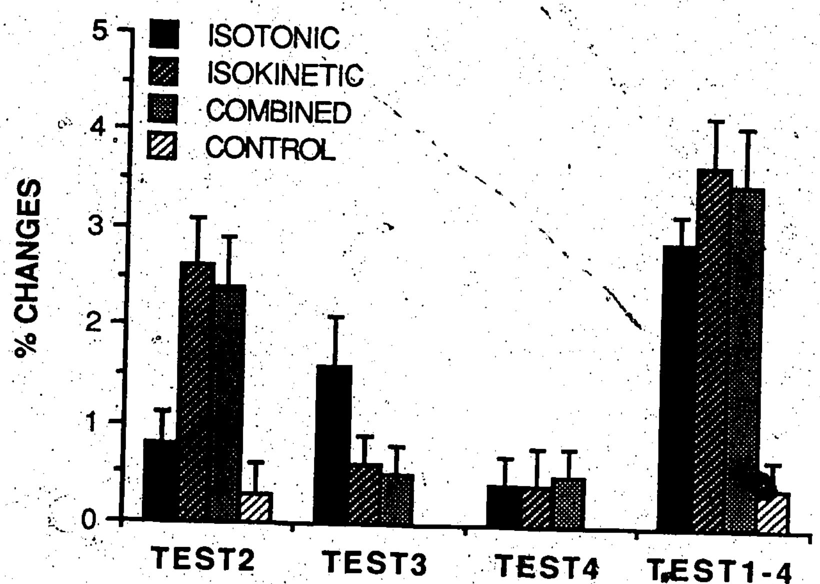

FIGURE 21. Left thigh girth: percent changes of group means (±SEM).

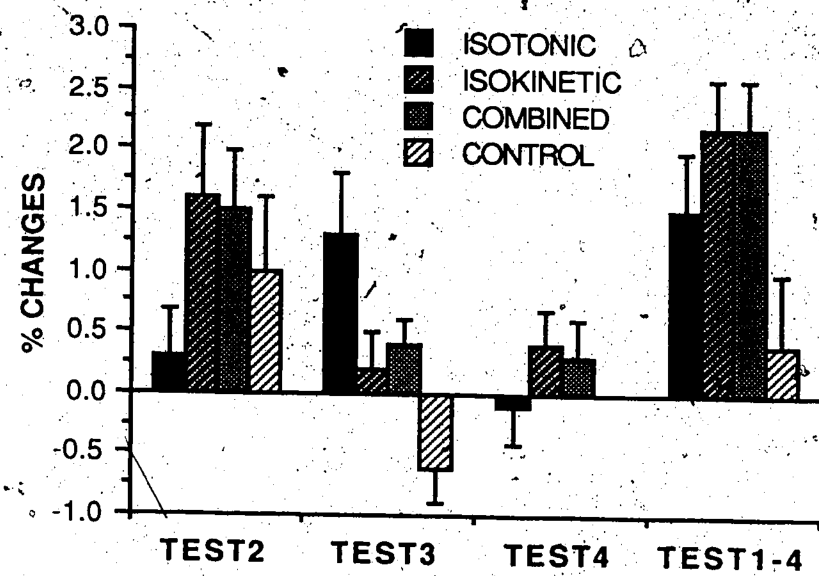

FIGURE 22. Right calf girth: percent changes of group means (±SEM).

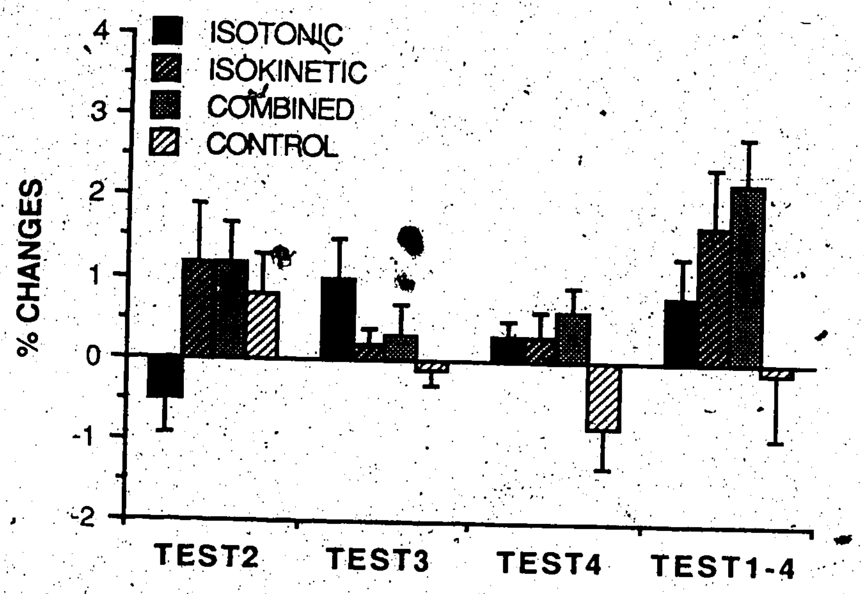

FIGURE 23. Left calf girth: percent changes of group means (±SEM).

J. GENERAL DISCUSSION

The preceeding evidence suggests that any form of resistance training will result in increased functional capacity of the muscle as long as the stimulus is above the threshold of improvement. This has been demonstrated in this study since all the exercise groups significantly increased their quadriceps strength variables over their pretest scores except Group 1 which did not exhibit any significant change in maximum impulsive force (Table 15). Some training methods were more effective in improving some variables because of specificity of training effects (Sale and MacDougall, 1981; Gonyea and Sale, 1982).

However, comparison of pre and posttest mean differences of the exercise groups for the strength variables, revealed no significant differences among the groups. In maximum isokinetic-concentric strength, all the exercise groups were significantly different ($P < .05$) from the control group (Group 4). But in maximum isokinetic-eccentric strength, only Groups 2&3's gains were significantly greater than that of the control group. No exercise group was however, superior in this variable.

The results presented in Tables 3&6 and the percent changes in figures 13&14 give additional support to the concept of specificity of training as found in this study. This is in line with the postulate of Pipes (1978) that the concept of specificity of training suggests that improvement should be greatest when tested with a device or procedure that approximates the training procedure. Groups 2&3 that were exposed to isokinetic training procedures showed more significant gains in strength tests involving isokinetic contractions. Group 2 increased by 2621 newtons (163%) while Group 3 gained 2225 newtons (125%) in maximum isokinetic-concentric strength at the end of the study. Group 1 which trained isotonically also demonstrated a significant but less improvement of 1654 newtons (105%). The increase of 17.9 newtons (9.4%) achieved by the control group was not significant.

The non significant difference exhibited by Group 1 from the control group in maximum isokinetic-eccentric strength could not be easily explained except to attribute it partly to the type of the training regimen done by this group. May be a biopsy of the trained muscles could have provided a more definite explanation. Skill acquisition and the specific conditioning of the neuromuscular system induced by the training contractions are other factors to consider in strength training and tests.

Maximum force exertion through a full range of joint motion is not possible in isotonic half squat exercise used by Group 1 because mechanical advantage decreases as the angle of contraction becomes smaller (Knuttgen and Kraemer, 1987). Bosco (1985) has remarked that human muscle groups cannot generate great force in a shortened position because as the joint angle decreases, force also decreases. During isotonic-eccentric contraction in the squats, as soon as knee angle changes, the high force developed at the beginning through the middle phase decreases to submaximal levels towards the final squatting position. The training stimulus therefore, works in the muscle very briefly which may not be optimal for the desirable effects. But in isokinetic training, maximal tension could be developed in the muscle through a full range of motion thus enabling the stimulus to act on the muscle for a longer period of time.

