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DIANNA L. SATRE

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AN EXAMINATION OF AEROBIC POWER
AND BODY COMPOSITIONAL CHANGES ASSOCIATED
WITH OMNIKINETIC TRAINING

submitted by Dianna L. Satre
in partial fulfilment of the requirements for the degree of
Master of Science.

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ABSTRACT

This study was comprised of 30 volunteer male and female subjects who trained for a ten week period using hydraulic resistive equipment, and were compared to a control group consisting of 29 male and female subjects. All subjects underwent a pre-test and a post-test designed to measure aerobic power and per cent body fat. T-tests demonstrated there was no significant difference between these groups prior to training with respect to VO_2max measures. However, three way analysis of variance on post-test VO_2max demonstrated a significant difference between these groups following training. The results of this analysis were not significantly influenced by sex, age or initial VO_2max. An examination of the treatment group means from pre-test to post-test indicated that the training group experienced a 12% increase in aerobic power. T-tests also demonstrated no significant difference between the control group and the training group prior to training with respect to per cent body fat measures. However, a three way analysis of variance also demonstrated a significant difference between these groups following training. An examination of the treatment group means for per cent body fat indicated that the training group experienced an absolute decrease of 1.87%. This absolute decrease is representative of a relative decrease of 8.1%. The three way analysis of variance on post-test per cent body fat also revealed that those individuals who were initially classified as showing a high percentage of body fat tended to experience greater decreases in body fat.

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CHAPTER I

STATEMENT OF THE PROBLEM

Introduction

The value of resistance exercise as a training mode has long been recognized. As early as 1948, Delorme and Watkins (28) advocated the first isotonic progressive resistance program. Later, in 1953, Hettinger and Muller (44) initiated research on isometric weight training programs. More recently, research has focused on resistance training involving isokinetic exercise which "allows movement at a mechanically fixed rate of speed and offers resistance inherently proportional to the muscle's dynamic tension developing capacity at every point in its shortening range." (59)

A number of variable resistance exercise systems have been designed in an effort to make the best practical use of training principles. Many of these systems consist of a number of machines designed to allow for joint movements which will accommodate the development of specific muscle groups. Each system is unique in the manner in which it provides variable resistance throughout the range of motion.

One of the most recent exercise systems developed is the Hydra-Gym system which is based on a new concept in resistance training referred to as omnikinetic training. Omnikinetics, as introduced by the manufacturers of Hydra-Gym equipment, is similar to isokinetic exercise in that it involves dynamic muscular contractions in which the force generated is, for all practical purposes, equal to the resistance. (59) However, omnikinetics varies both the speed of movement and the resistance, whereas isokinetics involves constant velocity.

The Hydra-Gym equipment operates through the use of a hydraulic cylinder which has a valve setting to increase the resistance through any given range of motion. As the lever arm of the machine is forced to move by the muscle, hydraulic fluid is forced through an opening inside the cylinder. The size of this opening is determined by setting the valve. "The uniqueness of Hydra's omnikinetic machines lies partly in the fact that while the valve is pre-set, the rate at which the limb moves against the resistance of the cylinder is determined not so much by the machine as it is by the contractile properties of the user's muscle groups." (59:11) Thus, at any given valve setting, the user receives optimal resistance with each repetition performed, even as the muscle fatigues. Although the speed of movement may decrease with muscle fatigue, the effective resistance load remains the same.

Most of this hydraulic resistive apparatus also develops balanced muscle groups by working both agonistic and antagonistic muscles during the same exercise set. This tends to reduce the time needed to work all the major muscle groups and provides a rhythmic pumping of blood through the muscles.

Such a system may have practical advantages in conditioning the cardiovascular system since anything from low power output with small muscle groups to ultra-high concurrent power outputs with larger muscle groups can be achieved. (73) If a training program designed for use on this equipment were to take into consideration the usual guidelines followed when prescribing a program for improvement of aerobic power, then theoretically, there should be an improvement.

The Problem

The primary purpose of this study was to critically examine whether any significant changes occur in aerobic power when individuals are subjected to a circuit training program utilizing hydraulic resistive equipment.

A secondary purpose of the study was to observe any changes which may have occured in body composition, specifically per cent body fat, as a result of this program.

Need for the Study

The benefits of regular physical activity are well documented. (6,39,64,67,79,84) In an effort to involve a greater percentage of our general population in regular activity, there is a need to direct research at finding alternative modes of exercise suitable for achieving a desirable personal level of physical fitness.

Further, much of the research conducted on resistance exercise to date is primarily concerned with strength gains rather than gains in aerobic power. (10,19,47,74,80,96) There is a need to critically examine all the possible benefits of resistance exercise training programs, in an effort to attain maximal benefits from them.

Since no research has currently been conducted using hydraulic resistive equipment there is also a need to critically examine the training benefits that may be associated with various programs using this equipment.

Null Hypothesis

The null hypothesis upon which this investigation was based asserts that no significant change would occur in aerobic power or per cent body fat as a result of the training program introduced here.

Limitations

1. The study was limited to volunteer subjects between the ages of 18 and 45.
2. The training program was limited to a maximum of thirty minutes per session, three times per week for a period of ten weeks.
3. The study was limited to a series of ten exercises using Hydra-Gym equipment.
4. Training sessions were scheduled to accommodate the individuals participating in the program and the only stipulation was that they did not train three days consecutively.
5. There was no control over the time of day for testing subjects.

Delimitations

1. Subjects participating in the program were asked to maintain their current patterns of physical activity throughout the ten week training period.
2. An effort was made to control alcohol, cigarette, food, caffeine and excessive activity prior to testing sessions by providing an instruction sheet for each subject before they were tested.
3. An attempt was made to match the control group with the training group by having each member of the training group choose a control

subject with characteristics similar to themselves.

4. Training sessions were supervised in an effort to achieve maximal effort from subjects during each session.

Definition of Terms

1. Resistance Exercise - a muscular contraction against any form of external resistance.
2. Variable Resistance Exercise - a muscular contraction against a movable resistance which varies in magnitude throughout the range of motion.
3. Isokinetic Exercise - a form of variable resistance exercise in which muscular contractions are performed at a constant velocity and resistance is accommodating to the maximum muscle force throughout this range of motion. (58)
4. Isotonic Exercise - a form of exercise in which the muscle shortens with varying tension while lifting a constant load. (39)
5. Isometric Exercise - a form of exercise in which tension is developed, but no change occurs in length. (39)
6. Omnikinetics - a form of variable resistance exercise that allows for optimal self accommodating resistance at varying speeds which are dependent upon the muscle's contractile properties.
7. Agonist - the muscle group which initiates a particular movement, usually through a shortening of the muscles involved.
8. Antagonist - the muscle group which opposes the action of the agonist.

9. Power Output - an expression of the amount of work performed per unit of time.

10. Strength - the force a muscle or muscle group can exert against a resistance in one maximal effort. (39)

11. Interval Program - a program characterized by short but regularly repeated periods of work interspersed with appropriate periods of relief.

12. Aerobic Power - (VO_2max, MVO_2) - the rate at which oxygen is transported to and consumed by the working muscles.

CHAPTER II

REVIEW OF LITERATURE

A considerable amount of research has focused on variable resistance training throughout the years. However, to date no research has been conducted using hydraulic resistive equipment which was used in this study. It therefore became necessary to review the literature of varied related areas in order to develop a suitable training program for this study. The review of literature has thus been organized under the following headings; training benefits associated with variable resistance training programs, a comparision of interval and continuous training and finally, considerations in developing an aerobic training program.

Further, there are a number of testing procedures utilized to measure aerobic power and per cent body fat and it becomes necessary to review the literature in this area in order to assess the available techniques. This literature will be reviewed under the following headings; measuring aerobic power and techniques for assessing body composition.

Training Benefits Associated with Resistance Exercise Programs

Over the years much of the literature dealing with resistance exercise has focused on strength gains and a comparison of strength gains observed for different types of resistance exercise.

Such research began with the work of Delorme and Watkins (28) who first attempted to systematize procedures for isotonic training. The work protocol of Delorme and Watkins for load-resisting exercise, commonly referred to as progressive resistance exercise (PRE), set the stage for further research dealing with alternative techniques for PRE and comparisons of these different techniques. (10,17,62,103)

The use of isometric exercise as a means of producing strength gains also received considerable attention in the early research dealing with resistance exercise. (23,44,63)

Both types of exercise have proven effective at improving strength gains but comparisons between these two types of training has produced conflicting results. Some investigators have reported isotonic training to be superior to isometric training (11,26,77) while others have reported isometric training to be superior. (44,68) There has also been research which demonstrates no significant difference in strength gains produced by either isotonic or isometric exercise. (9,19,80)

The conflicting evidence with regards to the comparison between isometric and isotonic exercise is partially explained by the difficulty investigators encounter when attempting to equalize the intensity of training for the two methods due to the obvious difficulty equating work loads. Further, the technique used to measure strength gains will strongly influence the results, due to the specificity of training. (6,20,93)

In the mid-to-late sixties a new concept of resistance exercise called isokinetic exercise emerged. (47,73) "The isokinetic contraction resembles the isotonic contraction, since the joint moves through a range of motion, but the speed of movement may be held constant by a special device." (20:83) This allows for the development of maximal tension throughout the full range of motion rather than the muscle groups contracting at different percentages of maximum through the range of motion as is the case with isotonic exercise.(73) Isokinetics also allows for training speeds to vary from 0^{o} to 360^{o} per second. "Matching the speed of training to the speed of performance may be important in light of recent work concerning the specificity of training." (74:262)

Thus far the studies investigating isokinetic training procedures are few and are somewhat limited in scope. (47,58,66,74,92)

Pipes and Wilmore (74:262) investigated differences between isotonic and isokinetic training procedures with regards to their "ability to affect changes in muscular strength, body composition, anthropometic measures and selected motor performance tasks." Strength gains were significant for both the isotonic group and for the two isokinetic groups (high speed and low speed) as compared to a control group. Both isokinetic groups also exhibited significantly greater strength gains than the isotonic group and the high speed isokinetic group showed significantly greater strength gains than the low speed group, even when both groups were tested at low speeds.

Thistle et al. (92) compared all three types of resistance exercise: isometric, isotonic and isokinetic. Following an eight week training session, the isokinetic group achieved significantly greater strength gains than did either the isotonic or isometric group. The isotonic group also achieved significantly greater gains than did the isometric group.

To date only one study has made an effort to compare two well known variable resistance exercise systems, which are the Nautilus equipment and the Universal Gym equipment. Coleman (22) had one group train on each system for a period of ten weeks. The program utilized with each system was based on the protocol recommended by the manufacturers of each system. The Nautilus group performed one set of each exercise using a weight load that could be lifted between 10 and 12 times. The Universal Gym group performed two sets of each exercise using weight loads equal to ten RM and eight RM, respectively. Significant gains in strength were reported for both groups, with no significant difference between the two training groups.

Although much of the literature to this point has concentrated on strength gains as a result of varying types of resistive exercise, there is also considerable evidence to support changes in body composition as well. Significant increases in lean body weight and decreases in absolute and relative body weight are well documented for isotonic weight training. (16,21,24,60,74,96)

Wilmore (96) examined body compositional changes in men and women as the result of a ten week progressive weight training program. The body composition measures used were lean body weight, absolute and relative body fat as determined by hydrostatic weighing, seven skinfolds and finally, 15 and 17 girths respectively for women and men. Significant reductions in five of seven skinfolds were observed in women, but only one skinfold decreased in men. The absolute decrease in per cent body fat was 1.86 and 1.32 for women and men, respectively. This change reflected a relative decrease in body fat of 7.59 per cent and 9.99 per cent in women and men respectively.

