AN ABSTRACT OF THE THESIS OF

Tae Won Jun for the degree of Doctor of Philosophy in Education presented on July 21, 1986.

Title: The Effect of Interval Weight Training on Dynamic Muscular Strength, Power and Cardiorespiratory Function in Male College Students

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Purpose: The purpose of this study was to determine the relative effectiveness of interval weight training on the development of dynamic muscular strength, power and cardiorespiratory function.

Procedure: This study was conducted during the spring term of the 1986 academic year. All training was done in the weight training room of the Department of Physical Education at Oregon State University, Corvallis, Oregon. The subjects consisted of sixteen male students who had registered for an intermediate weight training class.

The pre- and post-test control group research design was employed for this study. The subjects were randomly

assigned to either the experimental group (interval weight training program) or the control group (circuit weight training program). Training was limited to sixty minutes twice a week and continued for six weeks. All subjects were pre tested and post tested for dynamic muscular strength, power and cardiorespiratory function.

Analysis of Data: The amount of change in each group from pre-test to post-test was determined for each dependent variable. Initial and final means within each group were analyzed by the "t" test for related samples. The one-way analysis of covariance was used to determine significant difference between group mean scores. The .05 level of significance was used as the critical level for retention or rejection of the null hypotheses for the study.

Conclusions: From the statistical evaluation of the results, the following conclusions may be made.

1. Six weeks of interval weight training produces significant increases in strength and power.

2. Six weeks of interval weight training is superior to circuit weight training in producing squat strength.

3. Six weeks of interval weight training does not produce a statistically significant improvement in cardiorespiratory function.

THE EFFECT OF INTERVAL WEIGHT TRAINING ON DYNAMIC MUSCULAR STRENGTH, POWER AND CARDIORESPIRATORY FUNCTION IN MALE COLLEGE STUDENTS

by

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TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

LIST OF FIGURES

LIST OF TABLES

THE EFFECT OF INTERVAL WEIGHT TRAINING ON DYNAMIC MUSCULAR STRENGTH, POWER AND CARDIORESPIRATORY FUNCTION IN MALE COLLEGE STUDENTS

CHAPTER I

INTRODUCTION

Dynamic muscular strength, power and cardiorespiratory endurance are the essential factors which bring about winning and losing in athletic sports. Sports such as soccer, rugby, tennis, field hockey, handball and middle distance running (800m, 1500m, 5000m) require athletes to have both relatively high aerobic power and anaerobic power.

Development of the strength needed by such sports is no doubt aided by weight training (73). Yet the aerobic effects of weight training are disputed, and the idea of simultaneously training for both strength and endurance is controversial. It has in fact proven difficult to devise a specific type of training which develops both aerobic and anaerobic power to a high degree. Indeed, the specificity of training principle dictates that aerobic metabolism is affected by aerobic exercise, whereas anaerobic metabolism is affected by anaerobic exercise (75).

It seems apparent that there is some type of interference when simultaneously cross training for aerobic and anaerobic power, though the exact nature of that

interference has not been identified. Hickson (52), for example, concluded that endurance training interferes with gains in absolute strength, and a study by Nelson (70) concluded that absolute strength training interferes with improvement in maximum oxygen uptake (VO_2 max), though muscular endurance training does not interfere with strength training.

However, recent studies have reported that programs of circuit weight training are effective in producing modest increases in maximal aerobic power and in muscular strength (42, 43, 44, 45). Gettman (41) concluded that the gains in aerobic work capacity and in muscular strength induced by circuit weight training programs are moderate.

Moreover, it is believed possible to combine the development of both aerobic and anaerobic systems by using interval training (34). The major difference between interval training and other conditioning programs is that while most conditioning programs are conducted on a continuous basis without regard to rest periods, interval training intersperses periods of relative rest among periods of work. Activities such as calisthenics, running, cycling, swimming and weightlifting can be done in intervals, rather than continuously. As a result of such interval training, more work and less fatigue is realized in the exercise. Scientific evidence supports

the idea that a proper work to relief ratio is the key to interval training success (34).

One method of weightlifting that may tax the cardiorespiratory system and thus bring about a significant improvement in aerobic function as well as in muscular strength is interval weight training (34, 79). The application of the interval training concept to conventional weight training was first suggested by O'Shea (79) in 1984. Interval weight training applies concepts of intensity, volume and rest to a greater extent than circuit weight training and can be used to develop strength, power, and cardiorespiratory function. It can also be used to physiologically improve neuromuscular function, anaerobic metabolism, aerobic metabolism, and muscle hypertrophy in order to maximize athletic performance. According to O'Shea (79) the major benefits resulting from interval weight training are:

1. Training the lactic acid system pushes back anaerobic threshold which aids in delaying the onset of fatigue.

2. Interval weight training greatly improves cardiac function by bringing about maximal attainable stroke volume. In this manner the aerobic system is developed.

3. Interval weight training trains the fast twitch muscle fibers (strength-producing muscles), which may improve both muscular strength and muscular endurance.

4. Interval weight training trains the mind to accept and tolerate the pain that accompanies intense aerobic work.

The most advantageous time to use interval weight training is during the basic strength cycle, and it should be used for at least four weeks and not more than eight weeks (79).

Application of the overload principles of intensity to interval weight training programs is accomplished through the manipulation of five variables (79):

1. Work interval (type and selection of the weight training exercise.)

2. Intensity (a given percent of the 1 RM in a lift.)

3. Volume (number of repetitions.)

4. Density (a ratio relating to the duration of the work to relief interval.)

5. Relief interval (the rest time between the work interval or between sets.)

It is important to note that two types of relief interval were used:

1. Rest-relief interval: light stretching and walking between intervals and sets.

2. Work-relief interval: light to mild exercise between intervals and sets.

Interval weight training program prescriptions will depend mostly on three main rules (79). One must:

1. determine which energy systems need to be increased: ATP-PC, ATP-PC-LA, LA-O_2, or O_2 systems.

2. select the type of weight training exercise to be used.

3. employ the overload principle and the specificity of training.

However, research is untouched in the area of interval weight training related to the simultaneous development of dynamic muscular strength, power and cardiorespiratory function.

Purpose of the Study

The purpose of this study was to examine the relative effectiveness of interval weight training on the development of dynamic muscular strength, power and cardiorespiratory function.

Need for the Study

Physical educators and coaches are often faced with the problem of raising the levels of dynamic muscular strength, power and cardiorespiratory function in students and athletes. In recent years, various weight training programs have been used for this purpose. However, general agreement has not been reached as to the best program for the development of a combination of these factors.

If it could be shown that interval weight training is more effective than conventional weight training or circuit weight training for improving dynamic muscular strength, power and cardiorespiratory function, physical educators and coaches could use this system of training

when dynamic muscular strength, power and cardiorespiratory function are the primary objectives. Success in this type of training might also be of considerable interest to other areas of athletics and recreation.

Null Hypotheses

The general hypothesis tested in this study was that six weeks of interval weight training would result in no statistically significant improvement in dynamic muscular strength, power and cardiorespiratory function in college males.

Sub hypotheses

The following sub hypotheses were proposed for this study. As a result of the experiment the following sub hypotheses should be retained or rejected.

1. There will be no significant difference in the pre-test and six-week post-test means for strength within the circuit weight training group and within the interval weight training group.

2. There will be no significant difference in the pre-test and six-week post-test means for power within the circuit weight training group and within the interval weight training group.

3. There will be no significant difference in the pre-test and six-week post-test means for cardiorespiratory function within the circuit weight training group and within the interval weight training group.

4. There will be no significant difference in the six-week adjusted mean scores for strength between the circuit weight training group and the interval weight training group.

5. There will be no significant difference in the six-week adjusted mean scores for power between the circuit weight training group and the interval weight training group.

6) There will be no significant difference in the six-week adjusted mean scores for cardiorespiratory function between the circuit weight training group and the interval weight training group.

Basic Assumptions

The following assumptions were made for this study.