The observation of Hagan and Sale (1986) that free weights training causes a greater transfer of strength to isokinetic strength than vice versa has not been substantiated in this study. Groups 1&2 were not significantly different in the two variables (maximum dynamic strength-half squat 1-RM and isokinetic strength tests) at posttest. However, the isokinetic group achieved a higher difference in the isokinetic strength tests compared to what the isotonic group had in dynamic strength evaluation. As could be seen from the correlation matrix of Groups 1&2 in Appendix F, at pretest, the correlation coefficient between maximum isokinetic-concentric strength for Group 2 was .33. This non-significant correlation further decreased to .2 at posttest probably due to specificity of training effects. Group 1's pretest correlation between these two variables was .23 which decreased to nonsignificant -.38 at posttest. These correlation values indicate that results of strength tests are specific to the training contractions (Sale and Macdougall, 1981).

The force a maximally stimulated muscle can develop at a given length varies with velocity. The greater the velocity of forced lengthening, the greater is the force developed until a certain maximal value is reached (Sale and Norman, 1982; Knuttgen and Kraemer, 1987). An assessment of the training speed of eccentric contraction of Group 1, indicates that 4.5 seconds per repetition (from 180^0 to 90^0 knee flexion) may not be optimal to induce the adequate adaptation required for increased isokinetic-eccentric strength. Similarly, if the rate of contraction was too fast due to the downward force of the heavy weight, the required adaptive response would not occur which might therefore result in little or no training effect. During eccentric contraction, the overstretching of the muscle elastic components along with the accompanying delay in the recoil, would serve as a trophic stimulus to increase the force of contraction (Muller and Rohmert, 1963). In order for the desired adaptive response to occur, the optimal training speed must be employed. This has been a factor in the efficacy of the isokinetic training procedures in this study which took three seconds per repetition of maximal contraction through a full range of motion.

When examining the overall development of force during the 10 weeks of training, majority of the increase demonstrated by the exercise groups occurred after seven weeks of training. It was only in dynamic strength (1RM) that significant increase was observed after three weeks of training. Although Group 1 did not demonstrate significant increase in thigh girth in contrast to Groups 2&3 after three weeks of training (fig. 15&16), it had a significant increase in dynamic strength during this period. This phenomenon could be attributed to the postulate of Delorme and Walkins (1951) that the initial increase in strength in progressive resistance exercise occurs at a rate far greater than can be accounted for by morphological changes within the muscle. These initial rapid increments no doubt, are due to motor learning or neural inhibition. Maximum neural activation of the trained muscles has also been identified as a factor (Moritani and DeVries, 1979; Hakkinen, 1985; Howard et al., 1985).

The rate of development of maximal isokinetic strength and maximum impulsive force was highest in the isokinetic group and lowest in the isotonic group (Figures 13,14, and 16). The combined group (Group 3) showed superiority only in dynamic strength (1-RM) with the highest increase of 53.0 kgs (43.3%) followed by the isotonic group with 36 kgs (37%). Hakkinen et al. (1981) and Hakkinen and Komi (1981) have earlier confirmed the effectiveness of isokinetic-eccentric and concentric training procedures in developing muscle strength variables.

Since this investigation was concerned originally with the evaluation of the effectiveness of different resistance methods, the strengths and weaknesses of the individual training methods should be highlighted. The isokinetic device used in this study, if used alone, may not be the best for developing dynamic strength (1RM). The significant improvement of 28kgs (22.9%) achieved by Group 2 (isokinetic group) in this variable which was the lowest among the exercise groups could be traced back to the nature of its training method. Exercise without knowledge of results is a monotonous process. This factor may have played a large role in the motivational aspect of strength training for Groups 1&3. The isokinetic device provided resistance from the waist down (figure 5) whereas in the maximum dynamic strength test, the weight was directly on the shoulders (fig. 4). The line of force and gravitational effect of the resistance are through the trunk (the weak link) to the lower extremities. Group 2's training precluded the use of the trunk while in Groups 1&3, this formed a major component in the training program. The amount of weight lifted is dependent upon what the weak link (trunk) can effectively transmit from the legs to counteract the downward force of the weight. More muscle groups have been trained in Groups 1&3 therefore, more strength is expected to be developed as synergistic muscles which were equally trained would contribute to the force development during the test. Group 2 was handicapped in this regard hence its lowest gain in this variable among the exercise groups.

Of interest in this study is the non-linear increase of maximum impulsive force of the legs with the significant increase of the girth of the thigh muscles for all the exercise groups. The importance of enlarged muscle cross-sectional area for increased strength development (Ikai and Fukunaga, 1968; Howard et al, 1985) was demonstrated after seven weeks of training by all the exercise groups. This is in conformity with the observation of Moritani and DeVries (1979) that after five weeks of strength training, hypertrophic factors may contribute to increased strength development. The evidence in the literature suggests that the increased girth of the thigh muscles could be due mainly to the hypertrophy of fast twitch fibers and to a less degree, by slow twitch muscle fibers (Krotkiewski et al, 1979; Hakkinen et al, 1981). Fast twitch muscle fibers are mostly recruited during high intensity heavy strength training procedures (Hakkinen et al., 1981; Howard et al., 1985) like those utilized in this study. Dons et al. (1979) have opined that the positive correlation between the relative content of fast twitch fibers and the increase in dynamic strength per unit cross-section is a strong indication of a high content of fast twitch fibers constituting a pre-requisite for a successful response to training. Correlation between thigh girth and maximum impulsive force (Appendix B) increased significantly at posttest for isotonic and combined training groups. Group 1 increased from .38 to [illegible] while Group 3 improved from .80 to .95. The increase from .20 to .30 for Group 2 was not significant. This is an indication of the effectiveness of resistance parallel squat exercises in developing muscles involved in jumping. This confirms the work of Bangerter (1964) that the leg extensors are the major muscles involved in jumping. Stone et al. (1979) have reported a significant but low correlation of .49 between vertical jump and isotonic squat exercise while Wathen and Schuttes (1982) found a correlation of .38 between isotonic squats and jump and .86 for isokinetic squatting exercise and jump. Although the isokinetic training procedure elicited the highest gain of 215 newtons (12.7%) in this study (Table 15), this increase did not result in significant correlation between maximum impulsive force and thigh girth.

Increases in maximum impulsive force achieved by the exercise groups following significant increase in thigh girth were not great enough to elicit significant difference from the control group. Another possible explanation for this finding, could be derived from the reports of Goldberg et al. (1975); Hakkinen et al. (1981) and Bosco (1985) that hypertrophied muscle fibers respond slowly to peak tension development. This may not be the case in this study because the observed increases were not overwhelming to precipitate the negative effects of pronounced muscle hypertrophy.

The test protocol also, could have prevented maximum gains in this variable. Bosco et al. (1982) have theorized that the stretching of an activated muscle prior to its shortening, increases its performance during the following positive (concentric) phase of the exercise.

Elastic energy is stored in the series element of the muscle as an adaptive response to eccentric training (Cavagna et al. 1965; Asmussen and Bonde-Peterson, 1974). To take advantage of the stored elastic energy, there should be no time lost in the squatting position before rebounding because the utilization of the stored elastic energy depends upon the coupling time of the cross-bridge's life time (Bosco et al. 1986). The coupling time of the cross-bridge's life time has been reported to be 15 to 150 ms for dynamic contraction (Asmussen and Bonde-Peterson, 1974; Bosco, 1985). In this study, jumps were initiated off the force platform from a static knee bend position (fig. 7) thereby losing the beneficial effects of the stored elatic energy. Bosco et al. (1982) have observed that mechanical efficiency in rebound jumps were higher than jumps without rebounds. It therefore becomes apparent why the significant increase in thigh girth for the exercise groups did not translate into greater improvement in maximum force.

Most of the total strength increases exhibited by the exercise groups could partly be attributed jointly to neural adaptation and hypertrophy of the muscles since the exercise groups showed significant increase in thigh girth. As maximal stretch is a pre-requisite for hypertrophy of the muscles to occur (Goldberg et al. 1975, Goldspink, 1983), isokinetic training procedures as used in this study, provided the maximal stretch for the hypertrophic adapative response to occur. Is is no surprise therefore that Groups 2&3 that had the experience of the isokinetic training procedures had the highest significant increase in thigh girth with 3.3% followed by the isotonic group with 2.8%. The .4% gain achieved by the control group was not significant (Tables 33-34).