Clements (21) also reported a significant decrease in body fat as the result of a 14 week circuit training program. Subjects trained three times per week for 35 minutes per session. Each session consisted of a series of ten exercises.

Body composition was assessed using three skinfold measurements to determine body density which was then substituted into the formula of Keys and Brozek (54) to determine per cent body fat. The training group experienced a significant decrease in body fat when compared to a control group. Further, an initially higher fat group experienced a significantly greater decrease in body fat than did an initially low fat group.

Mayhew and Gross (60) evaluated the effects of circuit weight training on the body composition of college women. Body composition was assessed by seven skinfolds, four skeletal diameteres, eight muscular girths and total body potassium. The training group exercised 40 minutes per session, three times per week for nine weeks. Two sets of exercises were performed during each workout using the ten repetitions maximum technique. (28) Skinfold thicknesses were unaffected but there was a significant increase in total body potassium, indicating an increase in lean body mass.

Coleman (22) compared two types of variable resistance exercise systems, using work protocols recommended by the manufacturers. Body composition was assessed using specific skinfold and girth measurements as described by Wilmore and Behnke. (98) During the course of the program, total body weight increased and the mean thickness of each skinfold site decreased significantly. An absolute decrease of 1.22 per cent and 1.29 per cent body fat was observed for the two groups. This change represented a relative decrease of 9.11 per cent and 9.35 per cent for each of the two groups.

Gettman et al. (40) also reported changes in body composition as the result of circuit weight training. Subjects in this particular study trained for 20 weeks and were randomly assigned to one of three groups; control, circuit weight training, and running. Body composition was assessed using underwater weighing and per cent body fat determined using the formula of Brozek et al. (15) A significant decrease of 1.7 per cent body fat was observed.

In a more recent study by Gettman et al. (41) the benefits of circuit weight training were further examined. In this particular study absolute decreases of three per cent for males and 2.8 per cent for females were reported. These changes were representative of a relative decrease of 13.3 and 10.4 per cent for males and females, respectively.

Pipes and Wilmore (74) also reported significant decreases in absolute and relative body fat as a result of isokinetic training at both high speeds and low speeds. The high speed group experienced a significantly greater decrease than did the low speed group.

The literature focuses little attention on the possible improvements in aerobic power which may be associated with weight training exercise.

Nagle and Irwin (69) reported no significant improvement in cardiovascular function in subjects trained on high or low resistance weight lifting programs relative to a control group engaged in mild recreational activity.

The work capacity of weight lifters on a bicycle ergometer has been reported as not being significantly greater than that of the general population. (36,55,81) Saltin and Astrand (81) examined the maximal oxygen uptake of international calibre athletes and reported that although weightlifters had values significantly greater than the untrained group, they had the lowest values when compared to other groups of athletes.

Nupp (70) examined the cardiovascular improvement associated with four different training programs:

(1) Progressive resistance running
(2) Fartlek training
(3) Interval training
(4) Weight training

The weight training group performed three weight lifting exercises designed specifically to tax the cardio-respiratory system. All four groups also performed a circuit training program aside from the program they were assigned to. Following ten weeks of training each group was assessed for cardio-respiratory improvement based on performance time in a mile run. The weight training group showed significantly less improvement than the other three groups. However, the assumption that performance in a mile run is indicative of cardio-respiratory improvement is somewhat questionable. (2,38) Secondly, no consideration was given to the specificity of training associated with these conditioning programs.

Gettman et al. (40) examined the cardio-respiratory effects of circuit weight training over a 20 week period. Subjects were randomly assigned to one of three groups; control, circuit weight training or continuous running. There were 20 subjects in the control group and the circuit weight training group while the running group contained 30 subjects. Aerobic power was assessed using a maximal treadmill test. The circuit weight training group exercised on Universal Gym apparatus. Each circuit consisted of ten exercises. The weight for each exercise corresponded to approximately 50 per cent of each individual's maximum. The number of repetitions progressed from ten to 20 for the first six weeks and were then reduced to 15 per set for the remaining 14 weeks since subjects could not complete two circuits when performing 20 repetitions. The rest period between sets of each exercise was 30 seconds and was reduced gradually to 20 seconds. Two circuits were completed each workout. This program resulted in no significant increase in VO_2max when expressed in ml/kg/min.

However, in a more recent study, Gettman et al. (41) reported improvements in aerobic power of 12 per cent for males and 13 per cent for females following participation in a circuit weight training program. The program followed was similar to the one used in the earlier study by Gettman et al. (40) with some modifications. In this particular study subjects worked between 40 to 60 per cent of their maximum one time lifting capacity, doing as many repetitions as possible during a 30 second time interval followed by a 30 second relief interval. One circuit consisted of ten stations and subjects performed three circuits for a total workout time of 30 minutes.

This program involved a timed work interval during which subjects performed between 12 and 15 repetitions unlike the previous study by Gettman et al. (40) in which subjects performed 15 repetitions with no time restriction. Introducing a timed work interval may have increased the rate of work and hence increased the intensity of the workout. Further, three circuits were performed per workout in the more recent study (41) as opposed to only two in the earlier study. (40) This work protocol would have considerably increased the total work performed with each workout and may explain the different results observed in these studies.

The work protocol used by Gettman et al. (41) is characteristic of an interval training program, unlike much of the earlier research in which the work protocol was based on the original work of Delorme and Watkins. (28)

An interval type of circuit training program may be the key approach to take if an improvement in aerobic power is of prime concern.

A Comparison of Interval and Continuous Training

A review of the literature in this area indicates that interval training can be an effective means for inducing improvements in aerobic power.

> With very short work periods of about 30s or less, a very severe workload may be imposed upon both muscles and oxygen-transporting organs without the engagement of anaerobic processes leading to any significant elevation of the blood lactate. It is thus possible to select the proper workload and work and rest periods in such a manner that the main demand is centered on (1) muscle strength without a major increase in the total oxygen uptake; (2) aerobic processes without significantly mobilizing anaerobic processes; (3) anaerobic processes without maximal taxation of the oxygen-transporting organs; and (4) both aerobic and anaerobic processes simultaneously. (2:401)

Astrand et al. (3) indicated that with intermittent exercise of 30 seconds work and 30 seconds relief, oxygen consumption was similar to that of continuous exercise of the same average power output.

According to Saltin et al. (84) during intermittent exercise with a work interval of less than 60 seconds and a relief interval in the range of 1:1, oxygen consumption should oscillate only slightly around the requirements of average power output.

Essen (33) reported that an interval schedule of 15 seconds of work and 15 seconds of relief resulted in a similar heartrate from work to rest and that this heartrate was similar to the heartrate observed during continuous exercise of the same average power output.

Thus far the literature reviewed here has discussed only the acute responses of interval work compared with continuous work. A further examination of the literature has demonstrated that interval training programs do produce significant improvements in aerobic power. (24,31,36, 37,38,57)

Fox et al. (37) examined the effects of different interval running distances on aerobic power. Subjects trained five days per week for 7.5 weeks at a work:relief ratio of 1:3. Significant increases in aerobic power were observed in each training group with no significant between group differences.

Knuttgen et al. (57) also examined the effects on aerobic power of training with intervals of different lengths. Subjects were randomly assigned to one of three groups. The first group worked for 15 seconds while the second group worked for three minutes. The relief interval was the same length as the work interval for each group. Subjects trained between ten and 15 minutes, three days per week for eight weeks. Both groups experienced a significant increase in aerobic power. The short interval group experienced an increase of 13.2 per cent while the long interval group experienced an increase of 18 per cent. There was also a significant between group difference. Knuttgen et al. (57) also found that gains in aerobic power were inversely related to initial aerobic power measurements.

Eddy et al. (31) compared the effects of interval and continuous training, over a 12 week period, in both men and women. Both types of training produced almost identical increases in aerobic power when the total workload was equated for each training session. Increases in aerobic power were in excess of 20 per cent and the response in both males and females was of the same magnitude and in the same direction.

The cardiovascular response of women to interval vs. continuous training was further examined by Cunningham et al. (24) Significant increases in aerobic power, in excess of 18 per cent, were reported for both training groups as compared to a control group. However, there was no significant difference between training groups.

Thus, there is evidence to suggest that an interval training program can be a viable alternative to continuous training for the purpose of increasing aerobic power.

Considerations in Developing an Aerobic Training Program

Prior to designing any aerobic training program, interval or continuous, it is important to take into consideration the training variables which will effect the program.

The key variable we must consider is the intensity of the work to be done by the participants. When using an interval training program the work intensity must be sufficient to produce an average power output that will result in an oxygen consumption high enough to result in an increase in aerobic power. (4,24,29,59). Since it is not practical to directly monitor oxygen consumption during training sessions, training heartrates should be monitored to ensure that they are within the appropriate target zone considered necessary to facilitate improvement in cardiovascular function. (6,39) Although this "threshold intensity" (29) varies from individual to individual it has generally been suggested that individuals should train at a heartrate between 60% and 85% of their maximum heartrate, as estimated according to their age. (6,24,31, 39,85,95) The initial percentage chosen by various researchers varies with the characteristics of subjects and depends primarily on initial fitness levels and age. (6,39,85)

Another important consideration when designing an aerobic training program is the duration of each session. The minimum duration necessary for each training session is still controversial. (39,85) A minimum of 20 minutes of continuous exercise is often recommended. (72) However, "most North American authors regard a minimum duration of 30 minutes as more appropriate." (85:230)

With regards to interval training the total duration of each session is often the same, however, the total duration of work amounts to approximately half that of the workout, depending upon the work:relief ratio. (18,27,29)

The next consideration is to establish the frequency of training. Many researchers have subjects train four times per week (24,31,38) and four or five times are most often recommended. (85) However, there is still some controversy as to the minimum number of session per week required to produce changes in aerobic power.

Astrand and Rodahl (6:409) suggest that "for an untrained individual an exercise that demands an oxygen uptake exceeding 50 per cent of his or her maximal will, when repeated two or three half hours a week gradually increase the maximal oxygen uptake."

In the case of interval training, Pollock et al. (75) reported significant gains in aerobic power for each of two groups; one which trained two times per week and one which trained four times per week. Over a period of 20 weeks the group who trained four times per week had significantly greater gains in aerobic power over the group who trained two times per week. However, it is interesting to note that after ten weeks of training, although both groups had significant gains in aerobic power, there was no significant difference between the two groups at this stage.

Contrary to these findings, Fox et al. (36) found that frequencies between two and five days per week over periods of seven to 13 weeks did not significantly affect gains in aerobic power. However, in the study by Gettman et al. (41) the frequency of circuit weight training was three times per week and significant increases in aerobic power were reported after 12 weeks of training.

Thus, the literature with regards to the necessary frequency of training also remains controversial. Although it is generally recommended that individuals train four or five times per week (85) it seems that two or three times per week is adequate providing the intensity of the program is sufficient. (6,36,38,41)

In research, consideration must also be given to duration of time over which subjects trained before the training benefits were assessed.