1. The one-repetition maximum of bench press and squat is a valid test for measuring dynamic muscular strength.

2. The vertical jump test is a valid test for measuring power.

3. The subjects performed maximally in their training programs and during the testing periods.

Delimitations

The scope of this study was delimited by the following factors:

1. The subjects were 16 male college students registered in an intermediate weight training class at Oregon State University during the spring term of 1986.

2. No subjects who participated in endurance training or additional weight training activity were included in the study.

3. All training groups trained only two days per week throughout the training period of six weeks.

4. Strength was assessed only by using the one repetition maximum of dynamic muscular strength in the bench press and the squat.

5. Power was assessed only by using the vertical jump test.

6. Cardiorespiratory function was assessed only by using graded exercise testing.

7. Control of physical activities outside of weight training and varsity sports was not possible.

8. Motivation of the subjects to perform at maximum capabilities could not be controlled completely.

Definition of Terms

For the purpose of this study, the following definitions of terms are necessary.

Strength -- The force that a muscle or muscle group exerts against resistance in one maximal effort.

Dynamic muscular strength -- The ability of a muscle or muscle group to exert force in a given situation while taking into account the phenomenon of inertia. That is, the weight or object being lifted or moved must be first accelerated, and once a velocity has been attained, the weight or object has momentum that causes it to continue moving even after the contraction is over.

Power -- Muscle strength multiplied by limb velocity.

Endurance -- The ability to repeat a series of muscular contractions.

Cardiorespiratory function -- The adequate function or response of those physiological systems that deliver fuel and oxygen to the active muscles.

Circuit weight training -- A method of training in which the participant moves from one weight station to another

in a continuous fashion with minimal rest between stations.

Interval weight training -- A series of repeated bouts of weightlifting (the work interval) performed at the anaerobic threshold, alternated with periods of work relief.

Work interval -- That part of the interval training which consists of the work effort.

Relief interval -- The rest time between the work interval and between sets.

Rest-relief interval -- Very light exercise between work intervals.

Work-relief interval -- Medium exercise between work intervals.

Work-relief ratio -- A ratio relating the duration of the work interval to the duration of the relief interval.

One repetition maximum (1 RM) -- The maximum load a muscle or muscle group is able to contract against for one repetition.

Repetition -- The number of times a dynamic or static contraction is repeated in a given exercise set.

Set -- One series of repetitions without a rest for a given exercise.

Maximal oxygen consumption ($\dot{V}O_2$ max) -- The highest oxygen uptake a subject can attain during physical work while breathing air at sea level. This is often measured as oxygen uptake in liters O_2/minute or in relation to body weight in kg (ml/kg/min).

$\dot{V}e$(BTPS) -- Minute volume expired ventilation - BTPS conditions (normal body temperature 37°C, ambient pressure, saturated with water vapor).

Ventilatory equivalent ($\dot{V}e/\dot{V}O_2$) -- The ratio of minute ventilation to O_2 consumed.

CHAPTER II

REVIEW OF RELATED LITERATURE

The literature reviewed was concerned with the effectiveness of interval weight training on muscular strength, power and cardiorespiratory function. No studies were found which dealt directly with interval weight training. Thus, it appeared appropriate to review studies relating to physiological changes, strength, power and cardiorespiratory function in weight training programs and interval training, all of which have a direct relationship to this study.

Physiological Changes Resulting from Weight Training Programs

Biochemical research in the past decade has shown that there is an increase in the functional capacity of skeletal muscle in response to weight training and repetitive exercise (18, 29, 56, 59, 103). Such an increase is a reflection of changes in the structure of muscle fiber and its protein content (75).

Morpurgo (94) in 1887 was the first to demonstrate that muscle hypertrophy could be achieved through exercise. This finding was subsequently confirmed by other investigators (11, 21, 77). The enlargement of

muscle that results from weight training is mainly due to an increase in the cross-sectional area of the muscle fibers (35). Yet increased strength is not always accompanied by muscle hypertrophy. Brouha (15) states that it is possible to increase the power of muscle three times or more without a proportional increase in volume.

Penman (81) indicates that the lack of muscle hypertrophy with strength increase is related to an increase in packing density of the myofibrilar elements and changes in the actin and myosin ratio in the muscle.

It is thought by researchers that weight training results in hypertrophy (increase in size of muscle cells) and not in hyperplasia (increase in number of muscle cells) of the muscle fiber. Overall, the degree of muscle hypertrophy associated with an increase in muscle strength depends largely on the duration, intensity, frequency, and type of exercise of the imposed training program (75).

According to Mathews and Fox (35) the aerobic and anaerobic changes due to training are as follows:

Aerobic changes

1. Increased myoglobin content.
2. Increased oxidation of glycogen.

3. Increased number and size of the mitochondria in skeletal muscle fibers.

4. Increased concentration of enzymes involved in the Krebs cycle and electron transport system.

5. Increased amounts of glycogen stored in the muscle.

6. Increased activity of glycogen synthetase.

7. Increased oxidation of fat which reduces lactic acid accumulation, resulting in less fatigue.

Anaerobic changes

1. Increased capacity of the ATP-PC system.

2. Increased muscular levels of ATP, PC and creatine kinase.

O'Shea (74) summarized the effects of super quality strength training on the neuromuscular system. As a result of isotonic, full range, multiple-joint strength training, there occurs in the neuromuscular system:

1. an increase in the nerve fiber diameters

2. an increase in the length of the motor-neuron, providing a greater synaptic area for the effective release of the neurotransmitter.

3. an increase in the size of the neuromuscular junction in proportion to muscle fiber type

4. an increase in the motor endplate area (synaptic control area of the muscle fiber) which expands in proportion to the increase in axon length in the hypertrophied muscle

5. an increase in the number of functional synapses, which allows the athlete to utilize a greater percent of the motor units in a

group of synergistic muscles at any one time; by performing a dynamic strength movement over and over for a prolonged period of time, correct patterns of "nerve-reflexes" are developed in which the synapse blocks weak signals while allowing the strong ones to pass, channeling the signal in the proper direction

6. Associated with number 5 is a corresponding increase in neuronal facilitation and spatial summation; voluntary motorneuron recruitment patterns are enhanced and modified-select facilitation is developed.

7. a "learning process" in the motor cortex that makes possible smoothness and accuracy of full-range muscular movement that is acquired only by practice; dynamic strength is increased by more efficiently synchronizing motor units; the mechanics of the process of learning how to time nerve impulses and how to make a highly complex motor action effortless and automatic are unknown.

Strength Development in Weight Training Programs

There is overwhelming evidence that weight training can lead to significant gains in strength (7, 9, 11, 12, 13, 14, 17, 28, 33, 55, 62, 65, 68, 93, 105, 107, 108). Investigators who used a one-repetition maximum test protocol for assessing strength in circuit weight training programs have also reported improvements in leg press and bench press ranging from 7% to 27% and 8% to 32% respectively (42). It is well established in the literature that an increase in muscular strength can be achieved only by an increase in intensity of work beyond that previously demanded of a muscle or muscle group (progressive overloading principle) (75). The intensity of the

training program, based upon the selection of the number of repetitions, sets, and load utilized for each exercise, is the most important requirement for increasing strength (19). Dynamic strength has been defined by O'Shea (75) as:

> The ability of muscle to exert force through a wide range of multiple joints, to repeat maximum or near maximum contractions, to contract the muscles in proper sequence with other muscle groups, and to allow mobility of multiple joint action (p. 15).

One of the first experimental demonstrations in humans of the overload principle was performed by Hellebrandt and Houts (48). Delorme (24) investigated the effectiveness of dynamic resistance training and introduced the progressive overload principle, which increases the load as the muscle becomes stronger. He indicates that one to three repetitions for three to four sets with maximum load are best for the development of strength. Delorme's progressive resistance principle became the foundation of strength training programs.

Berger (7, 9, 10, 11) conducted several studies to determine the optimal training program for strength. In his study a 1 RM in the bench press was used for measuring changes in dynamic strength. He found that three sets of 2-6 RM, three times per week, produced the greatest increase in muscle strength (11).