The increase in thigh girth which was significant for the exercise groups did not parallel the non-significant increase of the triceps surae (calf muscles). The girth of the calf muscles did not exhibit any significant change to warrant any meaningful comparisons among the groups (Tables 35-36). The non-significant change of the girth of the calf muscles, could be ascribable to the localized effects of the training regimes employed in this study. To increase the girth of the calf muscles which are mostly made of slow twitch fibers (Guth, 1983; Gollnick and Matoba, 1984), a more definite exercise program would have been designed to actually stress them.

As could be seen in Figure 17, there was no significant change in lean body mass (LBM) for all the groups. The weight of the subjects was stable throughout the course of this study. Studies that have reported significant increases in LBM as a result of strength training (Pipes and Wilmore, 1975; Sanders, 1975; Hunter, 1985) performed exercises that involved both the upper and lower parts of the body. In this study, the training was restricted to the lower extremities hence a significant increase was noted in the girth of the leg extensors that were trained.

There were no observable changes in body fat as determined by unweighted skinfold thickness scores (Table 23) or by hydrostatic weighing procedure (Table 25). Further analysis of the significant Groups X Tests interaction in skinfold thickness revealed that the control group significantly increased from 86.1 mm at pretest to 96.0 mm at posttest. The ineffectiveness of the various training regimens on body fat was due to the stimulus provided by the resistance training. It will be recalled that the exercise performed by the exercise groups most likely produced minimal expenditure of calories. To aid weight loss, calories in the range of 5-9 kcal/min should be burnt continuously for 30-45 minutes (Katch and Drumm, 1986). In this study, the training contraction time lasted for 72 seconds which might not be optimal for fat reduction.

Any strength training that has aerobic components in its design and implementation and done for prolonged period may result in fat reduction. Hence Goldberg et al. (1984) cited the training program of body builders as being suitable and effective for body fat reduction. Body builders train with moderate resistance and high repetition with short rest intervals while the strength trainers (similar to the subjects in this study) utilize heavy resistance with low repetition as well as long rest intervals.

Any exercise for body fat reduction must engage large muscles of the trunk and extremities for prolonged periods of time (Katch and Drumm, 1986). Group 1 showed greater fat reduction (14.7%) (Table 25) becasue the training program involved more muscle groups compared to Group 2 whose training effects only targeted the lower extremities. As could be seen from Table 24, the skinfold thickness of the thighs of the groups did not exhibit any significant change from pre to posttest. This is due probably to the fact that specific spot reduction of adipose tissue cannot occur (Krotkiewski et al, 1979; Katch et al, 1984) because mobilization of fatty acids occurs from the fat depots throughout the body (Goldspink, 1983). The non significant change in body fat and body weight of the exercise groups corroborated the findings of Hakkinen et al. (1981). They reported a slight but insignificant decrease in body fat of their subjects after 16 weeks of combined isokinetic-concentric and eccentric strength training.

As used in this study, the combined training regimes (isotonic and isokinetic methods) trailed behind the isokinetic training method in improving most of the strength parameters. It only showed superiority in improving dynamic strength although its improvement was not significantly different from the gains achieved by the other exercise groups. The isotonic group was also effective but on a lower scale. It had the largest reduction of body fat at posttest. This could be due to the initial high fat content in this group (Table 23).

CHAPTER V

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

The purposes of this study were to compare the relative effects of three muscle resistance training methods on the development of quadriceps strength variables and to determine the effectiveness of each training method in effecting positive change in impulsive force and body composition.

Forty-two healthy male University students (mean age; 22.5 years years), who were inexperienced in resistance, training volunteered to participate in this study. (All the training and testing was done at the department of Physical Education and Sport Studies of the University of Alberta, Canada between the months of February and May, 1987)

The subjects were randomly assigned to three exercise and one control groups. The groups were designated as follows:Group 1 (11 subjects) isotonic; Group 2 (10 subjects) isokinetic; Group 3 (10 subjects) combined isotonic and isokinetic and Group 4 (11 subjects) control. The control group did not participate in the training but took part in all the tests conducted. Before the study began, all the subjects took part in three familiarization sessions to acquiant them with the equipment including the different training procedures and testing protocols. This was done to prevent injuries and to neutralize the skill factor in the strength tests during the pretest. The subjects trained three times a week and a training session lasted 15-20 minutes. The total time of training contraction done per training session was equalized for the exercise groups.

Four tests were conducted during the eleven week duration of this study. They were pretest (Test 1); midtest1 (Test 2) after 3 1/2 weeks of training; midtest2 (Test 3) after 7 weeks of training and posttest (Test 4) after 10 weeks of training. The criterion variables were maximal isokinetic-concentric, maximal isokinetic-eccentric strength, maximum impulsive force, maximum dynamic strength (1-RM), thigh and calf girths, lean body mass and body fat.

The statistical procedure used to analyze the data was the Unique two-way analysis of variance with repeated measures on the last factor (tests) as well as the Greenhouse-Geiser conservative test. Where there was significant main effect and interaction, Scheffe post hoc test was employed to locate the significant differences. Pearsons Product-Moment correlation coefficient technique was used to determine the reliability of the testing procedures and also the relationship between the individual variables.

There was no significant difference among the exercise groups as regards their effectiveness in improving the strength variables under study. Analysis of the data however, revealed that the isokinetic training group (Group 2) led the other groups (although not significantly different from the other exercise groups) in all the strength variables except in the maximum dynamic strength in which the combined training group excelled. All the training methods were effective in significantly increasing thigh girth but there were no significant differences among them in this variable. All the experimental groups demonstrated no significant increase in lean body mass and percent body fat.

A. CONCLUSIONS

Within the limitations of this study, the following conclusions were made:

1. The exercise groups achieved significant gains in maximum isokinetic-concentric strength more than the control group. All the three training methods were not significantly different in developing maximum isokinetic-concentric and eccentric strength. However, in maximum isokinetic-eccentric strength, the gains achieved by Group 1 were not significantly different from that of the control group. The improvement in maximum isokinetic-concentric and eccentric strength achieved by Group 2 was the greatest because of the specific nature of the training contraction and the criterion variables.
2. Groups 2 and 3 demonstrated significant increase in maximum impulsive force while the increase achieved by Groups 1 and 4 was not significant. With this significant increase of 12.7% achieved by Group 2, isokinetic training procedures as used in this study elicited the highest gain in maximum impulsive force of the legs.
3. The three exercise treatments were equally effective in developing maximum dynamic

strength as determined by 1-RM (half squats). The combined training methods induced the highest percentage improvement, in this variable. The isokinetic training method elicited the lowest gain probably becasue of the specific adaptation to the training contraction which was different from that espoused for the test.

4. There were no significant differences among the exercise groups in the significant increase of the girth of the leg extensors achieved by them. Groups 2 and 3 exhibited the highest improvement while the control group had a .4% insignificant increase.

5. Increase in lean body mass was not significant for all the groups although the increase in thigh girth was. This has been attributed to the specificity and localized effects of the training regimes. Isokinetic training procedures elicited the highest gain in lean body mass.

6. None of the exercise groups demonstrated effectiveness in reducing body fat as there were no significant changes above the pretraining levels after 10 weeks of heavy resistance training.

B. RECOMMENDATIONS

The following recommendations are made for future study:

1. Muscle biopsy in conjunction with objective strength measurements should be done in a similar study to fully explain the differences in the efficacy of the training methods.

2. A more sophisticated equipment like the CT scanning device should be used in addition to hydrostatic weighing technique to objectively determine changes in body composition as a result of heavy strength training.

3. Residual volume of the subjects should be measured directly as this will affect the estimation of per cent body fat.

4. A similar study in which male and female subjects experienced in muscle resistance training should be conducted in order to extrapolate the findings to an athletic population.