Much of the early research examined changes over a period of four to eight weeks and it is suggested that perhaps this is not sufficient enough time to allow for major increases in aerobic power, particularly if the frequency of the training sessions is minimal. (36,38,39,75)

More recent research studies tend to observe aerobic training effects over a period of 12 weeks, (24,31,41) although no optimal period of time has yet been established in the literature. Significant increases in aerobic power have been reported over time periods anywhere from seven weeks (95) to 20 weeks (75) and the magnitude of change varies with the intensity and the frequency of training. (24,31,36,95)

Measuring Aerobic Power

Interest in measuring aerobic power dates back to the work of Hill et al. (15) Since this time a great deal of practical and theoretical knowledge has been accumulated and many methods for assessing VO_2max have been developed and recorded in the literature. (5,8,65,91,99) However, these techniques require complicated apparatus and require maximum effort from subjects. Demanding maximal effort from individuals can present motivational problems since two or three measurements of oxygen consumption are required above the level at which maximum oxygen intake occurs in order to obtain a reliable estimate of maximum oxygen uptake. (100) Further, the health risks involved with subjecting relatively unfit individuals, particularly those over 30, to maximal effort exercise are of major concern. (27,100)

With these problems in mind, exercise physiologists endeavored to develop a submaximal test which would give a reliable and accurate estimate of an individual's true maximum oxygen uptake. A number of submaximal tests have been developed (1,45,88,94) based on the linear relationship observed between heartrate and oxygen consumption. On the basis of this oxygen-heartrate relationship it is possible to predict an individual's maximum oxygen uptake by the heartrate response to two submaximal workloads, assuming a maximal heartrate of approximately 190 to 200 beats per minute. (6) However, since maximal heartrate declines with age, it is necessary to make corrections for age. These considerations formed the basis for the nomogram by Astrand and Rhyming (1) which was modified by I. Astrand (4) to include an age correction factor. This nomogram has been used extensively over the years and has provided reasonably accurate predictions of maximal oxygen uptake. (4,29,45,94) The standard error of estimate ranges from approximately 7% (29) in relatively well-trained individuals of the same age up to 15% for moderately trained individuals of varying ages. (4)

Every researcher must be aware of the limitations of submaximal predictive tests and should evaluate the usefulness of such tests accordingly. Astrand and Rodahl (6:355) suggest that "the submaximal exercise test is a very useful tool in evaluating whether or not a training program has been effective in improving the individual's circulatory capacity."

Techniques for Assessing Body Composition

Many techniques are available for assessing the fat and lean components of the body. (14) Two of the most familiar techniques used are hydrostatic weighing and anthropometric measures.

Hydrostatic weighing is based on the principal of Archimedes, and the volume of the body is determined from its displacement of water. (87)

In order to eliminate the volume of the air in the lungs the gross volume of the body must be corrected for residual air volume in the lungs. "The density of the whole body is simply the total weight in air divided by the total body volume as estimated by hydrostatic weighing." (54:267) Since the density of fat is less than that of the other body components such as bone and muscle, the lower the density the greater the proportion of fat. Therefore, hydrostatic weighing is used to estimate body density which is substituted into a formula for determining per cent body fat.

Hydrostatic weighing is considered to be one of the more valid indirect techniques available for assessing body composition, with an error of estimate of approximately three to four per cent. (15,87) However, validation of this technique has been accomplished primarily through research with animals (54,78) and through analysis of a very limited number of human cadavers. (54) The question of validity of assessing human body composition indirectly has only been dealt with on occasion (14,54,87) and "there is probably little one can do to improve the situation except to acknowledge there are some limitations and unavoidable constraints and assumptions one must contend with." (51:250)

There are also a number of sources of measurement error associated with hydrostatic weighing. (15,50,52,54) In order to limit measurement error it becomes important to do repeated measurements on subjects due to an apparent practice effect in achieving a true underwater weight score. (50) However, repeated measurements of underwater weighing become very time consuming and inconvenient to subjects. Further, the necessary equipment for hydrostatic weighing is not readily available. Therefore, many researchers have chosen to use anthropometric measurements for assessing body composition. These measurements are most often used in a regression equation to determine body density, which is in turn substituted into a formula to determine per cent body fat. However, there are a great number of regression equations which have been developed to predict body density from skinfold measurements, from girth measurements and from a combination of both types of measurements. (30,49,50,51,89) The assumption upon which such measurements are based is that 50 per cent of the body's fat is deposited subcutaneously. (54) Most of these regression equations which have been developed have been validated by correlating body density prediction efficiency with measurements using hydrostatic weighing. Correlations reported in the literature vary from .85 to .87 when male subjects were used, (12,49,51,71,97) while somewhat lower correlations ranging from .70 to .78 have been reported for female subjects. (49,51,89,98,101)

Some measurement sites are better predictors than others and skinfold measurements are generally better predictors than girth measurements. (49, 51) The sites which tend to predict more efficiently are the triceps, iliac crest and subscapular. (49,51,89) The juxtanipple site is also an effective predictor in males. (51,71) Katch (52) suggests that as a minimum number, the skinfold sites which are most useful are the triceps, subscapular and iliac crest. Thus, when selecting a prediction equation to use, researchers must keep in mind the most efficient prediction sites for measurement. It is also important to consider sites which provide ease of measurement to reduce tester error. The tester must also allow for considerable practice in order to establish test-retest reliability and a minimum of two measurements should always be taken. (52)

CHAPTER III

METHODS AND PROCEDURES

Sample Selection

The sample consisted of 70 volunteer subjects, both male and female, who were medically screened using the Par-Q questionnaire. (18)

Subjects who volunteered to participate in the training program were asked to find an individual willing to participate in the control group. The individual they chose was to be as similar to them as possible with regards to age, stature, weight and activity patterns. The selection of control subjects in this manner was an attempt to match the two groups in an effort to limit some of the bias introduced when volunteers are used in a study.

The training group initially consisted of 19 females and 22 males while the control group consisted of 13 females and 16 males. However, during the course of the training program three females and two males dropped out of the training group leaving 16 females and 20 males in this group.

Testing

Testing procedures consisted of a pre-test, administered within two weeks prior to the start of training and a post-test, administered within two weeks of completion of training. All subjects were required to sign a consent form prior to having each test adminstered.

In order to ensure that everyone was aware of factors which might bias test results, a list of instructions was distributed to all subjects prior to any testing.

When subjects arrived to be tested they were weighed using a physician's scale calibrated in kilograms. All subjects were weighed without shoes and while wearing gymnasium apparel.

Body Fat

Skinfolds were measured and per cent body fat was determined based on the mean of calculations using two different methods.

The first method used was that described by Durnin and Rahaman. (30) The regression equations for the estimation of body density (Y) from the log of the sum of four skinfold thicknesses in mm. (X) were:

$$\text{Men:} \quad Y = 1.1610 - .0632X$$

$$\text{Women:} \quad Y = 1.1581 - .0720X$$

The four skinfold measurements taken were the triceps, biceps, subscapula and suprailiac.

The values determined for body density were then substituted into the Siri equation (62) to estimate per cent body fat. This equation was:

$$\% \text{ Fat} = [\,(4.95/Y) - 4.5]\ X\ 100$$

The second method used for men was described by Pascale. (71) The regression equation used to determine body density (D) from three skinfold thicknesses in mm. (X_1, X_2, X_3) was:

$$D - 1.088468 - [.0007123\ (X_1) + .004832\ (X_2) + .0005513\ (X_3)]$$

The three skinfold measurements taken were the triceps, juxtanipple and midaxillary line.

The second method used for women was that ~~described~~ by Sloan et al. (89) The regression equation used to determine body density (D) from two skinfold measurements in mm. (X_1, X_2) was:

$$D = 1.0764 - [.00081\ (X_1) + .00088\ (X_2)]$$

The skinfold measurements taken were the triceps and the supra-iliac.

The values determined for body density for both men and women, were then substituted into the Brozek and Keys equation (15) to estimate per cent body fat. This equation was:

$$\%\ Fat = [4.570/D - 4.142] \times 100$$

All skinfold measurements were taken on the right side of the body with the subjects standing relaxed and erect. Two measurements were taken at each site and if they were less than or equal to one mm. apart the average of the two was recorded. If the two measurements were more than a mm. apart a third measurement was taken and the average of the two closest measurements was recorded. The caliper dial was read when the indicator came to a relative stop after the initial quick movement. Measurements were taken at each site according to the following technique.

Triceps - The caliper was applied over the midpoint of the muscle belly, midway between the tip of the acromion and the olecranon process with the arm hanging relaxed and vertical. The jaws of the caliper were placed in the vertical plane.

Biceps - The calipers were applied in the vertical plane over the muscle belly, with the arm hanging relaxed and vertical.

Subscapular - The caliper was applied immediately below the tip of the inferior angle of the scapula at approximately a 45 degree angle to the vertical plane.

Suprailiac - The caliper was applied approximately three cm. above the iliac crest at an angle along the line of the crest.

Juxtanipple - The caliper was applied just above the nipple, along the line of Linn.

Midaxillary - The caliper was applied, in the vertical plan, along the midaxillary line of the body, at the level of the xiphoid process.

In all cases the skin and subcutaneous fat were firmly grasped between the left thumb and forefinger and pulled up and away from any underlying tissues. The caliper jaws were placed approximately one cm. below the fingers.

Eight Minute Bicycle Ergometer Test

This test was performed in order to estimate maximal oxygen consumption. (6) The test involved riding the bicycle ergometer continuously for eight minutes at a constant rate of 60 revolutions per minute. A metronome was used to help subjects keep the correct cadence.

During the first four minutes the workload was set primarily to provide the subject with a warm-up and to give the tester an indication of what level to set the workload at for the final four minutes. Following the initial four minutes the workload was increased to a level that the tester felt would evoke a steady state heartrate of approximately 70% to 80% of each subject's estimated maximum heartrate (220-age). An exersentry was used to moniter heartrate throughout the eight minutes of the test.

The seat of the bicycle ergometer was adjusted according to each subject's height such that the leg was almost fully extended when the pedal was in the lowest position.

The total amount of work accomplished was calculated by multiplying the load setting times the number of revolutions per minute. It was assumed that all subjects kept cadence with the metronome.

Maximal oxygen consumption was then estimated using the Astrand-Rhyming Nomogram. (1) Using this nomogram an absolute value of oxygen consumption expressed in litres per minute was attained for each subject. This value was then multiplied by an age correction factor (2) and converted to a relative value of oxygen consumption using Astrand's (2) tables. This value was expressed in millilitres per kilogram of body weight per minute.

Training Program

The training program consisted of a circuit of ten exercises using various Hydra-Gym machines. The following stations were included in the program and whenever possible were performed in the order listed: (See Appendix A)

1. Power Squat (legs)
2. Bench Press
3. Pro Power (legs)
4. Power Butterfly
5. Power Runner (legs)
6. Shoulder Press
7. Uni-Lateral Knee (legs)
8. Arm Curls
9. Sit-Ups
10. Abductor-Adductor (legs)

Exercises were arranged in this manner so as to alternate leg and arm exercises. This order was followed to prevent excessive local muscular fatigue which might prevent subjects from continuing the workout at a rate that would have a greater influence on their overall cardiovascular response.

For each exercise, subjects performed as many repetitions as possible in 20 seconds, followed by a 40 second relief interval, during which each individual moved to the next station.

All subjects started the program by completing two circuits of the exercises and progressed to three complete circuits within the first two weeks of the program.

During the first four weeks of the program the work:relief ratio remained at 20:40. From the fifth week on, the rest interval was gradually reduced and the work time gradually increased such that the work:relief ratio was 23:32 at the end of ten weeks when the program was completed.

Statistical Analysis

A three way analysis of variance was employed to analyze the data from this study. Four individual analyses were run through computer facilities at the University of Alberta using the SPSS batch system. The following classification variables were involved in the analyses:

1. Treatment - control or training
2. Sex - male or female
3. Age level - young or old
4. Initial VO_2max - high or low
5. Initial per cent body fat - high or low

The dichotomy of the first two variables is obvious. The age criterion for the age level dichotomy was 35 years. Anyone less than 35 was classified at young and the rest as old. Initial VO_2max was based on predicted values attained in the pre-test and subjects were classified as high or low according to population norms for their particular sex and age group. (90) Initial per cent body fat was also based on predicted values attained from the pre-test and subjects were classified as high or low according to the median of the group as a whole.