O'Shea (76) conducted a study in which the subjects trained three times per week for six weeks using the 1 RMK

in the squat and a leg dynanometer for knee flexion, respectively. The subjects were divided into three groups, one group performing three sets of 10 RM, the second group performing three sets of 5 RM and the third group performing three sets of 2 RM. All groups made statistically significant gains in static and dynamic strength, but no significant difference was found between the three groups.

O'Shea (73) has summarized the research in strength training which indicates three types of programs are utilized to develop muscle strength and endurance. The summary of his weight training method is shown in Table 1. The programs are: (1) three sets of one to three repetitions at 90% of 1 RM for maximum strength development, (2) four to five sets of four to ten repetitions at 75-85% of 1 RM for strength plus muscular endurance development, (3) five to seven sets of eight to twelve repetitions at 60-75% of 1 RM for the development of muscular endurance.

Table 1. Weight Training Intensity

Training Phase	Work Load % of 1 RM	Repetitions	Sets
1. Maximum Strength	90+	1-3	3
2. Strength Plus Muscular Endurance	75-85	4-10	4-5
3. Muscular Endurance	60-75	8-12	5-7

Stone and others (98) analyzed eleven studies and presented a theoretical model for strength and power training. This model is shown in Table 2. The four phases in the model were hypertrophy, basic strength, strength and power, and peaking or maintenance. The recommended intensities of training programs were low intensity for hypertrophy, moderate volume at high intensities for basic strength, low volume at high intensity for strength and power, and very low intensity for peaking or maintenance. This model is similar to the cycle program established by O'Shea (72). O'Shea's cycle weight training program is shown in Table 3.

Table 2. A Hypothetical Model of Strength Training

Preparation	Transition 1	Competition		Transition 2
Phase	Hypertrophy	Basic Strength	Strength & Power	Peaking* or Maintenance
Sets[x]	3-5	3-5	3-5	1-3
Reps	8-20	2-6	2-3	1-3
Days/Wk	3-4	3-5	4-6	1-5
Times/Day	1-3	1-3	1-2	1
Intensity Cycle (week)**	2-3/1	2-4/1	2-3/1	-
Intensity	low	high	high	very high to low
Volume	high	moderate to high	low	very low

* Peaking for sports with a definite climax or maintenance for sports with a long season such as football.
** Intensity Cycle -- ratio of the number of heavy training weeks to light training weeks.
x Does not include warmup sets.

Table 3. The Cycle Program

Training Week	Work Load % of 1-RM	Reps	Sets
Heavy	85-100+	1-3	4-5
Light	60-75	4-5	3-4
Medium	70-85	4-5	4-5

O'Shea (72) recommends a cycle program for dynamic strength development. The program is divided into four weekly periods of heavy, light, and medium training using a varying percentage of 1 RM for a given number of repetitions and sets. A typical cycle program by O'Shea includes (1) four to five sets of one to three repetitions at 85-100% for heavy training, (2) three to four sets of four to five repetitions at 60-75% of 1 RM for light training, and (3) four to five sets of four to five repetitions at 70-85% of 1 RM for medium training.

The frequency and duration of the training programs vary. The frequency of training largely depends on the sports event, but at least two to three days a week are recommended by most researchers (47, 72, 89). Duration of the training program should be long enough to acquire physiological adaptations. Studies (47, 99) indicate that

a minimum of five weeks is required for adaptations to take place.

Power Development in Weight Training

Power is very easy to understand with a basic knowledge of physics. It is the amount of work which can be accomplished per unit of time and is calculated simply as the product of force multiplied by velocity.

Power = Work/Time = Force x Velocity

In the typical sports situation, power can be thought of as the muscular strength a limb can generate in a given movement times the limb velocity during that movement (50).

Power = Muscular Strength x Limb Velocity

O'Shea (74) states that power interlocks the concepts of strength and power. To develop high velocity power, the athlete needs to emphasize both strength and speed in the training program.

Garhammer (40) explained the training effect as a relationship between force and velocity, as the following.

He explained, as shown in Figure 1, that force and velocity are inversely related in a hyperbolic manner.

While this relationship was originally found in isolated muscle, it also is true for intact single joint movements (82) and has recently been shown to hold for multi-segment movements (37, 38, 58). There is considerable evidence to show that strength training can shift this curve to the right in beginners, as shown in Figure 2 (61). Because Power = Force x Velocity, this clearly entails an increase in power at all points on the curve, and it is likely that the lower portion of the curve will continue to shift to the right, as shown in Figure 3 (40). Furthermore, it is possible that specific types of high speed, high power training may positively influence the higher velocity portion of the curve (58).

Garhammer (39) has filmed the maximum snatch and clean and jerk of many weight lifters at national and international contests over a period of several years. He concluded that for a given lifter the higher power output occurred when the heaviest weight was lifted (40).

He also found that Olympic style weightlifters have been shown to produce the highest power output of any human movement athletes to date (40).

According to O'Shea (73) whenever the skill demands of running, jumping, lifting, throwing, blocking or tackling are involved in a sport, strong rotary hip action is required. Thus, the athlete utilizing these skills needs a strong "power zone" in order to execute them

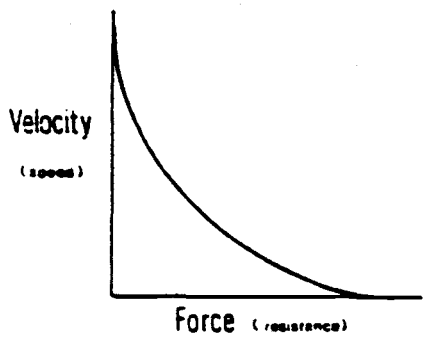

Figure 1. Force-Velocity Curve

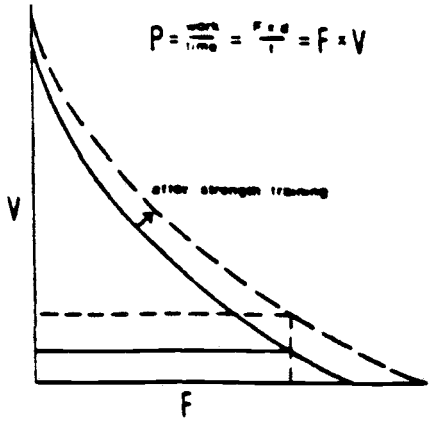

Figure 2. Force-Velocity Curve (Training Effects)

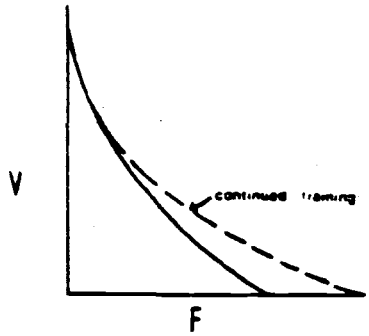

Figure 3. Changes in the force-velocity curve with advanced training

effectively and safely. He indicates that the muscle groups encompassing the body's power zone are the abdominals, obliques, lower back, hip extensors and flexors, thighs and other smaller stabilizing muscles surrounding the knee and hip joints. To maximize development of these muscle groups requires working and training them as a unit through a wide range of forceful joint movement with speed using fairly heavy resistance (approximately 25-30 percent of maximum speed) (73).

Several studies have been conducted to determine the effect of weight training on power. Chui (20) examined the effect of weight training on the development of power. After three months of training, the weight training group gained substantially in power, while the control group showed no gains. Capen (16), in a similar study, also reported significant development in power for the experimental group.

In a comparison of dynamic and static training programs, Berger (8) found that groups who were trained dynamically improved significantly more in the vertical jump than groups who trained statically.

Flood (32) studied the effects of power weight training on the development of power. He used the vertical jump test as his criterion measure. The conventional weight training group executed two sets of six to eight repetitions of five selected exercises and

two sets of fifteen repetitions of two exercises. The power training group executed a single one-minute bout of each of the seven prescribed exercises during each training session. A two minute recovery period was provided between each exercise bout. Both groups trained twice weekly for ten weeks. Flood concluded that both groups significantly improved power.

Cardiorespiratory Function in Weight Training Programs

Research looking at the effects of weight training on cardiorespiratory function has produced conflicting results, but there is general agreement that high resistance, low repetition weight training does not effectively increase cardiorespiratory endurance (3).