5. The free weights training apparatus should be redesigned to incorporate the mechanism

by which the weight could be lifted independent of the efforts of the trainers. This will be useful during eccentric training in which the load has to be lifted back to the starting position.

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Appendix A: Participant Activity Readiness Questionnaire

Physical Activity Readiness Questionnaire (PAR-Q)*

PARTICIPANT IDENTIFICATION

PAR Q & YOU

PAR-Q is designed to help you help yourself. Many health benefits are associated with regular exercise, and the completion of PAR-Q is a sensible first step to take if you are planning to increase the amount of physical activity in your life.

For most people physical activity should not pose any problem or hazard. PAR-Q has been designed to identify the small number of adults for whom physical activity might be inappropriate or those who should have medical advice concerning the type of activity most suitable for them.

Common sense is your best guide in answering these few questions. Please read them carefully and check (√) the ☐ YES or ☐ NO opposite the question if it applies to you.

YES	NO	
☐	☐	1. Has your doctor ever said you have heart trouble?
☐	☐	2. Do you frequently have pains in your heart and chest?
☐	☐	3. Do you often feel faint or have spells of severe dizziness?
☐	☐	4. Has a doctor ever said your blood pressure was too high?
☐	☐	5. Has your doctor ever told you that you have a bone or joint problem such as arthritis that has been aggravated by exercise, or might be made worse with exercise?
☐	☐	6. Is there a good physical reason not mentioned here why you should not follow an activity program even if you wanted to?
☐	☐	7. Are you over age 65 and not accustomed to vigorous exercise?
☐	☐	8. Are you suffering from a back problem?

If You Answered

YES to one or more questions

If you have not recently done so, consult with your personal physician by telephone or in person BEFORE increasing your physical activity and/or taking a fitness test. Tell him what questions you answered YES on PAR-Q, or show him your copy.

programs

After medical evaluation, seek advice from your physician as to your suitability for:

- unrestricted physical activity, probably on a gradually increasing basis.
- restricted or supervised activity to meet your specific needs, at least on an initial basis. Check in your community for special programs or services.

NO to all questions

If you answered PAR-Q accurately, you have reasonable assurance of your present suitability for:

- A GRADUATED EXERCISE PROGRAM - A gradual increase in proper exercise promotes good fitness development while minimizing or eliminating discomfort.
- AN EXERCISE TEST - Simple tests of fitness (such as the Canadian Home Fitness Test) or more complex types may be undertaken if you so desire.

postpone

If you have a temporary minor illness, such as a common cold.

Appendix B: Informed Consent Form

Consent Form

I,.........................hereby volunteer to participate in a 10 week-strength training study. During the course of this experimental study, I will not participate in any resistance training exercise for the lower extremity muscles. I can however, continue with my normal daily activities.

I have completed the PAR Q and I have no contraindication against my participating in a strength training program of this nature.

During the 10 weeks of this study, I will be required to participate in 4 tests; one at the beginning of the training while the others at three weeks interval. The tests shall be Maximum leg impulsive force, max. isotonic strength, max. isokinetic concentric and eccentric strength; measurement of the girth of thigh and calf muscles and skinfold thicknesses measurement.

Every effort shall be made to minimize any unnecessary discomfort and risk that may be associated with these training and tests during my participation. I understand however, that just like any other physical conditioning and fitness tests, there are episodes characterized by muscle soreness, leg cramps and perhaps transient light headedness.

In agreeing to participate in this study and tests, I waive any legal recourse against the investigator or the Faculty of Physical Education, University of Alberta from any and all claims resulting from personal injuries or mishaps resulting from these tests and training.

I acknowledge that the testing and training procedures have been fully explained to me and that I can withdraw my participation from this study at any time. I hereby consent to participate on my own volition.

Date:................

Signature:..................

Witness:......................

Appendix C: Data Collection Sheets

Appendix C-1:
Data Sheet for maximum impulsive force.

Test:

Name

Weight:

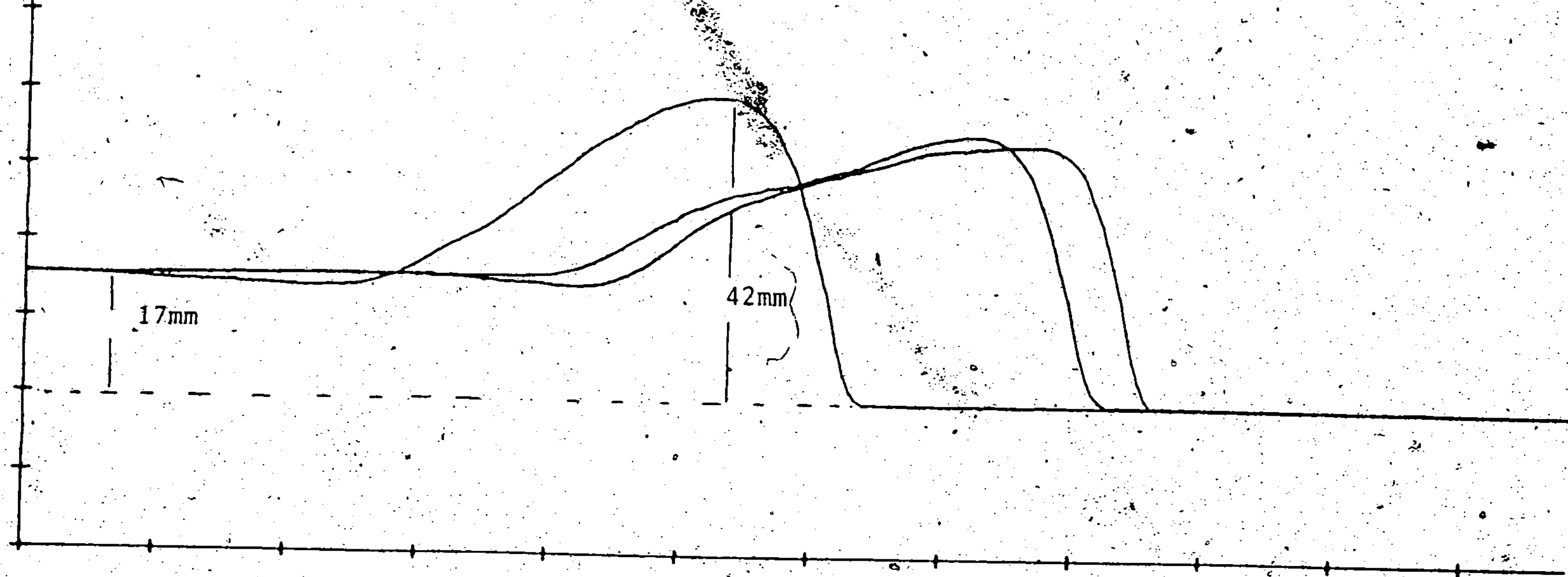
Date:

Time:

Calculation of max. impulsive force: (example)

Body weight (kgs) ÷ 17mm X peak force X 9.8 N (to convert to newtons)

70 ÷ 17 = 4.12 X 42 = 172.9 X 9.8 = 1694.8 N



Appendix C-2: Data sheet for thigh and calf girth measurement

Name:		Date		
Group:		Time		
Test:				
				Mean
Right Thigh	(1)....cms	(2)....cms	(3)....cms	
Right Calf	(1)....cms	(2)....cms	(3)....cms	
Left Thigh	(1)....cms	(2)....cms	(3)....cms	
Left Calf	(1)....cms	(2)....cms	(3)....cms	
Left Calf	(1)....cms	(2)....cms	(3)....cms	

Appendix C-3: Data sheet for Skinfold thickness measurement

Name: Date

Group: Time

Test:

				Mean
Triceps	(1).....mm	(2).....mm	(3).....mm	
Subscapular	(1).....mm	(2).....mm	(3).....mm	
Suprailiac	(1).....mm	(2).....mm	(3).....mm	
Abdomen	(1).....mm	(2).....mm	(3).....mm	
Front Thigh	(1).....mm	(2).....mm	(3).....mm	
Back Thigh	(1).....mm	(2).....mm	(3).....mm	
Calf	(1).....mm	(2).....mm	(3).....mm	