The dependent variable in the first two analyses was post-test VO_2max. The classification variables used in the first of these analyses were treatment, sex, and initial VO_2max. In the second of these analyses age level was substituted for sex, while the other two variables remained the same.

The dependent variable in the second two analyses was post-test per cent body fat. The classification variables for the first of these analyses were treatment, sex and initial per cent body fat. In the second analyses the age level variable was again substituted for sex while the other two variables remained the same.

T-Tests were also done to determine the level of significance between the means of the following groups for pre-test VO_2max and per cent body fat:

1. training and control
2. male and female
3. old and young
4. high and low

The level of significance for this analysis was also set at .05.

As a test of reliability, a Spearman Rho correlation coefficient was calculated between pre and post measures for VO_2max and per cent body fat using the data for the control group.

CHAPTER IV

RESULTS AND DISCUSSIONS

Results

A summary of the results of the first three way analysis on post-test VO_2max are presented in TABLE I. The main effects were signficant at the .05 level of significance, as were the effects of treatment, sex and initial VO_2max. There was no significant interaction between these factors.

A summary of the second three way analysis on post-test VO_2max, in which age level was substituted for sex, is presented in TABLE II. Again the main effects were significant at the .05 level of significance. The effects of treatment, age level and initial VO_2max were also significant and there was no significant interaction between any of these factors.

TABLE I

SUMMARY OF THREE WAY ANALYSIS OF VARIANCE ON POST-TEST VO_2MAX - FACTORS: TREATMENT, SEX, INITIAL VO_2MAX

Source of Variation	Degrees of Freedom	Mean Square	F Ratio	Critical F
Main Effects	3	734.012	14.908	2.75
Treatment	1	655.879	13.321	3.99
Sex	1	433.452	8.803	3.99
Initial VO_2max	1	1467.774	29.811	3.99
Error Term	57	49.237		

TABLE II

SUMMARY OF THREE WAY ANALYSIS OF VARIANCE ON POST-TEST VO_2MAX - FACTORS: TREATMENT, AGE LEVEL, INITIAL VO_2MAX

Source of Variation	Degrees of Freedom	Mean Square	F Ratio	Critical F
Main Effects	3	758.642	16.009	2.75
Treatment	1	891.214	18.806	3.99
Age Level	1	507.342	10.706	3.99
Initial VO_2MAX	1	805.254	16.993	3.99
Error Term	57	47.389		

The significant effects between age groups, sexes and initial VO_2max were expected. The results of T-tests, as shown in TABLE III, demonstrated a significant difference between these groups as a result of the pre-test. Since the initial VO_2max groups were based on pre-test measures the relationship between these groups was expected to remain unchanged. Further, the difference between VO_2max values for males and females is well documented (2,6,31,39) as is the steady decline in VO_2max with increasing age (2,6,39,90) and since there was a significant difference between the groups as a result of the pre-test, this relationship was expected to remain unchanged.

However, there was no significant difference between the training and control groups initially. An examination of the group means, as shown in TABLE IV and TABLE V, indicated that the training group experienced an 11.90 per cent increase in VO_2max. These findings are graphically represented in FIGURE I.

TABLE III

SUMMARY OF T-TESTS ON PRE-TEST VO_2MAX

Group	Degrees of Freedom	Variance Estimate	T Ratio	Critical T
Treatment	63	1.15	1.90	2.00
Sex	63	2.17	7.00	2.00
Age Level	63	1.27	29.01	2.00
Initial VO_2max	63	49.39	4.97	2.00

TABLE IV

PRE-TEST GROUP MEANS FOR PREDICTED VO_2MAX (ml/kg/min)

Factor	Group	N	Pre-Test $\bar{X}$	Standard Deviation
Treatment	Training	36	35.73	10.34
	Control	29	36.24	8.53
Sex	Male	36	37.24	9.18
	Female	29	34.73	7.66
Age Level	Young	44	39.00	7.46
	Old	21	30.28	8.82
Initial VO_2max	High	20	43.89	6.14
	Low	45	32.28	7.53

TABLE V

POST-TEST GROUP MEANS FOR PREDICTED VO_2MAX (ml/kg/min)

Factor	Group	N	Post-Test $\bar{x}$	Standard Deviation
Treatment	Training	36	41.12	8.87
	Control	29	35.12	7.95
Sex	Male	36	39.16	9.41
	Female	29	36.65	8.18
Age Level	Young	44	40.61	8.58
	Old	21	34.38	8.37
Initial VO_2max	High	20	45.05	7.00
	Low	45	35.93	8.33

A summary of the results of the first three way analysis of variance on post-test per cent body fat are presented in TABLE VI. The main effects were significant at the .05 level of significance, as were the effects of treatment, sex and initial per cent body fat. There was no significant interaction between any of these factors.

A summary of the second three way analysis on post-test per cent body fat, in which age level was substituted for sex, is presented in TABLE VII. Again the main effects were significant. Treatment, age level and initial VO_2max effects were also significant at the .05 level.

Again, the significant differences between sex, age level and initial per cent body fat were expected. Results of T-tests, as shown in TABLE VIII, demonstrated a significant difference between these group means based on the pre-test. Since the initial per cent body fat groups were based on pre-test measures, the relationship between these groups

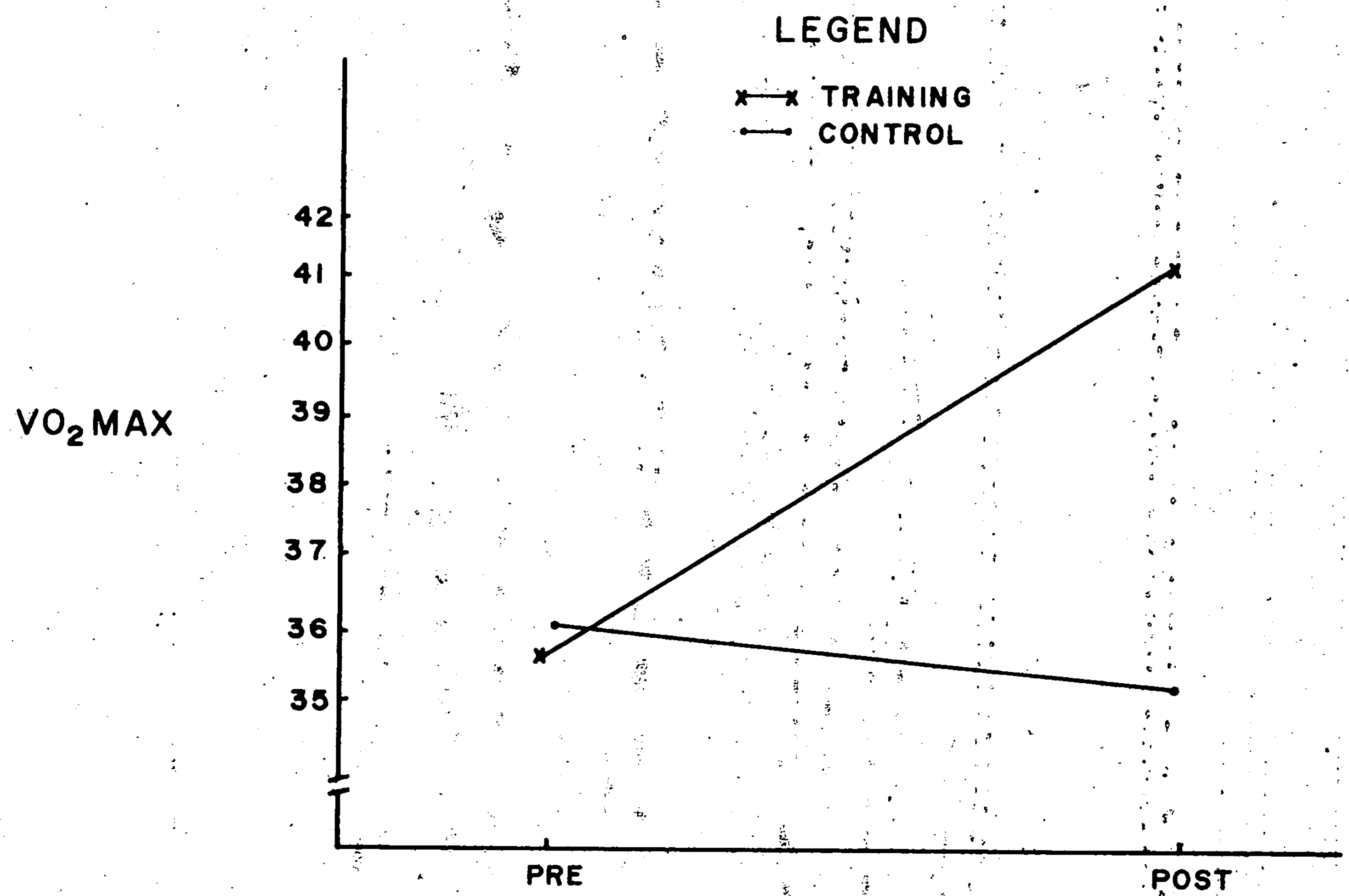

FIGURE I. GROUP MEANS FOR PREDICTED VO_2MAX (ml/kg/min)

TABLE VI

SUMMARY OF THREE WAY ANALYSIS ON POST-TEST PER CENT BODY FAT FACTORS: TREATMENT, SEX AND INITIAL PER CENT BODY FAT

Source of Variation	Degrees of Freedom	Mean Square	F Ratio	Critical F
Main Effects	3	470.435	34.914	2.75
Treatment	1	85.464	6.343	3.99
Sex	1	110.664	8.213	3.99
Initial Per Cent Body Fat	1	373.669	27.737	3.99
Error Term	57	13.474		

TABLE VII

SUMMARY OF THREE WAY ANALYSIS OF VARIANCE ON POST-TEST PER CENT BODY FAT-FACTORS: TREATMENT, AGE LEVEL AND INITIAL PER CENT FAT

Source of Variation	Degrees of Freedom	Mean Square	F Ratio	Critical F
Main Effects	3	473.152	41.340	2.75
Treatment	1	150.469	13.147	3.99
Age Level	1	118.814	10.381	3.99
Initial Per Cent Body Fat	1	1277.051	111.577	3.99
2 way Interactions	3	23.143	2.022	2.75
Tr Aged	1	31.724	2.772	3.99
Tr BFPR	1	45.886	4.009	3.99
Aged BFPR	1	1.129	.099	3.99
3 way Interactions	1	53.197	4.648	3.99
Tr Aged BFPR	1	53.197	4.648	3.99
Error Term	57	11.445		

was expected to remain unchanged. Again, as with VO_2max values, the difference between males and females with respect to body fat is well documented. (6,39,51,90) The tendency for individuals to increase fat deposition as age increases is also well documented. (6,13,39,90) Therefore, since the pre-test demonstrated a significant difference, it was expected that this relationship would remain the same for the post-test.

However, there was no significant difference between the training and control groups as a result of the pre-test but the post-test differences were significant.

TABLE VIII

SUMMARY OF T-TESTS ON PRE-TEST PER CENT BODY FAT

Group	Degrees of Freedom	Variance Estimate	T Ratio	Critical T
Treatment	63	36.23	.13	2.00
Sex	63	16.55	7.81	2.00
Age Level	63	22.71	2.58	2.00
Initial Per Cent Body Fat	63	14.40	9.84	2.00

An examination of the pre-test and post-test means for these groups, as presented in TABLE IX and TABLE X, revealed that the training group had an absolute decrease of 1.87 per cent body fat. This absolute decrease represents a relative decrease in body fat of 8.1 per cent. The group means are graphically illustrated in FIGURE II.