In a study involving sixty college students, Nagel (69) reported significant gains in cardiorespiratory endurance as tested using bicycle ergometers. Two groups trained with one hour weight training programs involving five repetitions for one group and fifteen repetitions for the other. Both groups improved in cardiorespiratory endurance and no difference in improvement was found between the high and low repetition groups. He concluded that weight training increases cardiovascular endurance as measured by heart rate responses to all-out exercise.

De Pauw and Vrijens (25) studied strength and cardiorespiratory endurance of twenty Belgian weightlifters who were training for Olympic competition. The report stated that, although the weightlifters belonged to a group which records the highest absolute scores for isometric strength, their measures of cardiorespiratory function do not differ significantly from those of the normal sedentary population. De Pauw and Vrijens concluded that weight training systems used by this group do not result in any statistically significant adaptations in cardiorespiratory function, and indicated that endurance type activities should be included in weight lifting programs.

Research showing that weight training does not affect cardiovascular endurance was done by Pickney (85), who compared the effects of a weight training class and a basketball class on physical fitness. The weight training group used three sets of ten repetitions for all major muscle groups whereas the basketball group used fundamental skills and practice under game conditions. After seven weeks the basketball group showed a significant mean gain in cardiovascular endurance as measured by the Harvard Step Test. The weight training group did not make significant gains in cardiovascular endurance as measured by the same test.

A study with opposite results was done by Kuisinitz and Keeney (60) in which a randomly selected group of junior high boys participated in an eight week progressive weight training program and made significant gains in the Harvard Step Test. A control group which participated in regular physical education made no such gain.

Nagle and Irwin (68) cite statements by Steinhaus (95) and McCloy (66) which offer opposing views. Steinhaus believed that weight training decreased cardiorespiratory endurance due to increased skeletal muscle bulk which is not accompanied by similar increases in the size and efficiency of cardiorespiratory mechanisms. McCloy thought that muscle strength, which increases along with muscle size, was necessary for developing cardiorespiratory endurance, since an increase in strength would necessitate fewer muscle fibers being used by an individual in an exercise bout. If true, then fatigue would be delayed and the demand on the cardiorespiratory system would be decreased.

Wilson (109), who studied the effects of weight training on physical fitness, found that a group of students who trained with weights for a period of twelve weeks showed an average decrease in treadmill running time of 11.15 percent. A control group which participated in volleyball showed a decrease of 1.0 percent. Wilson concluded that weight training adversely affected

cardiorespiratory function. Capen (16) however, found that a group that trained with weights improved 6.2 percent in the three hundred yard run compared to a 6.3 percent gain by a control group which emphasized endurance activities. Capen concluded that both of his programs were equally effective in producing cardiorespiratory endurance.

The use of the three hundred yard run as a test to measure cardiorespiratory endurance might be questioned, as might all other tests in the literature reviewed. In a test of all-out bicycling to exhaustion on a bicycle ergometer by Swegan (101), a weight training group increased its all-out pedaling time, indicating an improvement in cardiorespiratory endurance. However, strength and muscular endurance may have been tested to a greater degree than cardiorespiratory endurance in this study.

Hickson (51) examined the strength training effects on aerobic power and short-term endurance. Nine men participated in an exercise program five days a week for 10 weeks. He found that there was a small increase in $\dot{V}O_2$ max during bicycle exercise (3.40 l/min to 3.54 l/min) after training, but no significant differences were observed when expressed in ml/kg/min.

Hurley (54) studied the effects of high intensity strength training on cardiorespiratory function. After a 16 week training, maximal oxygen uptake did not change

significantly in either the training or the control group, and there were no changes in the hemodynamic responses to submaximal exercise after training. These findings indicate, therefore, that high intensity, variable resistance strength training produces no adaptative improvement in cardiorespiratory function.

Fahey and Brown (31) reported a decrease in $\dot{V}O_2$ max after a nine-week weight training program. These weight training studies showed no training effects on cardiorespiratory endurance.

Allen (1) examined the effects of circuit weight training on cardiorespiratory function. After a 12-week program three days per week, no significant changes occurred in $\dot{V}O_2$ max, maximum cardiac output, stroke volume, or arteriovenous oxygen content difference (A-$\dot{V}O_2$ difference) measured on a bicycle ergometer. Their circuit program consisted of 30 seconds of high resistance, low repetition work sessions followed by 60 seconds of recovery, for a total workout duration of 30 minutes.

Wilmore (106) studied a program using 15-second rest periods interspersed between 30-second sessions. After ten weeks training three days a week, 12 women improved 11% in $\dot{V}O_2$ max, but 16 men showed no improvement.

He concluded that the women were working at a greater percentage of their maximal heart rate (87.6% versus

78.12%) and their $\dot{V}O_2$ max (46.8% versus 41.1%) than the men.

Gettman (45) conducted a 20 week study on circuit weight training based on the premise that better training effects would be observed after a longer training program. However, ony a 3.5% improvement in $\dot{V}O_2$ max was observed after 20 weeks in 11 men training three days a week, 30 minutes a session, at 50% of their maximum strength. The $\dot{V}O_2$ max improvements were statistically significant, indicating that the circuit weight training had an aerobic component. However, the changes were substantially lower than the 17% improvement in $\dot{V}O_2$ max during a 20-week running program conducted simultaneously on another group of 16 men.

Gettman (44) studied the training effects of eight weeks of circuit weight training followed by eight weeks of jogging and then eight weeks of either circuit weight training or continuous jogging. Both groups maintained cardiorespiratory function equally well for the subsequent eight weeks.

A study conducted by Garfield (36) showed that young men and women increased their $\dot{V}O_2$ max 6% and 5% respectively, after 12 weeks of a circuit weight training program that consisted of 30 seconds of exercise followed by 15 seconds of rest, using a 15 station circuit. Subjects completed two circuits in the first half of the

study and three circuits in the last half. Approximately 40% of maximum strength was used for each exercise.

Gettman (43) compared slow speed isokinetic training with isotonic circuit weight training over 20 weeks, three days a week, with 12 repetitions at 50% maximum strength and 30 second rest periods between sets. Both groups improved significantly in $\dot{V}O_2$ max-7% in the isotonic group and 8% in the isokinetic group.

Messier (67) investigated the effects of a Nautilus circuit weight training program on muscular strength and maximal oxygen uptake. He concluded that for a training period of short duration, Nautilus circuit weight training appears to be an equally effective alternative to standard free weight and aerobic training programs for untrained individuals. Marcinzk (64) studied the effects of two training programs, the calisthenic and circuit weight training program. Study findings show the circuit weight training program produced significantly greater dynamic muscular strength and muscular endurance changes than the calisthenic program.

Connor (22) compared the effects of two weight training systems, the traditional set system and the interval circuit system. The interval circuit systems were performed in accord with circuit training format, however a one minute work rest interval was employed for each exercise. Both groups exercised three times per

week during nine weeks and experienced a significant increase in cardiorespiratory function.

Fox and Mathews (34, 35) suggest interval weight training as a method of increasing cardiorespiratory endurance, provided that the exercise stimulus is sufficient enough to bring about and maintain a heart rate between 120 and 180 beats per minute during the exercise period.

Interval Training

The early works of Astrand, Christensen and their co-workers (5, 6, 19) undoubtedly paved the way for much of the research upon which interval training is based. These researchers used the term 'intermittent' rather than 'interval' and the two terms have become synonymous over the years.

The important aspects of the findings of these studies are that the length of individual work bouts is most critical in determining the reaction of the body to intermittent running and that different combinations of work and recovery can be used to stress the body in different ways. In their book on interval training, Fox and Mathews (35) refer to interval training as a series of repeated bouts of exercise with periods of relief.

Saltin (92) used the terms 'intermittent' and 'interval' synonymously. He also suggested that there are

different types of interval training, depending upon whether the training is aimed at improving aerobic or anaerobic capabilities. MacDougall and Sale (63), in a discussion of the merits of continuous and interval training, also used 'interval' and 'intermittent' interchangeably. Additionally they agree with Saltin's idea of using a type of interval training based on the results desired.