Total:

Appendix C-4: Determination of percent body fat and lean body mass by the under water weighing technique

Measurements

1. Weight in air =
2. Vital capacity (VC) = litres X 1000 = cu. cm.
3. Residual volume = 25% VC = cu. cm.
4. Volume of gastro-intestinal track (VGI) = 114.87 cu. cm.
5. Weight in water = chart reading X belt weight/75 - belt weight

   = kgs

Calculations:

6. Total body air (TBA) = VC + RV + VGI (from 2, 3, and 4 above)

   = X .0165 kgs
7. True weight in water = weight in water (5) + total body air (6)

   = kgs
8. Body volume = weight in air (1) - true weight in water (7)
9. Body density = weight in air (1)/body volume (8) X density of water (at water temperature in centigrade)

   = gm/cu. cm
10. Percent fat = 4.570/body density (9) - 4.142 X 100

    = %
11. Fat weight = percent fat (10) X weight in air (1)

    = kgs
12. Lean body mass = weight in air (1) - fat weight (11)

    = kgs

Appendix D: Reliability Coefficients

Appendix D-1: Reliability Coefficie[illegible]

VARIABLE	MEAN	SD	r	r^2
TEST: Max. Isok. Ecct. Strength	3031.5	608.1	.99	.98
RETEST:	3143.7	622.4		
TEST: Max.Isok. Con. Strength	1921.4	547.7	.98	.96
RETEST:	1935.7	480.3		
TEST: Max. Dynamic Strength	128.0	15.0	.96	.92
RETEST:	127.7	14.4		
TEST: Max.Impulsive Force	1747.6	291.0	.97	.94
RETEST:	1796.1	271.2		
TEST: Skinfold Thickness	73.3	26.8	.97	.94
RETEST:	75.1	31.2		
TEST: Body Density	1.066	.014	.98	.96
RETEST:	1.067	.011		
TEST: Right Thigh Girth	54.3	3.7	.98	.96
RETEST:	54.7	3.7		

Appendix D-2 Reliability Coefficients

VARIABLE	MEAN	SD	r	r^2
TEST: Left Thigh Girth	54.0	3.7	.97	.94
RETEST:	54.3	3.8		
TEST: Right Calf Girth	36.5	2.7	.99	.98
RETEST:	36.6	2.7		
TEST: Left Calf Girth	36.5	2.6	.99	.98
RETEST:	54.3	3.8		

Appendix E: Summary of F-Ratios and Probability for Unique Analysis of Variance and Greenhouse-Geiser Conservative Test

Appendix E-1: Unique Analysis (UA) Vs Greenhouse-Geiser (GG) Conservative Test.

Variable	Stats. Procedure	Source of Variation	MS	DF	F-ratio	F-Prob.
Max. Isok. Ecct. Strength	UA	W. Groups	17789800	3	121.86	0.000
	GG	"	17789800	1.9	121.86	0.000
	UA	Group X Time	1989620	9	13.68	0.000
	GG	"	1989620	5.8	13.68	0.000
Max. Isok. Con. Strength	UA	W. Groups	22936600	3	214.57	0.000
	GG	"	22936600	2.5	214.57	0.000
	UA	Group X Time	2276470	9	21.30	0.000
	GG	"	2276470	7.5	21.30	0.000
Max. Dynamic Strength (1-RM)	UA	W. Groups	9482.9	3	239.63	0.000
	GG	"	9482.9	2.6	239.63	0.000
	UA	Group X Time	736.38	9	18.61	0.000
	GG	"	736.38	7.7	18.61	0.000
Max. Impulsive Force	UA	W. Groups	124777.1	3	19.11	0.000
	GG	"	124777.1	2.1	19.11	0.000
	UA	Group X Time	25356.56	9	3.88	0.0003
	GG	"	25356.56	6.4	3.88	0.0015
Lean Body Mass	UA	W. Groups	17.58	3	6.64	0.0004
	GG	"	17.58	2.2	6.46	0.0019
	UA	Group X Time	2.52	9	0.93	0.5055
	GG	"	2.52	6.5	0.93	0.4866
Skinfold Thickness	UA	W. Groups	17.21	3	1.17	0.33
	GG	"	17.21	2.1	1.17	0.32
	UA	Group X Time	72.9	9	4.95	0.000
	GG	"	72.9	6.3	4.95	0.002
Front & Back Thigh Skinfold	UA	W. Groups	28.22	3	0.54	0.659
	GG	"	28.22	2.4	0.54	0.619
	UA	Group X Time	41.68	9	0.79	0.623
	GG	"	41.68	7.2	0.79	0.598
Per cent Body Fat	UA	W. Groups	7.13	3	5.04	0.0026
	GG	"	7.13	2.7	5.04	0.0038
	UA	Group X Time	1.80	9	1.27	0.2589
	GG	"	1.80	8.1	1.27	0.2652

Appendix E-2: Unique Analysis (UA) Vs Greenhouse-Geiser (GG) Conservative Test.

Variable	Stats. Procedure	Source Variation	ofMS	DF	F-ratio	F-Prob.
Right Thigh Girth	UA	W. Groups	17.98	3	88.42	0.000
	GG	"	17.98	2.3	88.42	0.000
	UA	Group X Time	2.27	9	11.14	0.000
	GG	"	2.27	6.8	11.14	0.000
Left Thigh Girth	UA	W. Groups	17.34	3	73.59	0.000
	GG	"	17.34	2.7	73.59	0.000
	UA	Group X Time	1.84	9	7.82	0.000
	GG	"	1.84	8.0	7.82	0.000
Right Calf Girth	UA	W. Groups	2.65	3	19.95	0.000
	GG	"	2.65	2.3	19.95	0.000
	UA	Group X Time	0.35	9	2.62	0.009
	GG	"	0.35	7.0	2.62	0.016
Left Calf Girth	UA	W. Groups	1.42	3	7.74	0.0001
	GG	"	1.42	2.1	7.74	0.0006
	UA	Group X Time	0.43	9	2.33	0.019
	GG	"	0.43	6.4	2.33	0.036

Appendix F: Correlation Matrix for the Dependent Variables for the Groups

Correlation Coefficients of Dependent Variables for Group 1:

Pretest

	Max. Isokinetic Ecct. Strength	Max. Isokinetic Con. Strength	Max. Impulsive Force	Max. Dynamic Strength (1-RM)	Right Thigh Girth	Right Calf Girth	Left Thigh Girth	Left Calf Girth	Lean Body Mass	Percent Body Fat	Skinfold Thickness	Body Weight
Max Isokinetic Ecct. Strength	1.0											
Max. Isokinetic Con. Strength	.66*	1.0										
Max. Impulsive Force	-.11	.24	1.0									
Max. Dynamic Strength (1-RM)	.05	.24	.50	1.0								
Right Thigh Girth	.05	.02	.38	.12	1.0							
Right Calf Girth	-.08	.11	.58*	.38	.90**	1.0						
Left Thigh Girth	.01	-.06	.38	.08	.99**	.87**	1.0					
Left Calf Girth	-.11	-.02	.50	.34	.94**	.98**	.93**	1.0				
Lean Body Mass	-.16	-.10	.80**	.56*	.70*	.78**	.71*	.80**	1.0			
Percent Body Fat	.18	.05	-.02	-.31	.83**	.62*	.83**	.66*	.24	1.0		
Skinfold Thickness	-.09	-.19	.04	-.31	-.70*	.55*	.84**	.64*	.33	.89**	1.0	
Body Weight	-.11	-.26	-.41	-.25	-.70*	-.82**	.20	.80**	-.59*	-.42	-.25	1.0