TABLE IX

PRE-TEST GROUP MEANS FOR PER CENT BODY FAT

Factor	Group	N	Pre-Test $\bar{x}$	Standard Deviation
Treatment	Training	36	21.31	5.71
	Control	29	21.37	6.36
Sex	Male	36	17.36	4.22
	Female	29	25.35	4.74
Age Level	Young	44	19.95	5.52
	Old	21	22.70	6.26
Initial Per Cent Body Fat	High	32	25.61	4.37
	Low	33	16.36	3.24

TABLE X

POST-TEST GROUP MEANS FOR PER CENT BODY FAT

Factor	Group	N	Post-Test $\bar{x}$	Standard Deviation
Treatment	Training	36	19.30	5.36
	Control	29	21.12	6.37
Sex	Male	36	16.62	4.11
	Female	29	24.45	4.70
Age Level	Young	44	19.46	5.80
	Old	21	21.47	5.89
Initial Per Cent Body Fat	High	32	24.48	4.61
	Low	33	15.88	3.25

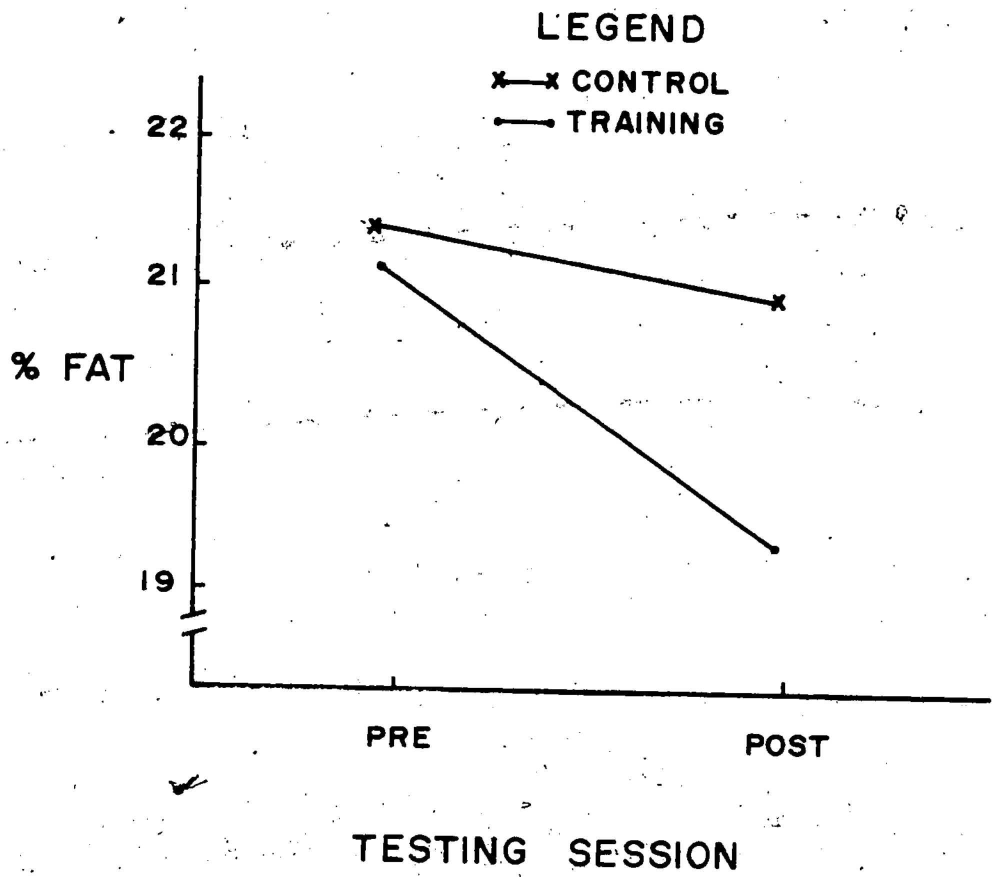

FIGURE II. GROUP MEANS FOR PER CENT BODY FAT

The second analysis of variance on post-test per cent body fat also revealed a significant interaction between initial per cent body fat and treatment. (See TABLE VII) The group means for these interacting variables are presented in TABLE XI and are graphically represented in FIGURE III.

TABLE XI

GROUP MEANS FOR THE TWO INTERACTING VARIABLES IN THE SECOND THREE WAY ANALYSIS OF VARIANCE ON POST-TEST PER CENT BODY FAT

Group	N	$\bar{X}$ Post-Test	Standard Deviation
Control/Initially High	13	26.57	4.62
Control/Initially Low	16	16.70	4.08
Training/Initially High	19	23.05	3.84
Training/Initially Low	17	15.12	3.88

An examination of group means indicates that those individuals who were involved with the training program and who were initially high in per cent body fat demonstrated a greater reduction in body fat. This finding is supported in the literature. (6,39)

There was also significant interaction between all three factors. The group means for the interacting factors are presented in TABLE XII.

An examination of these group means indicate that all the training groups had considerably lower values than the corresponding control groups and that the old training groups demonstrated greater differences between corresponding control groups than did corresponding young training groups when compared to the appropriate control group. These differences are best illustrated in FIGURE IV. Further observations of the group means

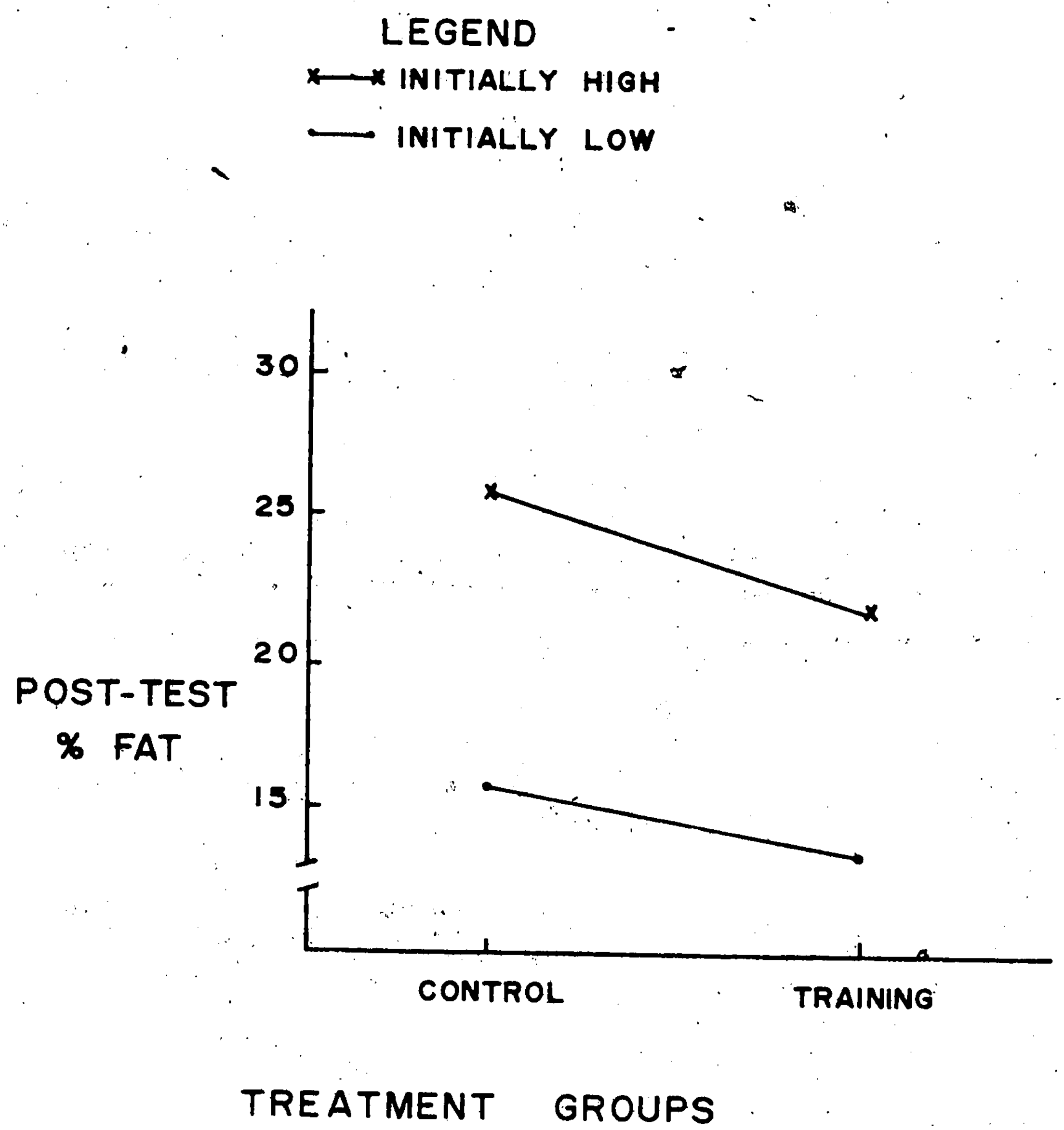

FIGURE III. GROUP MEANS FOR INTERACTING VARIABLES-TREATMENT AND INITIAL PER CENT BODY FAT

TABLE XII

GROUP MEANS FOR THE THREE INTERACTING VARIABLES IN THE SECOND THREE WAY ANALYSIS OF VARIANCE ON POST-TEST PER CENT BODY FAT

Group	N	Post-Test $\bar{x}$	Standard Deviation
Training/Old/Initially Low	8	17.85	1.98
Control/Old/Initially Low	4	20.04	1.07
Training/Young/Initially Low	10	13.04	2.44
Control/Young/Initially Low	10	14.91	2.72
Training/Old/Initially High	7	24.88	5.09
Control/Old/Initially High	2	28.26	13.00
Training/Young/Initially High	11	22.15	2.31
Control/Young/Initially High	13	25.13	3.06

indicate that the means of the old training groups are considerably higher than the corresponding young training groups. This relationship primarily explains the greater differences observed between the old training groups and the corresponding old control groups since individuals who were initially high in per cent body fat tended to experience greater decreases in per cent body fat. This tendency is obvious from observations of the group means presented in TABLE XI as well as from the significant two-way interaction between treatment and initial per cent body fat as illustrated in FIGURE III. This observation is also supported in the literature. (6,39) However, it should be noted that the significant three-way interaction observed in this analysis <u>may</u> be somewhat biased by the discrepancy in cell numbers for the different groups since there were considerably fewer old subjects.

Finally, reliability coefficients of .98 and .90 were calculated for per cent body fat and predicted VO_2max, respectively.