Haskell (46) observed large changes in performance ability with aerobic interval training but could observe no consistent differences in metabolic and cardiorespiratory variables produced by interval training programs which differed in work rate.

Ekblom and co-workers (30) trained eight young males for 16 weeks on a mixed program of short interval sprints, long interval runs and continuous running. They observed a mean increase in blood lactate after maximal exercise of 10.9% and again in maximal oxygen consumption of 16.2%. In a similar program, Cunningham and Faulkner (23) examined the effects of six weeks of training using both anaerobic interval running and longer all-out runs on several physiological and performance variables. The participants in the conditioning regimen increased 8% and 9% in maximum oxygen uptake and debt, respectively.

Hollering (53) also used a treadmill training program consisting of repeated bouts of 30 second maximal runs

with 45 seconds of rest over a period of 7 weeks. He found a 10.9% increase in maximum oxygen consumption and a 15.1% increment in peak lactate.

In an evaluation of two intense interval running programs, Knuttjen (57) observed that subjects who engaged in repeated intermittent exercise of 15 seconds maximal effort and 15 seconds rest did not improve in physiological responses as much as individuals who took part in 3 minutes work and 3 minutes rest. The latter group was seen to increase 26% in $\dot{V}O_2$ max and 11% in maximal lactate, while those who trained over the shorter distances increased 16% in maximal aerobic power and decreased 5% in peak attainable blood lactate.

Several authors (5, 83) have shown that in performing a given amount of work, the characteristics of the exercise and recovery periods are critical in determining the proportion of energy contributed by aerobic and anaerobic sources. The exact importance, however, of the rest pauses in intermittent work and interval training has been disputed.

In recent years considerable enthusiasm has developed with respect to the use of interval training for the training of athletes. Much of the interest generated probably resulted from the very interesting study of intermittent work done by Scandinavian investigators. Their work showed that subjects could handle very heavy exercise

loads with surprisingly low accumulations of O_2 debt and lactic acid when work and rest intervals were interspersed.

However, Saltin (92), who is one of the Scandinavian authorities in this area of investigation, reviewed the evidence and came to the conclusion that interval training does not appear to have an advantage over continuous training as a way of enhancing endurance capacity.

Roskamm (91), a German pioneer in interval training, performed a carefully controlled experiment comparing the training effects of continuous exercise with interval training. He found very small differences when testing the training responses at maximal exercise. When heart rate at moderate exercise loads was used as the criterion for testing, continous exercise produced better results.

Pollock (86, 87) reported that the dropout rate in a high intensity interval training program for adults was double that of a continuous jogging program.

It should be pointed out that interval training for athletes may have an advantage over continuous training, in that the faster pace of interval training may come closer to game conditions and therefore may favor the involvement of the same muscles, fiber types, and muscle recruitment patterns utilized in the competitive situations (26).

Fox and Mathews (35) summarized physiological development of the energy systems resulting from interval training.

> 1. The ATP-PC system can be used over and over. This, in turn, provides an adequate stimulus for promoting an increase in the energy capacity of this system and aids in delaying the onset of fatigue by not delving so deeply into the lactic acid system.
>
> 2. With proper regulation of the duration and type of relief interval, the involvement of the lactic acid system will be maximal and thus improved.
>
> 3. By working long enough at a sufficient intensity and by improvement in the maximal attainable stroke volume, the aerobic system is developed.

Mathews and Fox (34) have also identified five variables which describe the nature of an interval training program:

> (1) the rate and distance of work interval (which govern the intensity of work);
>
> (2) the number of repetitions during each workout (affecting the length of total work);
>
> (3) the frequency of training per week;
>
> (4) the type of activity during the relief interval;
>
> (5) the length of the relief interval.

Fox and Matthews (34) also summarized guidelines for the construction of interval training programs on the basis of training time and training distance. These guidelines are shown in Table 4 and Table 5.

TABLE 4

Guidelines for the Construction of an Interval Training Program (Training Time)

(A) WORK EFFORT AREA	(B) MAJOR ENERGY SYSTEM	(C) TRAINING TIME (min:sec)	(D) REPETI-TIONS PER WORKOUT	(E) SETS PER WORKOUT	(F) REPETI-TIONS PER SET	(G) WORK-RELIEF RATIO	(H) TYPE OF RELIEF INTERVAL
1	ATP-PC	0:10	50	5	10		Rest-Relief (e.g.,
		0:15	45	5	9		walking, flexing)
		0:20	40	4	10	1:3	
		0.25	32	4	8		
2	ATP-PC-LA	0:30	25	5	5		Work-Relief (e.g.,
		0:40-0:50	20	4	5	1:3	light to mild
		1:00-1:10	15	3	5		exercise,
		1:20	10	2	5	1:2	jogging)
3	LA-O_2	1:30-2:00	8	2	4	1:2	Work-Relief
		2:10-2:40	6	1	6		
		2:50-3:00	4	1	4	1:1	Rest-Relief
4	O_2	3:00-4:00	4	1	4	1:1	Rest-Relief
		4:00-5:00	3	1	3	1:1/2	

TABLE 5

Guidelines for the Construction of an Interval Training Program
(Training Distance)

(A) WORK EFFORT AREA	(B) MAJOR ENERGY SYSTEM	(C) TRAINING DISTANCE YARDS		(D) REPETI-TIONS PER WORKOUT	(E) SETS PER WORKOUT	(F) MAXIMAL REPS PER SET	(G) WORK-RELIEF RATIO	(H) TYPE OF RELIEF INTERVAL
		Run	Swim					
1	ATP-PC	55	15	50	5	10	1:3	Rest-Relief (e.g., walking, flexing)
		110	25	24	3	8		
2	ATP-PC-LA	220	55	16	4	4	1:3	Work-Relief (e.g., light to mild exer-cise, jogging)
		440	110	8	2	4	1:2	
3	LA-O_2	660	165	5	1	5	1:2	Work-Relief
		880	220	4	2	2	1:1	Rest-Relief
4	O_2	1100	275	3	1	3	1:1/2	Rest-Relief
		1320	330	3	1	3	1:1/2	

In concluding this review of literature relating to interval training, the lack of any published papers on interval weight training points out the critical need for research in this area.

CHAPTER III

METHODS AND PROCEDURES

The study was performed at Oregon State University, Corvallis, during the spring term of the 1986 academic year. The purpose of the study was to examine the relative effectiveness of interval weight training on the development of dynamic muscular strength, power and cardiorespiratory function of male college students. The training for both the experimental group and the control group was conducted in the weight training room of the Department of Physical Education at Oregon State University.

This chapter outlines the selection of subjects, testing procedure and training methods. The final part of the chapter summarizes evaluation method for the data collected during the testing period.

Subjects

The use of human subjects for the study was approved by the Human Subject Board at Oregon State University.

The subjects for the study were sixteen healthy male student volunteers among students registered in an intermediate weight training class during spring term, 1986. Students with any history of cardiorespiratory

problems were not used as subjects. All subjects received the informed consent form and signed it for participation in the study. The subjects were randomly assigned to either the experimental group (interval weight training group) or the control group (circuit weight training group), with each group consisting of eight subjects. The experimental group met for a sixty minute period on Tuesday and Friday. The control group met on Tuesday and Thursday.

Although it is conceivable that some of the subjects might have been exposed to weight training at one time or another, none had previous systematic or regular interval weight training experience.

The subjects' ages ranged from eighteen to twenty-six years. A summary of their physical characteristics is contained in Table 6.

Table 6. Age and Physical Characteristics of the subjects.

Variable	Mean	Standard Deviation	Minimum Value	Maximum Value
Age	20	2.309	18	26
Height (cm)	178.5	4.662	173	191
Weight (kg)	76.75	7.407	62	90

Orientation

During the first week all subjects were oriented concerning what would be expected of them during the spring term. Interval weight training and circuit weight training techniques to be used during the experimental period were explained. Each subject was asked to use only the prescribed training routines and to avoid other vigorous activity as much as possible. Subjects were also asked to attend each class period and to put maximal effort into each class.