Posttest

	Max. Isokinetic Ecct. Strength	Max. Isokinetic Con. Strength	Max. Impulsive Force	Max. Dynamic Strength (1-RM)	Right Thigh Girth	Right Calf Girth	Left Thigh Girth	Left Calf Girth	Lean Body Mass	Percent Body Fat	Skinfold Thickness	Body Weight
Max Isokinetic Ecct. Strength	1.0											
Max. Isokinetic Con. Strength	.30	1.0										
Max. Impulsive Force	-.03	.13	1.0									
Max. Dynamic Strength (1-RM)	-.46	-.39	.60*	1.0								
Right Thigh Girth	.23	.14	.67*	.18	1.0							
Right Calf Girth	.27	.06	.73**	.39	.89**	1.0						
Left Thigh Girth	.28	.16	.62*	.10	.99**	.85**	1.0					
Left Calf Girth	.28	.08	.69**	.34	.90**	.99**	.87**	1.0				
Lean Body Mass	.09	.01	.88**	.56*	.78**	.83**	.75**	.81**	1.0			
Percent Body Fat	.35	.22	.31	-.32	.81**	.54*	.82**	.58*	.30	1.0		
Skinfold Thickness	.11	.29	.37	-.17	.84**	.56*	.88**	.61*	.42	.90**	1.0	
Body Weight	-.47	.06	-.43	-.24	-.62*	.83**	-.59*	.82**	.58*	.24	-.22	1.0

* Denotes Significance at .05 level. ** Denotes Significance at .01 level.

Correlation Coefficients of Dependent Variables for Group 2:

Pretest

	Max. Isokinetic Ecct. Strength	Max. Isokinetic Con. Strength	Max. Impulsive Force	Max. Dynamic Strength (1-RM)	Right Thigh Girth	Right Calf Girth	Left Thigh Girth	Left Calf Girth	Lean Body Mass	Percent Body Fat	Skinfold Thickness	Body Weight
Max Isokinetic Ecct. Strength	1.0											
Max. Isokinetic Con. Strength	.33	1.0										
Max. Impulsive Force	-.03	.20	1.0									
Max. Dynamic Strength (1-RM)	.07	.33	.50	1.0								
Right Thigh Girth	.04	.40	.26	.34	1.0							
Right Calf Girth	.23	.35	.38	.45	.89**	1.0						
Left Thigh Girth	.04	.39	.13	.27	.97**	.90**	1.0					
Left Calf Girth	.03	.14	.20	.33	.80**	.87**	.89**	1.0				
Lean Body Mass	.07	.36	.38	.26	.58*	.66*	.61*	.63*	1.0			
Percent Body Fat	-.56*	-.03	-.27	.05	.41	.46	.42	.36	.11	1.0		
Skinfold Thickness	-.15	.36	-.04	.10	.78**	.62*	[illegible]	.62*	.25	.45	1.0	
Body Weight	-.04	.40	.11	.21	.83**	.80**	.84**	.72**	.86**	.19	.42	1.0

Posttest

	Max. Isokinetic Ecct. Strength	Max. Isokinetic Con. Strength	Max. Impulsive Force	Max. Dynamic Strength (1-RM)	Right Thigh Girth	Right Calf Girth	Left Thigh Girth	Left Calf Girth	Lean Body Mass	Percent Body Fat	Skinfold Thickness	Body Weight
Max Isokinetic Ecct. Strength	1.0											
Max. Isokinetic Con. Strength	.61*	1.0										
Max. Impulsive Force	.18	.19	1.0									
Max. Dynamic Strength (1-RM)	.14	.20	.60*	1.0								
Right Thigh Girth	.70**	.42	.28	.33	1.0							
Right Calf Girth	.56*	.11	.22	.45	.90**	1.0						
Left Thigh Girth	.69*	.39	.28	.33	.99**	.89**	1.0					
Left Calf Girth	.49	.11	.13	.40	.85**	.92**	.90**	1.0				
Lean Body Mass	.65*	.61*	.60*	.52	.75**	.55	.75**	.60*	1.0			
Percent Body Fat	.24	-.13	-.28	-.12	.43	.62*	.37	.45	.25	1.0		
Skinfold Thickness	.44	.20	.08	-.04	.74**	.64*	.72**	.50	.44	.56*	1.0	
Body Weight	.70**	.48	.46	.46	.90**	.80**	.91**	.85**	.92**	.21	.45	1.0

* Denotes Significance at .05 level. ** Denotes Significance at .01 level.

Correlation Coefficients of Dependent Variables

Pretest

	Max. Isokinetic Ecct. Strength	Max. Isokinetic Con. Strength	Max. Impulsive Force	Max. Dynamic Strength (1-RM)	Right Thigh Girth	Right Calf Girth	Left Thigh Girth	Left Calf Girth	Lean Body Mass	Percent Body Fat	Skinfold Thickness	Body Weight
Max Isokinetic Ecct. Strength	1.0											
Max. Isokinetic Con. Strength	.80**	1.0										
Max. Impulsive Force	.80**	.76**	1.o									
Max. Dynamic Strength (1-RM)	.62*	.40	.67*	1.0								
Right Thigh Girth	.80**	.65*	.81**	.79**	1.0							
Right Calf Girth	.85**	.80**	.72**	.58*	.81**	1.0						
Left Thigh Girth	.80**	.62*	.78**	.81**	.99**	.80**	1.0					
Left Calf Girth	.87**	.78**	.69*	.57*	.80**	.99**	.78**	1.0				
Lean Body Mass	.77**	.69*	.84**	.82**	.87**	.83**	.87**	.82**	1.0			
Percent Body Fat	.12	-.09	-.02	.03	.25	-.06	.25	-.06	.22	1.0		
Skinfold Thickness	.37	.20	.49	.24	.63*	.21	.62*	.20	.28	.66*	1.0	
Body Weight	-.30	.09	.04	-.36	-.24	-.40	-.28	.46	-.36	.21	.23	1.0

Posttest

	Max. Isokinetic Ecct. Strength	Max. Isokinetic Con. Strength	Max. Impulsive Force	Max. Dynamic Strength (1-RM)	Right Thigh Girth	Right Calf Girth	Left Thigh Girth	Left Calf Girth	Lean Body Mass	Percent Body Fat	Skinfold Thickness	Body Weight
Max Isokinetic Ecct. Strength	1.0											
Max. Isokinetic Con. Strength	.49	1.0										
Max. Impulsive Force	.58*	.08	1.0									
Max. Dynamic Strength (1-RM)	.60*	-.13	.80**	1.0								
Right Thigh Girth	.45	.01	.95**	.66*	1.0							
Right Calf Girth	.49	.05	.77**	.51	.81**	1.0						
Left Thigh Girth	.45	.02	.95**	.68*	.99**	.79**	1.0					
Left Calf Girth	.45	.07	.71**	.43	.77**	.99**	.74**	1.0				
Lean Body Mass	.48	-.09	.87**	.79**	.91**	.83**	.90**	.78**	1.0			
Percent Body Fat	.22	.17	.43	.01	.38	.22	.34	.19	-.01	1.0		
Skinfold Thickness	.09	.06	.70**	.24	.74**	.42	.76**	.38	.43	.70**	1.0	
Body Weight	-.31	.39	.29	-.52	.70**	-.38	-.16	-.38	-.35	.20	.15	1.0

* Denotes Significance at .05 level. ** Denotes Significance at .01 level.