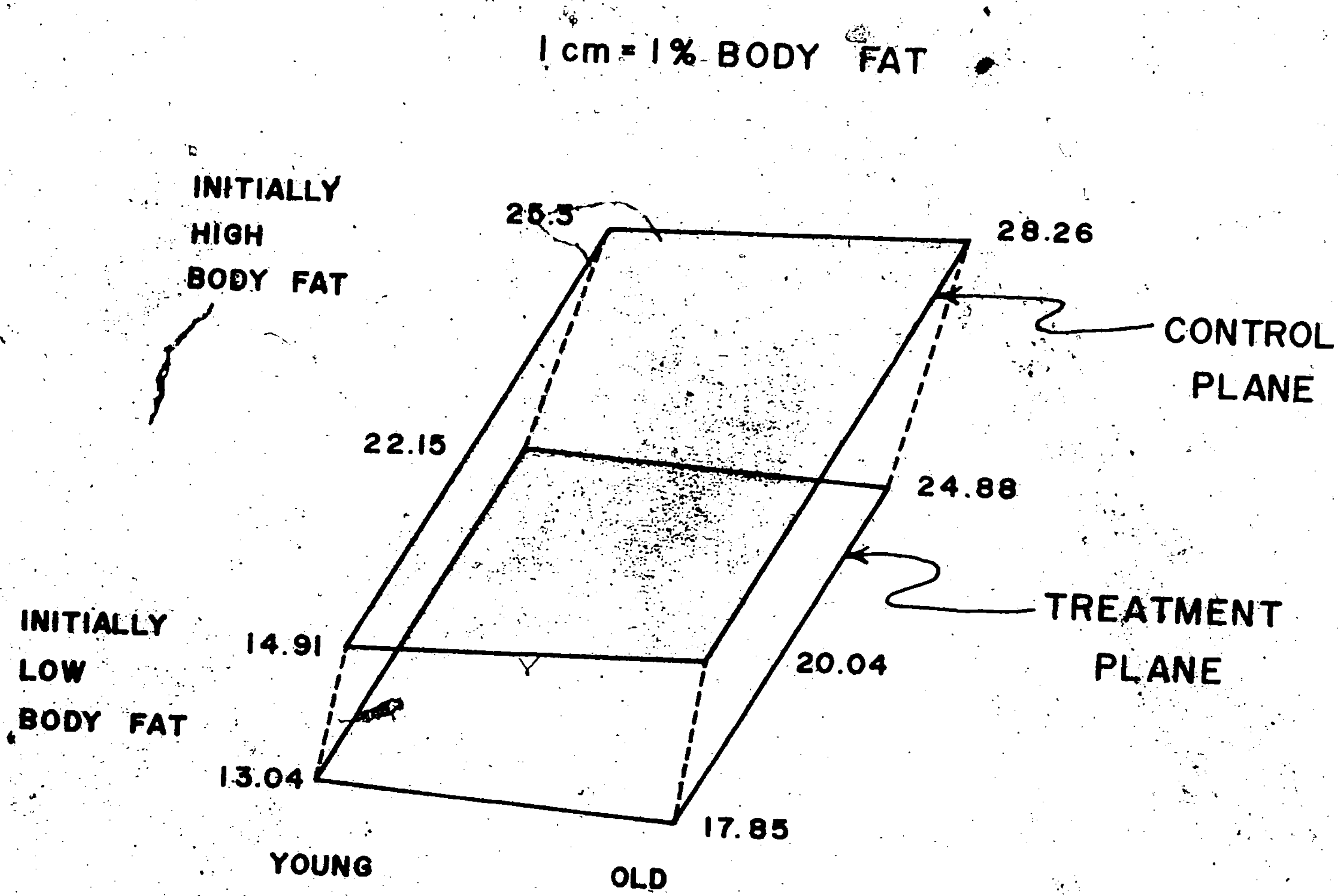

FIGURE IV GROUP MEANS FOR INTERACTING VARIABLES-TREATMENT, AGE AND INITIAL BODY FAT

Discussion

Aerobic Power

The results of the present study indicate that the training group experienced an overall increase in VO_2max of 12 per cent. These findings are consistent with those of Gettman et al. (41)

The evidence of these two studies strongly indicate that aerobic power can be significantly improved using variable resistance exercise equipment, provided the appropriate work protocol is utilized. However, the results of the present study were achieved over a shorter time period. The work interval used in the present study was also shorter than that used in the study by Gettman et al. One of the major reasons for this observation may be due to the nature of hydraulic resistive equipment. Since most of this apparatus works both agonistic and antagonistic muscles during the same exercise set, an individual can accomplish more work in a shorter time frame. Further, due to the rhythmic pumping of blood through the muscles, there may be less local fatigue which would allow the individual to work harder during each work interval.

However, more research is required to substantiate the findings of the present study. One of the major problems associated with comparing the relative effectiveness of different variable resistance exercise systems is the difficulty in equating the intensity of training or the total work accomplished in each training session. Equating the intensity of training is also a problem when attempting to compare the findings of the present study to other studies reporting greater increases in aerobic power but utilizing other modes of exercise. (22,23,24,31,32,34,48)

The three way analyses of variance on post-test VO_2max demonstrated that increases in aerobic power were not influenced significantly by age, sex or initial fitness level.

Sexual differences in VO_2max are well documented. (2,6,39) However, the results of this study suggest that sex does not influence the magnitude of the training effect. This finding is consistent with current literature in this area. (24,31,41)

It is also well documented that as age increases, VO_2max tends to decrease (6,39) however the results presented here indicate that age did not significantly influence the magnitude of the training effect. This finding is in agreement with those of Kasch et al. (48) and Kilbom. (56)

The initial fitness level, based on pre-test VO_2max, did not significantly influence the magnitude of the training effect achieved. This finding is contrary to the literature (6,39,56,57,95). This observation may be largely explained by the small number of fit subjects who were involved in the training group, since only ten of the 36 subjects who trained were initially classed as highly fit. Another factor may have been the degree to which natural endowment was responsible for the VO_2max of those who were classed as highly fit. When compared to population norms some individuals fall into a highly fit category due primarily to genetic endowment, even though they are not regularly involved in physical activity. If this is the case, such individuals may still have the genetic potential to improve considerably when they engage in regular physical activity. (6)

In the present study, two of the subjects, one male and one female, were initially classified as highly fit but still achieved increases in aerobic power of 19 per cent and 23 per cent, respectively.

Per Cent Body Fat

The results of the present study also indicated that the training group experienced an absolute decrease of 1.87 per cent body fat which represented a relative decrease of 8.1 per cent. This decrease was in close agreement with the findings of Wilmore (96) but was somewhat less than the decrease reported by Gettman et al. (41) This difference may have been partially due to the shorter training period utilized in the present study. In terms of an absolute decrease in body fat the results presented here are consistent with the findings of Pipes and Wilmore (74) but when compared in terms of relative change, the decrease in body fat in the present study is considerably less. However, when the results of the present study are compared to the results reported by Coleman (22) the decrease in body fat was greater in absolute terms and less in relative terms.

Again, a problem arises when attempting to compare studies reporting changes in body fat since few studies use the same technique or the same formula for determining per cent body fat. However, it is apparent that the training program utilized in this study does decrease body fat significantly.

The three way analyses of variance on post-test per cent body fat revealed that decreased body fat was not significantly influenced by sex or age. However, the initial level of body fat did significantly influence body fat decreases. Those individuals who were initially classified in the high body fat group experienced greater decreases in body fat. These results are in agreement with the current literature in this area. (6,21,39)

CHAPTER V

SUMMARY AND CONCLUSIONS

Purpose

The purpose of the present study was to examine changes in VO_2max and per cent body fat as a result of a resistance training program utilizing Hydra-Gym equipment.

Sample Selection

Subjects for the training group and the control group were selected on a volunteer basis. An effort was made to match the two groups in order to limit the bias associated with using volunteer subjects.

Procedures

Subjects from both groups were tested prior to the start of the program and again immediately following the completion of the training program.

VO_2max was estimated from two submaximal workloads based on the nomogram of Astrand and Rhyming. (1) Per cent body fat was estimated using the mean value determined from two formulas derived for calculation per cent body fat from various skinfold measurements.

The training program involved omnikinetic training equipment and was based on the principles of interval training. Subjects trained three times per week for ten weeks.

A three way analysis of variance was used to analyze the date. Four individual analyses were obtained; two on post-test VO_2max and two on post-test per cent body fat. Four classification variables were involved in each pair of analyses. The classification variables involved in the first post-test VO_2max analysis were treatment, sex and initial VO_2max level. In the second analysis on post-test VO_2max, age level was substituted for sex. Similarly, in the analyses on post-test per cent body fat the classification variables were treatment, sex and initial per cent body fat. Again, age level was substituted for sex in the second analysis on per cent body fat.

T-tests were calculated on pre-test means of those groups involved in the three way analyses of variance to determine any significant differences between groups prior to the start of the training program.

Reliability coefficients of .98 and .90 were calculated for per cent body fat and predicted VO_2max measures, respectively, using the data for the control group.

Results

The training group experienced a significant increase of 11.9 per cent in aerobic power. This increase was not significantly influenced by age, sex or initial fitness level.

An absolute decrease of 1.9 per cent body fat was also observed in the training group. In relative terms this represented a decrease of 8.1 per cent. This decrease in body fat was significant at the .05 level.

Age and sex did not significantly affect the observed decrease in body fat. However, the higher body fat group experienced a significantly greater decrease than did the low body fat group.

Conclusions

From the results of this study, the following conclusions are warranted:

1. Aerobic power can be significantly increased on a training program utilizing hydraulic resistance training equipment.

2. Per cent body fat can be significantly decreased on a training program utilizing the hydraúlic resistive equipment.

3. Initial body fat significantly influences the resulting decrease in body fat.

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APPENDIX A

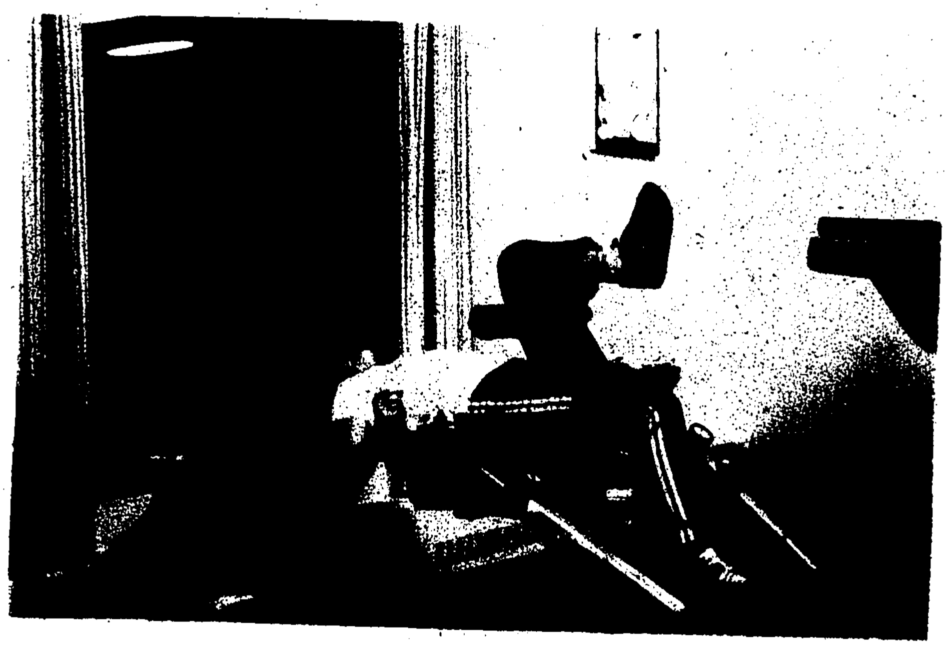
PHOTOGRAPHS OF HYDRAULIC RESISTIVE APPARATUS USED IN THE TRAINING PROGRAM

POWER SQUAT

BENCH PRESS

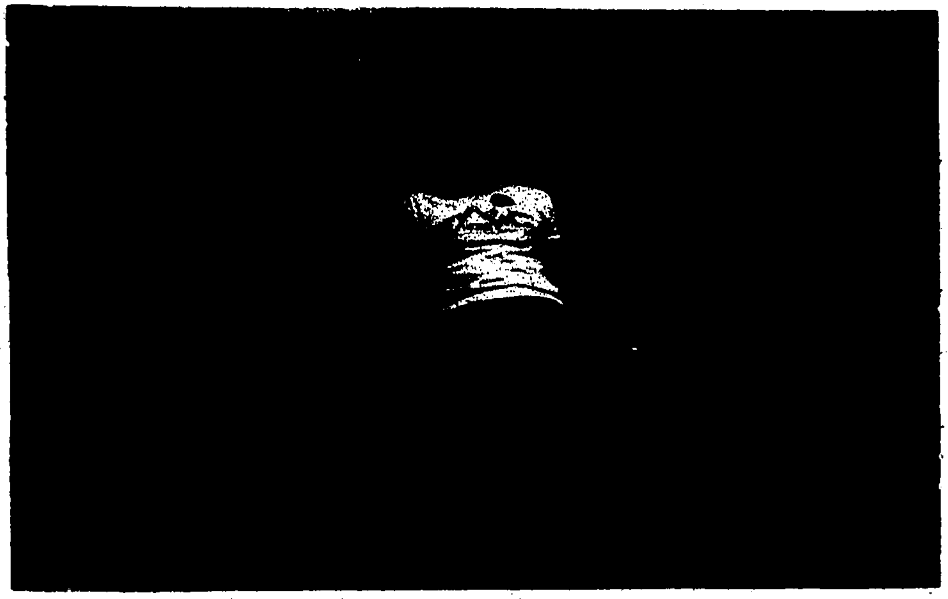
PRO POWER

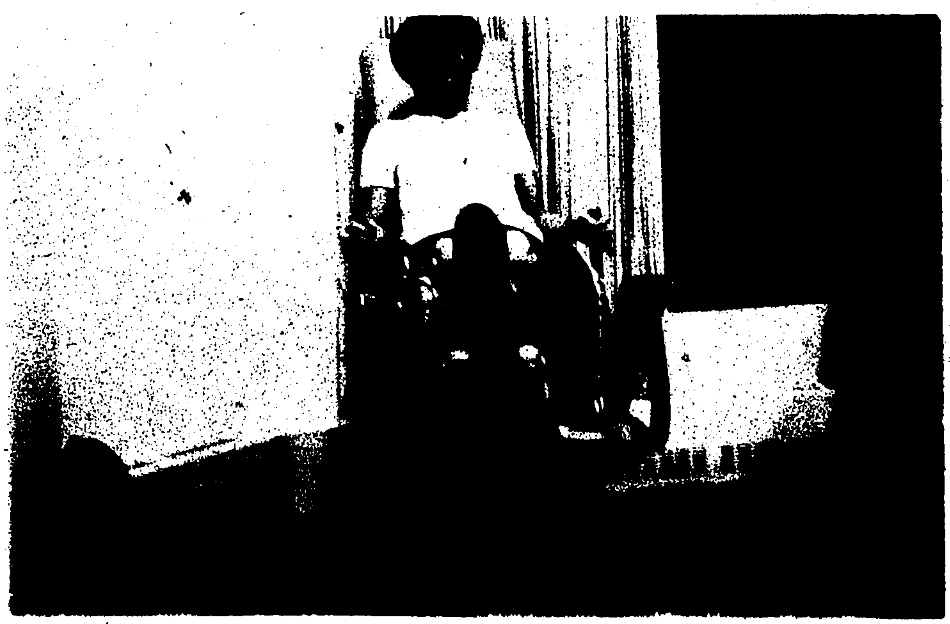
POWER BUTTERFLY



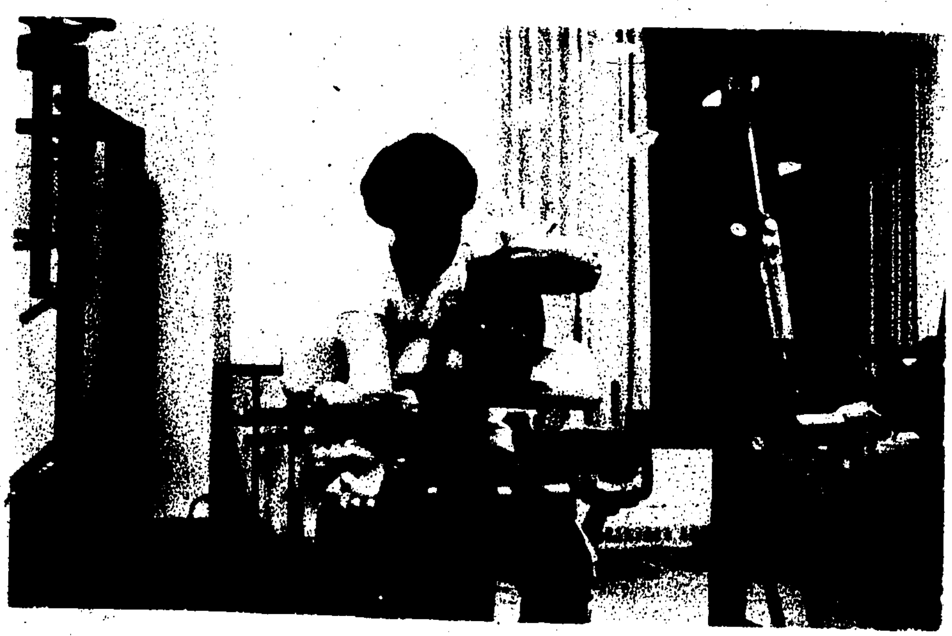
POWER RUNNER

SHOULDER PRESS

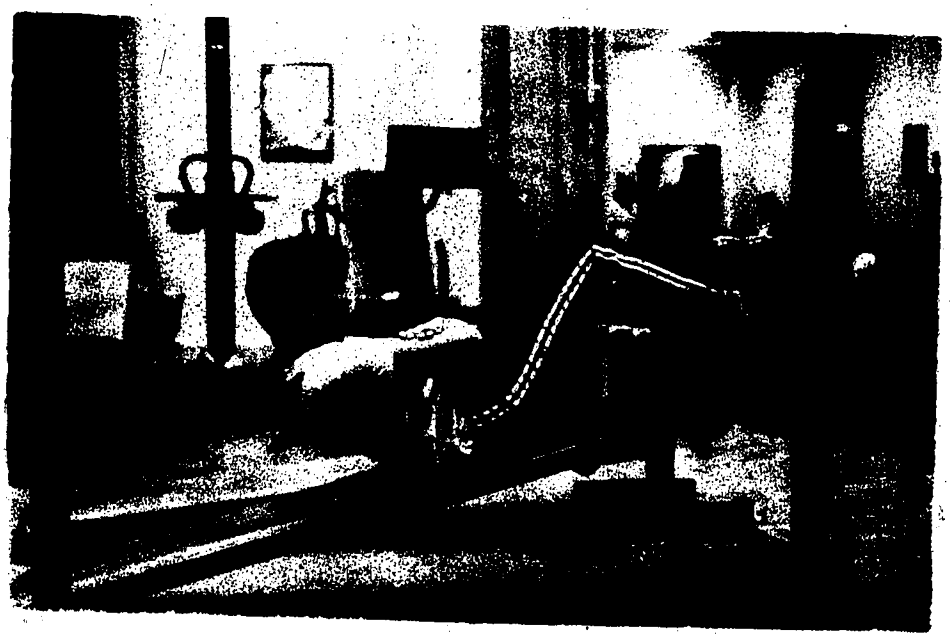




UNI-LATERAL KNEE



ARM CURLS



SIT-UPS

ABDUCTOR-ADDUCTOR

APPENDIX B

FORMS UTILIZED IN THE PROGRAM

PERSONAL INFORMATION

NAME:______________________________ AGE:__________

SEX: M F Height:__________ Weight:__________

Phone # Home__________ Work__________

1. Are you currently involved in any regular activity? If so what and how often:

____

____

____

____

2. How long have you been involved in the above activity?

____

____

3. If currently inactive, how long has it been since you were involved in any regular activity?

____

____

4. Do you smoke?______ If so, how much and for how long?__________

5. Have you ever been through a fitness test before?_____ If yes, how long ago?__________________

6. Are you presently on any medication?__________

If yes, what and for what condition?__________

____

____

7. Further comments:__________________

____

____

Date:______________ Signature:______________

To: ALL PARTICIPANTS

From: Diane Satre

Prior to your testing session would you please note the following instructions:

1. Do not smoke within ONE hour of the test.
2. Do not drink coffee or tea (or other beverages containing caffeine) within one hour of your testing session.
3. Do not eat within one hour of the test. If you cannot avoid eating, please eat lightly.
4. Do not consume any alcoholic beverages within twenty-four hours of your test.
5. Do not exercise strenuously within twenty-four hours of your test.

CONSENT FORM FOR EXERCISE TESTING

I,____, authorize Diane Satre and her assistants to administer and conduct a series of tests designed to assess cardio-respiratory capacity, strength and per cent body fat.

I understand that the test for assessing cardiovascular capacity will involve performing on a bicycle ergometer at two submaximal, progressive workloads, each being four minutes in duration. Throughout this eight minutes my heartrate will be monitored using an Exersentry and the resistance setting on the bicycle during the final four minutes will be set so as to illicit a heartrate response between 70% and 85% of my maximum heartrate, as estimated according to my age.

I also understand that for assessing strength, I will perform a series of six exercises, four upper body exercises and two lower body exercises. I will perform one repetition, of maximal effort, for each exercise, using two different exercise systems: the Universal Gym and Nautilus equipment. I will also perform three repetitions of maximal exercise for each exercise using the Hydra-Gym equipment.

Per cent body fat will be determined using a series of skinfold measurements.

These tests will be discontinued if I become distressed in any way or develop any abnormal response. Every effort will be made to conduct these tests in such a manner that any risk or discomfort is minimized, however, I understand that there are potential risks with these tests which include transient lightheadedness, faintness, leg cramps, chest discomfort and extremely rarely, heart attack.

In agreeing to participate in these tests, I waive any legal recourse against Diane Satre and her assistants, the Northern Alberta Institute of Technology, or the Edmonton Fitness Centre, for any personal injuries sustained or from death resulting from these tests. This waiver shall be binding upon my heirs and my personal representatives.

Date:________________________ Signature:__________________________

Witness:__________________________

Due to lack of availability of Copyright permission, page 76 has been removed. This page contained the Par-Q Questionnaire developed by Chisolm et al. (18) which was used as a means of medically screening subjects who participated in this study.

EXERCISE TESTING DATA SHEET

NAME: ______________________________ DATE: ______________

Age: __________ Weight: __________ kg. Sex: M F

1. Cardiorespiratory Data
   Astrand (modified): Resting H.R. ________ Resting B.P. ________ Bike # ________

Min.	Load	H.R.	B.P.	Min.	Load	H.R.	B.P.
1				5			
2				6			
3				7			
4				8			

Recovery: H.R. __________ 3 min. B.P. __________ 3 min.

Predicted VO_2max ________ l./min x A.C.F. ________ ℓ/min. ________ ml./kg/min.

2. Body Composition Data

Test 1 (Pascale)

	X_1	X_2	X_3
1.			
2.			
3.			
$\bar{x}$			

Σ=

Test 2 (Durnin)

	X_1	X_2	X_3	X_4
1.				
2.				
3.				
$\bar{x}$				

Σ=

3. Strength Data

Exercise	Hydra-Gym Resistance			Nautilus Resistance	Universal/Free Wts. Resistance
Total Power(Shoulders up)					
Arm Curls					
Total Power (Legs)					
Bench Press (Up)					
Total Power (Lat.pull)					
Power Squat(Leg Press)					

CONSENT FORM FOR PARTICIPATION IN TRAINING PROGRAM

I, ____, hereby give my consent to participate in a training program designed by Diane Satre for use on the Hydra-Gym equipment, a type of variable resistance exercise equipment.