Training Methods

Interval Weight Training Program

After completion of the pre-testing, the six-week interval weight training period was started. The interval weight training was divided into three phases.

During the first phase of the training the experimental group used 60 percent of their 1 RM in the core lifts, the bench press and the squat. For each of these lifts the subject executed 15-16 repetitions for three sets. Between each set the work-relief consisted of rope jumping for two minutes. A 1 1/2 minute rest followed the rope jumping. The subject then repeated the cycle.

At the completion of the two core lifts the subject took a 5 minute rest and then executed the mini-circuit

training twice, consisting of 4 bodybuilding exercises. Exercises consisted of dumbbell curls, lat-machine exercises, dumbbell flys and sit-ups (Figures 4, 5, 6, 7). Subjects were allowed to select whatever resistance felt comfortable at this time. Each exercise was executed 14-16 repetitions with a 30 second rest between exercises. At the completion of each circuit the work-relief consisted of two minutes of rope jumping (Figure 8) followed by a 1 1/2 minute rest.

During the second phase (second two weeks of the experimental period), the same training procedures were followed as outlined for the first phase, except that the training intensity was increased to 65 percent and 70 percent of the 1 RM in the bench press and squat respectively for 9-10 repetitions for 3 sets. Rope jumping time was reduced to 1 1/2 minutes and mini-circuit weight training remained unchanged.

During the third phase, the training intensity for the core lifts was increased to 70 percent of 1 RM for the bench press and 80 percent of 1 RM for the squat for 4-5 repetitions for two sets. Rope jumping remained at 1 1/2 minutes, and the mini circuit remained the same. Sample workouts are contained in Appendix A.

Training intensity and repetitions were based upon the established 1 RM value for each subject in the pre-test. Pulse rate was monitored by holding the hand over