Correlation Coefficients of Dependent Variables for Group 4:

Pretest

	Max. Isokinetic Ecct. Strength	Max. Isokinetic Con. Strength	Max. Impulsive Force	Max. Dynamic Strength (1-RM)	Right Thigh Girth	Right Calf Girth	Left Thigh Girth	Left Calf Girth	Lean Body Mass	Percent Body Fat	Skinfold Thickness	Body Weight
Max Isokinetic Ecct. Strength	1.0											
Max. Isokinetic Con. Strength	.65*	1.0										
Max. Impulsive Force	.37	-.10	1.0									
Max. Dynamic Strength (1-RM)	.88**	.62*	.48	1.0								
Right Thigh Girth	.35	.64*	-.16	.55*	1.0							
Right Calf Girth	.22	.17	.01	.28	.53*	1.0						
Left Thigh Girth	.33	.60*	-.16	.53*	.99**	.53*	1.0					
Left Calf Girth	.24	.13	.03	.30	.54*	.99**	.54*	1.0				
Lean Body Mass	.49	.72**	.22	.65*	.54*	-.06	.52*	-.07	1.0			
Percent Body Fat	-.49	-.61*	.38	-.30	-.30	-.01	-.27	.01	-.58*	1.0		
Skinfold Thickness	-.11	.12	.14	.04	.29	-.43	.29	-.43	.38	.18	1.0	
Body Weight	.08	-.34	.35	.18	.20	.67*	.24	.74**	-.15	.19	-.29	1.0

Postest

	Max. Isokinetic Ecct. Strength	Max. Isokinetic Con. Strength	Max. Impulsive Force	Max. Dynamic Strength (1-RM)	Right Thigh Girth	Right Calf Girth	Left Thigh Girth	Left Calf Girth	Lean Body Mass	Percent Body Fat	Skinfold Thickness	Body Weight
Max Isokinetic Ecct. Strength	1.0											
Max. Isokinetic Con. Strength	.61*	1.0										
Max. Impulsive Force	.52	.32	1.0									
Max. Dynamic Strength (1-RM)	.78**	.62*	.84**	1.0								
Right Thigh Girth	.44	.51	.20	.37	1.0							
Right Calf Girth	.27	.42	.31	.39	.34	1.0						
Left Thigh Girth	.46	.59*	.17	.40	.98**	.35	1.0					
Left Calf Girth	.24	.56*	.39	.43	.35	.87**	.33	1.0				
Lean Body Mass	.63*	.65*	.50	.75**	.43	-.06	.45	.21	1.0			
Percent Body Fat	-.45	-.64*	.01	-.38	-.08	-.30	-.11	-.45	-.51	1.0		
Skinfold Thickness	.08	-.01	.12	.20	.44	-.40	.45	-.40	.37	.35	1.0	
Body Weight	.06	-.03	.57*	.32	.19	.61*	.09	.54*	-.11	.06	-.35	1.0

* Denotes Significance at .05 level. ** Denotes Significance at .01 level.

Appendix G: Descriptive statistics of all dependent variables for the groups

Table 43-DESCRIPTIVE STATISTICS FOR MAX. ISOKINETIC-ECCENTRIC STRENGTH

Test1:	N	MEAN	SD	SE	MIN	MAX
Group1:	11	2765.5	953.8	287.6	1460	5204
Group2:	10	2731.1	589.9	186.6	1872	3499
Group3:	10	2917.5	[illegible]	211.8	1548	4028
Group4:	11	3133.4	[illegible]	[illegible]	1754	4479
Test2:						
Group1:	11	2948.0	709.7	214.0	2009	4410
Group2:	10	3296.7	536.7	169.7	2401	4116
Group3:	10	3372.4	903.0	285.6	1980	4381
Group4:	11	3054.0	809.7	244.1	1676	4087
Test3:						
Group1:	11	3770.2	775.9	233.9	2646	4714
Group2:	10	4344.9	429.6	135.9	3822	5243
Group3:	10	4230.7	795.0	252.4	2940	5449
Group4:	11	3154.3	780.4	235.3	1774	4116
Test4:						
Group1:	11	4114.2	704.3	212.4	3175	5292
Group2:	10	4988.8	443.3	140.2	4390	5772
Group3:	10	4931.3	824.8	260.8	4067	6017
Group4:	11	3218.8	813.9	245.4	1960	4312

Table 44-DESCRIPTIVE STATISTICS FOR MAX. ISOK. CON. STRENGTH

Test1:	N	MEAN	SD	SE	MIN	MAX
Group1:	11	1726.5	397.7	119.9	1058	2440
Group2:	10	1687.6	367.9	116.3	1343	2362
Group3:	10	2191.3	684.6	216.5	1091	2901
Group4:	11	1910.0	585.4	176.5	1019	2891
Test2:						
Group1:	11	1772.4	403.4	121.6	1274	2362
Group2:	10	2321.6	495.7	156.8	1588	2950
Group3:	10	2573.5	637.6	201.6	1686	3371
Group4:	11	1840.6	643.1	193.9	1117	2793
Test3:						
Group1:	11	2521.2	533.3	160.8	1744	3332
Group2:	10	3079.8	645.2	204.0	2274	4390
Group3:	10	3096.9	732.9	231.8	1872	4312
Group4:	11	1996.5	692.9	208.9	1186	3254
Test4:						
Group1:	11	3381.1	302.6	91.2	2940	3930
Group2:	10	4308.9	571.5	180.7	3420	5429
Group3:	10	4416.2	369.8	116.9	3969	5018
Group4:	11	2089.1	711.7	214.6	1137	3420

Table 45-DESCRIPTIVE STATISTICS FOR MAX. DYNAMIC STRENGTH (1-RM)

Test1:	N	MEAN	SD	SE	MIN	MAX
Group1:	11	124.4	15.5	4.7	93	150
Group2:	10	124.5	13.4	4.2	100	115
Group3:	10	126.5	29.5	9.3	80	180
Group4:	11	123.2	18.3	5.5	90	145
Test2:						
Group1:	11	149.0	20.9	6.3	105	185
Group2:	10	144.0	15.2	4.8	120	170
Group3:	10	157.0	28.9	9.2	120	210
Group4:	11	128.6	15.3	4.6	100	150
Test3:						
Group1:	11	160.4	22.0	6.7	115	190
Group2:	10	154.0	15.4	4.9	130	185
Group3:	10	169.5	28.9	9.1	125	220
Group4:	11	130.9	15.8	4.8	100	150
Test4:						
Group1:	11	169.8	17.0	5.1	145	200
Group2:	10	152.8	16.2	5.1	130	185
Group3:	10	170.5	36.4	11.5	130	255
Group4:	11	133.4	18.4	5.5	95	155

Table 46-DESCRIPTIVE STATISTICS FOR MAX. IMPULSIVE FORCE

Test1:	N	MEAN	SD	SE	MIN	MAX
Group1:	11	1721.2	276.6	83.4	1435	2280
Group2:	10	1743.5	197.2	62.4	1579	2151
Group3:	10	1797.1	294.8	93.2	1213	2096
Group4:	11	1650.2	184.3	55.6	1423	1986
Test2:						
Group1:	11	1742.3	272.8	82.3	1431	2273
Group2:	10	1810.5	184.9	58.5	1632	2170
Group3:	10	1905.5	388.2	122.8	1274	2599
Group4:	11	1674.0	189.6	57.2	1401	1979
Test3:						
Group1:	11	1790.2	260.8	78.6	1549	2299
Group2:	10	1851.6	181.3	57.3	1650	2256
Group3:	10	2019.2	376.3	119.0	1409	2646
Group4:	11	1683.9	179.9	54.2	1410	1950
Test4:						
Group1:	11	1763.2	257.4	77.6	1463	2277
Group2:	10	1959.4	182.4	57.7	1750	2277
Group3:	10	1991.2	328.5	100.7	1585	2564
Group4:	11	1672.0	166.0	50.0	1418	1934

Table 47-DESCRIPTIVE STATISTICS FOR LEAN BODY MASS

Test1:	N	MEAN	SD	SE	MIN	MAX
Group1:	11	65.5	8.1	2.4	55.0	84.2
Group2:	10	67.3	4.7	1.5	61.0	74.5
Group3:	10	65.2	11.8	3.7	45.4	88.3
Group4:	11	58.8	10.3	3.1	39.0	76.3
Test2:						
Group1:	[illegible]	[illegible]	9.7	2.9	51.6	87.5
Group2:	10	[illegible]	4.9	1.6	61.0	75.5
Group3:	10	65.2	11.8	3.7	46.5	88.7
Group4:	11	58.3	9.8	2.9	39.2	75.0
Test3:						
Group1:	11	66.7	8.8	2.7	57.1	88.8
Group2:	10	69.2	5.8	1.8	62.0	77.9
Group3:	10	65.7	11.8	3.7	46.5	89.0
Group4:	11	58.8	9.9	3.0	37.5	73.8
Test4:						
Group1:	11	66.8	9.3	2.8	56.5	89.0
Group2:	10	69.8	5.5	1.8	62.2	78.2
Group3:	10	66.7	11.5	3.6	47.6	89.2
Group4:	11	59.3	10.7	3.2	37.7	76.8