I understand that I will train 3 times per week for a period of 10 weeks. Each training session I will perform up to 3 circuits of 10 exercises involving various pieces of equipment. For each exercise I will work as fast as I can for 20 seconds, at a resistance between 40% and 60% of my maximum strength. Following the 20 second work interval, I will have a 40 second relief interval during which time I will prepare for the next exercise. I will continue in this manner throughout the workout for a total workout time of 30 minutes.

I acknowledge that I have been informed of and fully understand all the specific details associated with the training procedures. I have also been familiarized with the equipment I will be training on.

I fully understand as it has been explained to me that by notice given to the undersigned investigator that I may withdraw from this research project any time that I may elect to do so.

I further acknowledge that I have been informed of the potential health risks associated with a program of this nature.

In agreeing to participate in this training program, I waive any legal recourse against Diane Satre and her assistants, or against The Edmonton Fitness Centre, for any personal injuries sustained or from death resulting from this program. This waiver shall be binding upon my heirs and my personal representatives.

Date:______________________________ Signature:_________________________________

Witness:_________________________________

I hereby certify that I have given to the above individual an explanation of the contemplated study and any possible side effects.

Investigator's Signature:_____________________________________

APPENDIX C

THREE WAY ANALYSES ON POST-TEST VO_2MAX AND PER CENT BODY FAT

TABLE XIII

THREE WAY ANALYSIS OF VARIANCE - POST-TEST VO_2MAX BY TREATMENT, SEX AND INITIAL VO_2MAX

Source of Variation	Sum of Squares	DF	Mean Square	F	Significance of F
Main Effects	2202.036	3	734.012	14.908	0.000
Treatment	655.879	1	655.879	13.321	0.001
Sex	433.452	1	433.452	8.803	0.004
Fit	1467.774	1	1467.774	29.811	0.000
2-Way Interactions					
Tr Sex	35.233	3	11.744	0.239	0.869
Tr Sex	23.573	1	23.573	0.479	0.492
Sex Fit	4.454	1	4.454	0.090	0.765
	0.560	1	0.560	0.011	0.915
3-Way Interactions					
Tr Sex Fit	73.813	1	73.813	1.499	0.226
	73.813	1	73.813	1.499	0.226
Explained	2311.081	7	330.154	6.705	0.000
Residual	2806.485	57	49.237		
Total	5117.566	64	79.962		

TABLE XIV

THREE WAY ANALYSIS OF VARIANCE - POST-TEST VO_2MAX BY TREATMENT, AGE LEVEL AND INITIAL VO_2MAX[2]

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif of F
Main Effects	2275.926	3	758.642	16.009	0.000
Treatment	891.214	1	891.214	18.806	0.000
Aged	507.342	1	507.342	10.706	0.002
Fit	805.254	1	805.254	16.993	0.000
2-Way Interactions	134.858	3	44.953	0.949	0.423
Tr Aged	0.013	1	0.013	0.000	0.987
Tr Fit	30.899	1	30.899	0.652	0.423
Aged Fit	83.265	1	83.265	1.757	0.190
3-Way Interactions					
Tr Aged Fit	5.624	1	5.624	0.119	0.732
	5.624	1	5.624	0.119	0.732
Explained	2416.407	7	345.201	7.284	0.000
Residual	2701.159	57	47.389		
Total	5117.566	64	79.962		

TABLE XV

THREE WAY ANALYSIS OF VARIANCE - POST-TEST PER CENT BODY FAT BY TREATMENT, SEX AND INITIAL PER CENT BODY FAT

Source of Variation			Sum of Squares	DF	Mean Square	F	Significance of F
Main Effects			1411.305	3	470.435	34.914	0.000
Treatment			85.464	1	85.464	6.343	0.015
Sex			110.664	1	110.664	8.213	0.006
Body Fat Per Cent			373.669	1	373.669	27.732	0.000
2-Way Interactions			14.921	3	4.974	0.369	0.776
Tr		Sex	4.560	1	4.560	0.338	0.563
Tr		BFPR	13.822	1	13.822	1.026	0.315
Sex		BFPR	0.060	1	0.060	0.004	0.947
3-Way Interactions							
Tr	Sex	BFPR	0.214	1	0.016	0.016	0.900
			0.214	1	0.016	0.016	0.900
Explained			1426.441	7	203.777	15.123	0.000
Residual			768.030	57	13.474		
Total			2194.471	64	34.289		

TABLE XVI

THREE WAY ANALYSIS OF VARIANCE - POST-TEST PER CENT BODY FAT BY TREATMENT, AGE LEVEL AND INITIAL PER CENT BODY FAT

Source of Variation			Sum of Squares	DF	Mean Square	F	Significance of F
Main Effects			1419.455	3	473.152	41.340	0.000
Treatment			150.469	1	150.469	13.147	0.001
Aged			118.814	1	118.814	10.381	0.002
Body Fat Per Cent			1277.051	1	1277.051	111.577	0.0
2-Way Interactions			69.429	3	23.143	2.022	0.121
Tr		Aged	31.724	1	31.724	2.772	0.101
Tr		BFPR	45.886	1	45.886	4.009	0.050
Aged		BFPR	1.129	1	1.129	0.099	0.755
3-Way Interactions			53.197	1	53.197	4.648	0.035
Tr	Aged	BFPR	53.197	1	53.197	4.648	0.035
Explained			1542.081	7	220.297	19.248	0.000
Residual			652.390	57	11.445		
Total			2194.471	64	34.289		

APPENDIX D

POST-TEST MEANS FOR THREE WAY ANALYSES ON POST-TEST VO_2MAX AND PER CENT BODY FAT: TWO WAY COMBINATIONS

TABLE XVII

GROUP MEANS FOR THREE WAY ANALYSES ON POST-TEST VO_2MAX: TWO WAY COMBINATIONS

Group	N	Post-Test $\bar{x}$
Control/Initially High	10	42.78
Control/Initially Low	19	31.85
Training/Initially High	10	47.10
Training/Initially Low	26	39.08
Control/Old	6	28.67
Control/Young	23	39.96
Training/Old	15	36.67
Training/Young	21	44.62
Old/Initially High	4	38.20
Old/Initially Low	17	33.47
Young/Initially High	16	46.75
Young/Initially Low	28	37.11
Control/Female	13	33.92
Control/Male	16	36.31
Training/Female	16	39.38
Training/Male	20	42.00
Female/Initially High	12	43.33
Male/Initially High	28	48.00
Female/Initially Low	17	32.41
Male/Initially Low	8	38.00

TABLE XVIII

GROUP MEANS FOR THREE WAY ANALYSES ON POST-TEST PER CENT BODY FAT: TWO WAY COMBINATIONS

Group	N	Post-Test $\bar{X}$
Control/Initially High	13	26.57
Control/Initially Low	16	16.70
Training/Initially High	19	23.05
Training/Initially Low	17	15.12
Control/Old	6	22.32
Control/Young	23	20.81
Training/Old	15	21.13
Training/Young	21	17.99
Old/Initially High	10	25.12
Old/Initially Low	11	18.16
Young/Initially High	22	24.18
Young/Initally Low	22	14.75
Control/Female	13	25.71
Control/Male	16	17.39
Training/Female	16	23.43
Training/Male	20	16.29
Female/Initially High	25	25.37
Male/Initially High	7	21.27
Female/Initially Low	4	18.70
Male/Initially Low	29	15.50

APPENDIX E

RAW DATA

TABLE XIX

RAW DATA FOR CONTROL SUBJECTS

Subjects	Age	% Body Fat Pre-Test	% Body Fat Post-Test	Max VO_2 Pre-Test	Max VO_2 Post-Test
*1	27	22.64	23.06	39	41
2	31	22.38	24.70	22	19
3	23	26.31	27.11	30	30
4	24	30.28	31.30	27	27
5	39	37.63	37.45	25	25
6	30	19.68	18.77	43	42
7	29	22.00	23.31	49	46
8	27	28.24	25.89	31	33
9	34	19.75	19.20	39	41
10	24	26.56	26.52	34	30
11	23	28.58	29.54	36	33
12	34	27.87	26.61	33	32
13	32	21.78	20.80	35	42
**1	44	18.80	18.87	40	34
2	40	20.20	21.44	21	25
3	35	20.67	19.06	26	28
4	33	16.37	16.35	45	38
5	34	15.12	14.69	42	43
6	34	19.60	19.73	28	30
7	42	19.85	19.09	33	35
8	30	13.33	14.75	40	39
9	19	14.56	14.75	39	33
10	20	10.98	12.01	54	50
11	29	13.83	13.72	51	51
12	34	13.18	13.29	31	29
13	20	11.25	10.92	40	44
14	19	28.35	30.00	41	37
15	28	17.24	18.58	42	40
16	40	19.76	20.74	25	25

* 1 - 13 Females

** 1 - 16 Males

TABLE XX

RAW DATA FOR TRAINING SUBJECTS

Subjects	Age	% Body Fat Pre-Test	% Body Fat Post-Test	Max VO_2 Pre-Test	Max VO_2 Post-Test
*1	30	20.03	17.25	41	52
2	25	26.70	25.03	31	35
3	22	27.36	27.07	33	40
4	34	21.07	20.90	47	48
5	45	39.56	35.93	15	23
6	23	20.96	20.63	51	52
7	38	27.50	27.01	31	35
8	29	23.40	23.21	35	30
9	39	27.15	24.28	35	36
10	27	25.40	21.07	35	39
11	37	24.62	22.67	32	43
12	31	22.92	21.04	42	46
13	37	23.95	23.01	39	38
14	34	22.85	22.82	36	36
15	24	20.50	19.58	32	42
16	27	24.41	23.39	31	35
**1	40	18.45	16.30	33	41
2	34	16.50	14.10	35	38
3	33	15.33	14.59	39	43
4	44	19.48	17.98	26	34
5	35	21.36	18.58	43	45
6	37	24.84	22.84	19	24
7	32	11.88	10.72	51	51
8	19	14.63	14.46	52	57
9	26	15.47	13.83	43	51
10	32	21.14	18.95	45	55
11	34	11.28	9.92	44	42
12	29	13.60	12.10	48	56
13	35	23.82	21.03	38	45
14	19	18.06	17.15	34	43
15	36	18.73	17.96	40	40
16	35	14.44	13.98	22	32
17	43	20.25	19.56	31	37
18	40	17.74	17.46	38	53
19	42	22.13	18.42	24	24
20	28	10.05	10.03	40	46

* 1 - 16 Females

** 1 - 20 Males

APPENDIX F

BODY WEIGHTS FOR TRAINING SUBJECTS

TABLE XXI

BODY WEIGHTS FOR TRAINING SUBJECTS

Subjects	Age	Pre-Test Weight (kg)	Post-Test Weight (kg)
*1	30	53.6	49.5
2	25	64.5	64.5
3	22	63.5	65.0
4	34	58	58.0
5	45	84	83.0
6	23	61	63.2
7	38	68.2	69.1
8	29	54.75	56.0
9	39	62.0	61.0
10	27	53.50	55.2
11	37	60.2	60.5
12	31	49.5	50.0
13	37	61.25	61.5
14	34	58.0	58.0
15	24	57.4	57.0
16	27	62.2	57.3
**1	40	73.3	73.5
2	34	77.0	76.2
3	33	76.6	77.1
4	44	84.5	85.3
5	35	80.3	78.0
6	37	105.0	105.4
7	32	75.6	73.5
8	19	81.7	80.7
9	26	74.0	72.0
10	32	84.8	83.6
11	34	77.3	77.5
12	29	85.0	82.0
13	35	85.0	85.0
14	19	82.6	81.0
15	36	87.5	86.0
16	35	61.7	62.8
17	43	96.3	94.5
18	40	78.0	79.1
19	42	89.3	82.1
20	28	67.2	68.2

* 1 - 16 Females
** 1 - 20 Males