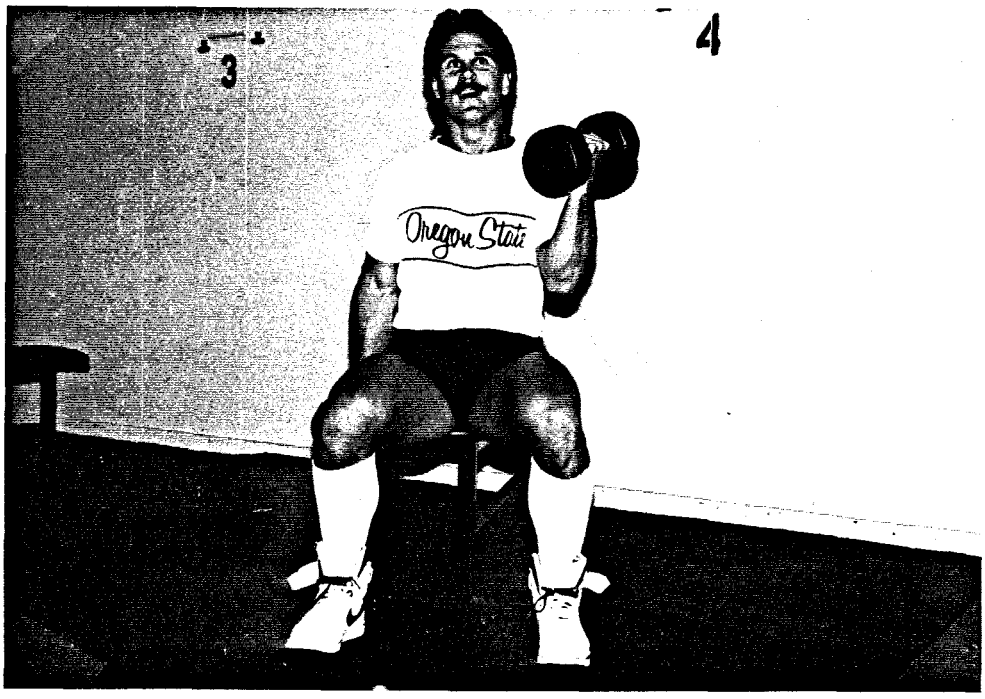

Figure 4. Dumbbell Curls

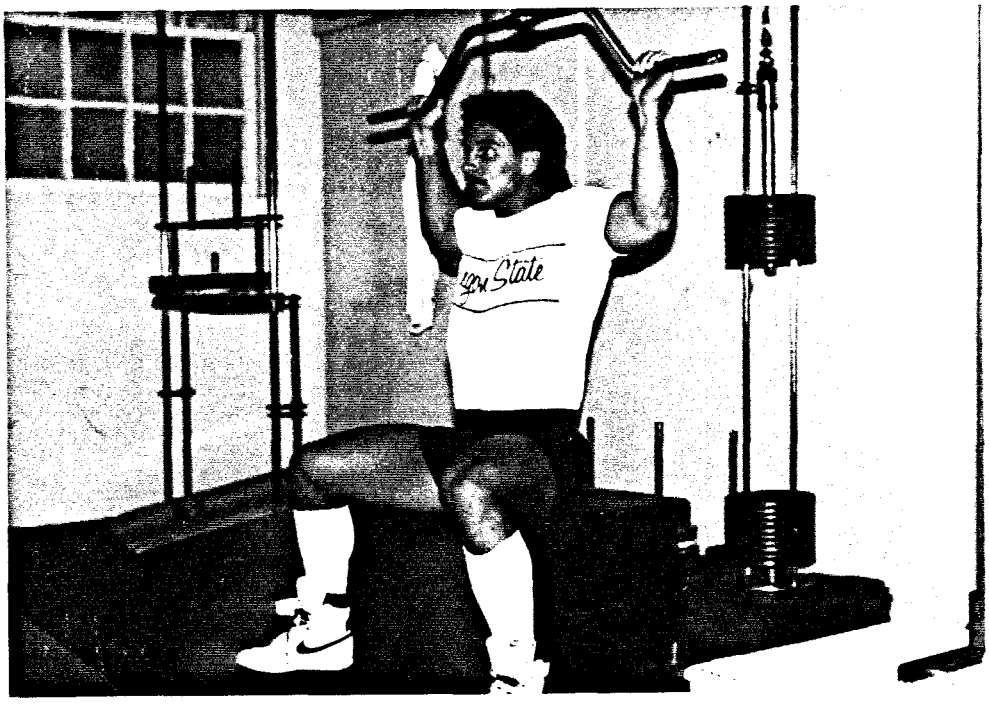

Figure 5. Lat-machine Exercises

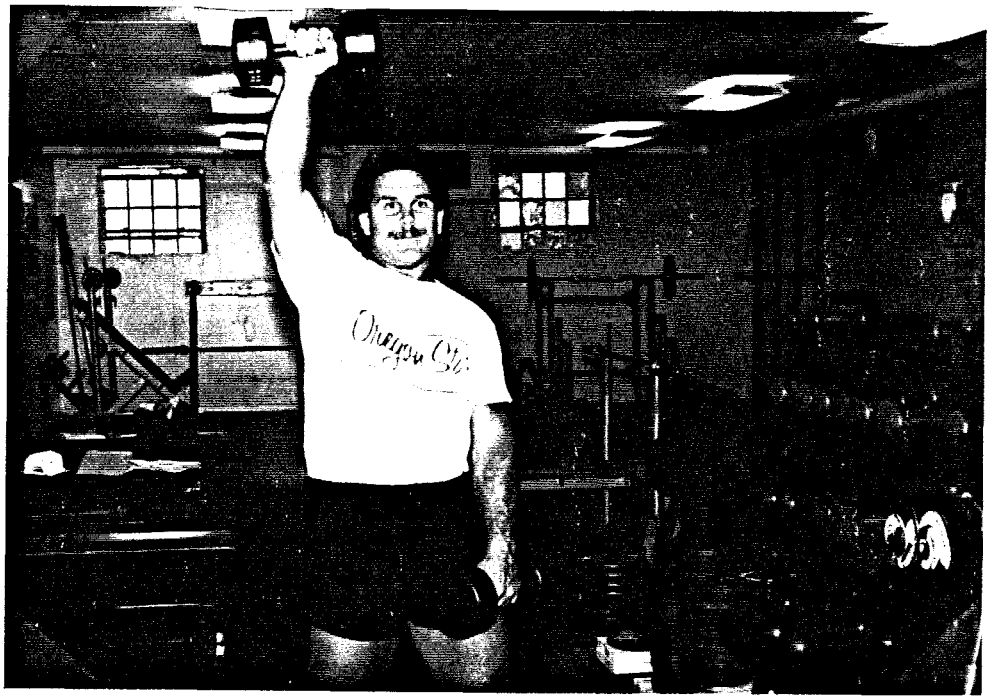

Figure 6. Dumbbell Flys

Figure 7. Sit-ups

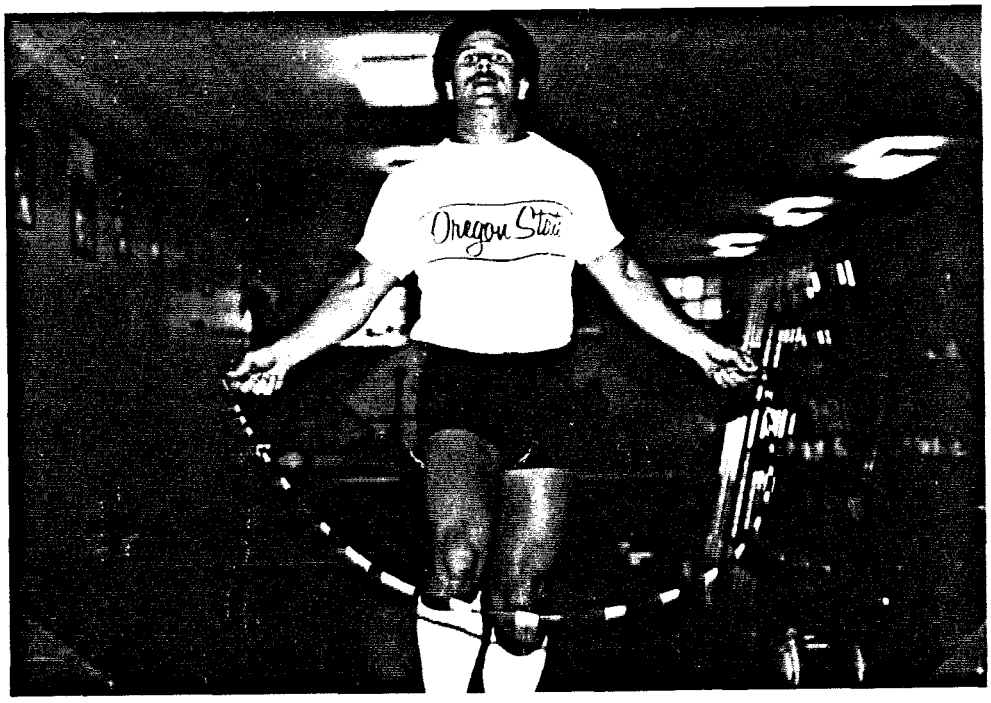

Figure 8. Rope Jumping

the left breast for establishing the work interval intensity. Subjects were required to maintain a heart rate between 120 and 180 beats per minute during the work interval. In this study Tuesday was a relatively light workout day while Friday was a heavy workout day. Before starting the interval weight training, the subjects participated in a warm-up set of lifting with lighter loads, performing 8-10 repetitions. After completion of interval weight training, the subjects had a cool down set of lifting with lighter loads using 8-10 repetitions. A critical feature of the interval weight training program was the progressive overload training principle. Every two weeks the training intensity was increased for all subjects.

Circuit Weight Training Program

The control group performed the circuit weight training program. The circuit weight training consisted of a twelve-station circuit which included exercises set up in the following order around the weight training room: squat, lock-knee deadlifts, bench press, leg extension, toe raise, seated dumbbell curl, front squat, leg curl, sit ups, leg press, hack squat, ladder walk. Each exercise was executed in short, all-out bursts of 45 seconds duration, then followed by a one minute rest. Subjects selected their resistance on the basis of body weight. Sample workouts are contained in Appendix B.

Safety Precautions

Because relatively untrained non-athletes might not have sufficient abdominal and lower back strength to withstand the intensity or stress imposed by interval weight training, specific safety measures were taken during the experimental period to reduce the possibility of injury. The following specific precautions were taken as suggested (75, 89):

1. training was never done alone;

2. correct techniques were used in all exercises;

3. every experimental workout started and ended with free and stretching exercise movements for the lower back muscles;

4. all subjects were required to wear a 10 cm wide leather belt to provide added support to the lower back and abdominal muscles.

There were no injuries during the entire experimental period of the study.

Testing Procedures

Strength

The one-repetition maximum for the bench press and squat was used as a base line for this study. The pre-test was administered immediately following the first week. Testing was conducted again at the conclusion of the 6th week of the experimental period. The criteria for judging the success of the lifts are outlined in the

official rules of the International Power-lifting Federation (80).

In executing the bench press to determine a 1 RM, the subject assumed a supine position on a bench, feet in contact with the floor. The barbell was lowered from an arms extended position down to the chest and back up to an arms extended position (Figure 9). Safety spotters were used in the event that weights were too heavy. In order for the attempt to be successful, the bar had to touch the chest with no bouncing; the head and trunk (including buttocks) had to remain in contact with the bench, the feet flat on the floor and the arms extended evenly (80).

In executing the squat to determine a 1 RM, the subject lifted a loaded barbell off the rack and onto the shoulders (Figure 10). For test consistency, the subject was squatted to a 50 cm high bench. From this standing position the subject squatted down until the buttocks touched the bench (approximately a 3/4 full squat) and then extended his legs and back in returning to the starting position.

Power

The vertical jump test was used to measure explosive power. The pre-test was administered immediately following the first week period.

In executing the vertical jump test, the subject first stood flatfooted facing the board with both arms