Table 48-DESCRIPTIVE STATISTICS FOR SKINFOLD THICKNESS

Test1:	N	MEAN	SD	SE	MIN	MAX
Group1:	11	104.1	54.8	16.5	39.0	194.0
Group2:	10	86.9	21.0	6.7	48.0	119.0
Group3:	10	90.4	40.4	12.8	51.0	189.0
Group4:	11	86.2	26.0	7.9	45.0	129.0
Test2:						
Group1:	11	104.6	52.8	15.9	41.0	191.0
Group2:	10	87.8	20.2	6.4	52.0	120.0
Group3:	10	88.2	37.9	12.0	49.0	180.0
Group4:	11	92.8	29.4	8.9	48.0	146.0
Test3:						
Group1:	11	103.3	53.2	16.0	37.0	190.0
Group2:	10	85.6	22.5	7.1	47.0	121.0
Group3:	10	88.7	38.3	12.1	49.0	180.0
Group4:	11	92.5	27.7	8.4	49.0	140.0
Test4:						
Group1:	11	101.6	53.1	16.0	39.0	185.0
Group2:	10	84.4	21.4	6.8	46.0	118.0
Group3:	10	90.1	40.6	12.8	48.0	188.0
Group4:	11	96.0	30.2	9.1	48.0	145.0

Table 49-DESCRIPTIVE STATISTICS FOR PERCENT BODY FAT

Test1:	N	MEAN	SD	SE	MIN	MAX
Group1:	11	15.0	7.0	2.1	4.7	27.1
Group2:	10	11.1	3.4	1.1	6.6	15.9
Group3:	10	13.6	3.8	1.2	7.8	19.6
Group4:	11	11.7	4.3	1.3	5.3	18.1
Test2:						
Group1:	11	14.1	7.1	2.1	4.9	27.9
Group2:	10	10.7	3.1	1.0	6.1	15.3
Group3:	10	13.4	2.8	.9	8.5	17.5
Group4:	11	11.7	4.7	1.3	5.0	18.4
Test3:						
Group1:	11	13.6	6.2	1.8	4.8	24.4
Group2:	10	11.3	3.3	1.0	6.7	17.3
Group3:	10	13.3	3.3	1.1	8.5	19.2
Group4:	11	11.2	3.7	1.1	3.6	15.9
Test4:						
Group1:	11	12.7	6.2	1.9	4.8	24.4
Group2:	10	10.3	2.8	.9	6.0	14.8
Group3:	10	12.8	3.5	1.1	8.0	18.9
Group4:	11	11.4	3.8	1.1	5.1	16.9

Table 50-DESCRIPTIVE STATISTICS FOR RIGHT THIGH GIRTH

Test1:	N	MEAN	SD	SE	MIN	MAX
Group1:	11	57.0	5.8	1.7	52.0	72.4
Group2:	10	56.8	3.0	.96	53.0	62.5
Group3:	10	56.4	5.7	1.8	46.4	66.0
Group4:	11	55.8	2.1	.62	52.5	60.0
Test2:						
Group1:	11	57.2	5.8	1.8	52.0	72.8
Group2:	10	58.3	2.6	.84	55.0	63.5
Group3:	10	57.8	5.8	1.8	47.5	66.5
Group4:	11	55.0	2.1	.63	52.5	54.6
Test3:						
Group1:	11	58.4	5.9	1.8	53.0	73.5
Group2:	10	58.4	2.5	.80	55.7	63.5
Group3:	10	58.3	2.8	1.8	48.0	67.5
Group4:	11	55.9	2.2	.70	52.0	59.5
Test4:						
Group1:	11	58.5	5.9	1.8	53.5	73.5
Group2:	10	58.8	2.5	.80	56.0	64.0
Group3:	10	58.6	5.8	1.8	48.5	67.5
Group4:	11	56.0	1.9	.60	52.3	59.0

Table 51-DESCRIPTIVE STATISTICS FOR LEFT THIGH GIRTH

Test1:	N	MEAN	SD	SE	MIN	MAX
Group1:	11	56.4	6.1	1.9	50.0	52.3
Group2:	10	56.5	2.9	.90	53.5	63.0
Group3:	10	56.4	6.0	1.9	46.2	67.0
Group4:	11	56.0	2.1	.64	52.5	60.0
Test2:						
Group1:	11	56.9	6.1	1.8	51.0	72.4
Group2:	10	58.0	2.7	.90	55.0	63.0
Group3:	10	57.7	6.0	1.9	48.0	67.5
Group4:	11	56.1	2.2	7.0	53.0	60.0
Test3:						
Group1:	11	57.8	6.3	1.9	51.0	73.5
Group2:	10	58.3	2.8	.80	55.0	63.5
Group3:	10	58.0	5.8	1.8	48.5	67.5
Group4:	11	56.1	2.2	.70	53.0	60.0
Test4:						
Group1:	11	58.0	6.3	1.9	51.0	73.5
Group2:	10	58.6	2.7	.90	55.5	64.0
Group3:	10	58.3	6.0	1.9	67.5	54.0
Group4:	11	56.2	2.0	.60	52.5	59.0

Table 52-DESCRIPTIVE STATISTICS FOR RIGHT CALF GIRTH

Test1:	N	MEAN	SD	SE	MIN	MAX
Group1:	11	37.1	3.9	1.2	33.4	48.3
Group2:	10	37.3	2.5	.80	42.2	42.2
Group3:	10	37.7	2.9	.9	43.3	43.3
Group4:	11	37.3	2.0	.60	34.0	40.5
Test2:						
Group1:	11	37.2	3.9	1.2	34.5	48.5
Group2:	10	37.9	2.3	.70	35.3	42.7
Group3:	10	38.2	2.6	.8	34.6	43.0
Group4:	11	37.6	1.7	.50	35.0	40.0
Test3:						
Group1:	11	37.6	3.8	1.1	34.5	48.5
Group2:	10	37.9	2.2	.70	35.3	42.5
Group3:	10	38.4	2.6	.8	34.5	43.4
Group4:	11	37.4	1.5	.50	35.0	39.5
Test4:						
Group1:	11	37.6	3.8	1.2	34.3	48.5
Group2:	10	38.1	2.2	.70	35.0	42.5
Group3:	10	38.5	2.6	.8	34.5	43.5
Group4:	11	37.4	1.5	.50	35.0	39.3

Table 53-DESCRIPTIVE STATISTICS FOR LEFT CALF GIRTH

Test1:	N	MEAN	SD	SE	MIN	MAX
Group1:	11	37.2	3.8	1.2	34.0	48.0
Group2:	10	37.5	2.4	.80	34.5	42.2
Group3:	10	37.7	3.1	1.0	33.3	44.0
Group4:	11	37.4	2.1	.60	34.0	40.5
Test2:						
Group1:	11	37.0	4.0	1.2	34.0	48.5
Group2:	10	37.9	2.0	.60	35.5	42.3
Group3:	10	38.2	2.8	.9	34.7	43.6
Group4:	11	37.7	1.7	.50	35.0	40.0
Test3:						
Group1:	11	37.3	3.9	1.2	34.0	48.5
Group2:	10	38.0	2.0	.60	35.8	42.5
Group3:	10	38.3	2.6	.8	34.5	43.4
Group4:	11	37.6	1.6	.50	35.0	40.0
Test4:						
Group1:	11	37.4	3.9	1.2	34.0	48.5
Group2:	10	38.1	2.2	.70	35.5	42.5
Group3:	10	38.5	2.7	.9	34.5	43.5
Group4:	11	37.3	1.3	.40	35.0	40.0