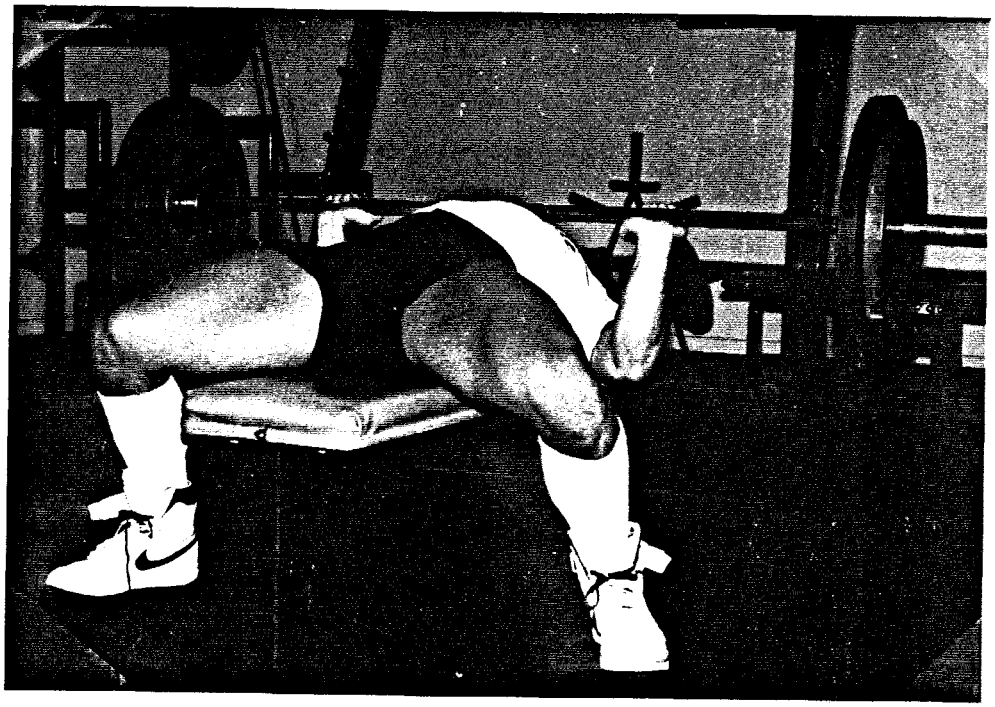

Figure 9. The Bench Press

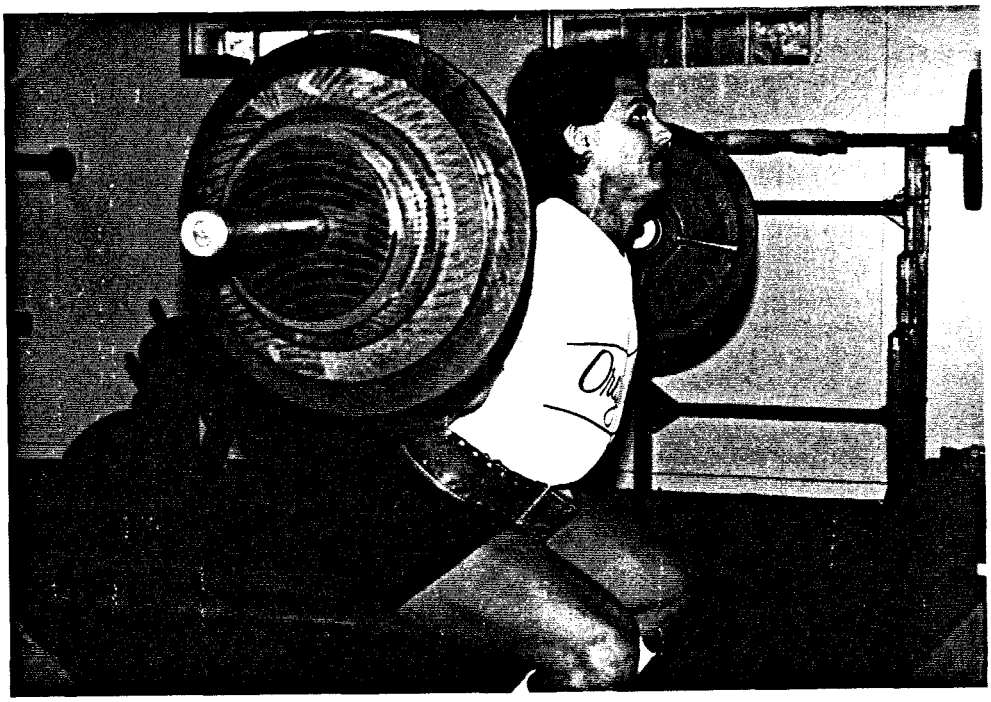

Figure 10. The Squat

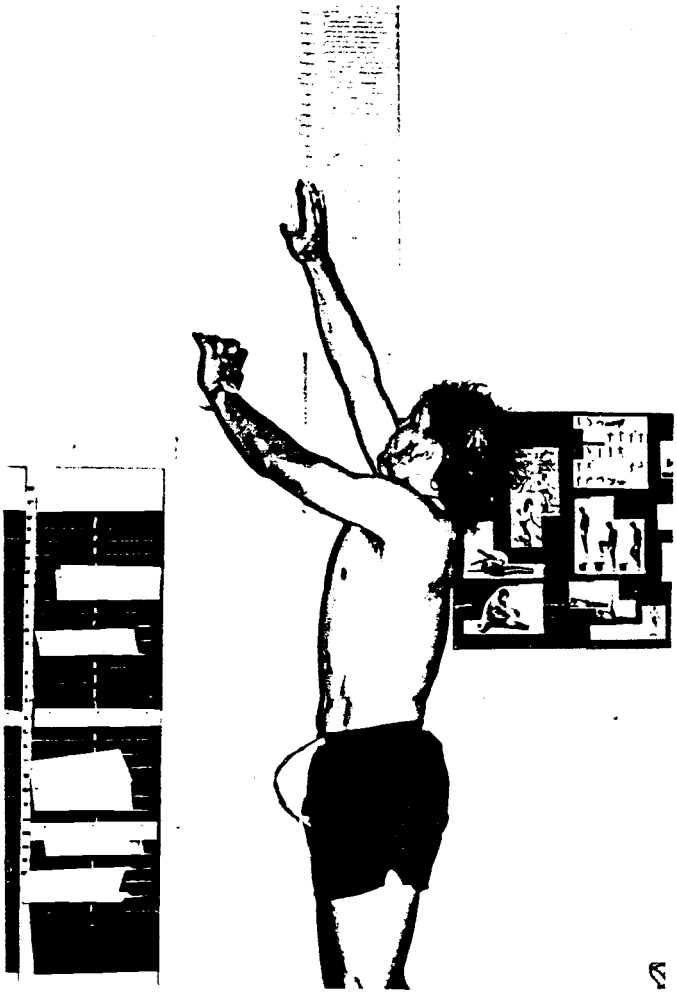

Figure 11. The Vertical Jump Test

stretched as high as possible overhead. After chalking the fingers of one hand, the subject took a crouched position with a knee angle approximately 115 degrees and the feet spread 13 cm to 25 cm laterally and about 13 cm anteriorly-posteriorly (Figure 11). The subject was allowed to practice the jump several times to find the most comfortable position. The subject held the crouched position for approximately two seconds and then jumped as high as possible. As he reached the peak of his jump, the subject touched as high as possible on the board with the chalked hand while thrusting downward with the opposite arm. The score for each trial was the number of centimeters from the bottom of the board to the point touched during the jump. Measurement was to the nearest half-centimeter. Three consecutive trials were given. The highest score was used as the power score.

Cardiorespiratory Function

The cardiorespiratory function test was conducted in the Human Performance Laboratory within the Department of Physical Education at Oregon State University. Prior to testing, each subject was introduced to the testing equipment and given the opportunity to become accustomed to graded treadmill walking. The subjects also had the opportunity to breathe through the mouth-piece and breathing valve which was used in all metabolic determinations.

A modified treadmill $\dot{V}O_2$ max protocol was administered to each subject to derive a direct measurement of maximal oxygen uptake and respiratory function. The treadmill test followed the standards recommended by Thoden (104).

1. The purpose and procedures of the test were explained to the subject.
2. The subject was prepared with electrodes (V_5).
3. Introduction to treadmill running began at 4.0 mph and was gradually increased to the subject's preferred warm-up speed (usually 5.0-7.0 mph). This was continued for a minimum of 5 minutes until the subject was satisfied.
4. Subjects attaining a heart rate greater than 160 beats per minute were run at 7.5 mph; of 140 to 160 bpm, at 8.0 mph; of less than 140 bpm, at 8.5 mph.
5. The subject was attached to the breathing apparatus and began to run at 0% grade.
6. The treadmill angle was increased by 2.5% of its length each two minutes until termination of the test.
7. The subjects were encouraged to cool down by resuming moderate exercise at 0% grade and a speed of 4.0 to 5.0 mph for several minutes.

Metabolic determinations were made each minute via open circuit spirometry. The subjects breathed through a Daniels' Type low resistance two-way valve with the volume of inspired air being measured by a Parkinson-Cowan CD-4 dry gas meter. The expired air then passed through a 5 liter mixing chamber with a sample being drawn off continuously at a rate of 500 cc per minute. This sample then passed through a Beckman LB-2 infrared carbon dioxide (CO_2) analyzer and an Applied Electrochemistry S-3A oxygen (O_2) analyzer. The gas analyzers were calibrated against gases of known concentration before and after each test. Oxygen consumption ($\dot{V}O_2$), CO_2 production ($\dot{V}CO_2$), ventilation ($\dot{V}e$), and the respiratory exchange ratio (R.E.R.) were calculated immediately via an automated computer system (Rayfield Electronics, Chicago, IL).

The subject's heart rate was monitored using a Physio-Control Lifepak 7 (Physio-Control Corp.) in order to attain maximum heart rate during the test.

Statistical Null Hypotheses

The general hypothesis was that six weeks of interval weight training would result in statistically no significant improvement in dynamic muscular strength, power and cardiorespiratory function in college males.

The specific sub hypotheses which were tested are the following:

1. There will be no significant difference in the pre-test and six-week post-test means for strength within the circuit weight training group and within the interval weight training group.

2. There will be no significant difference in the pre-test and six-week post-test means for power within the circuit weight training group and within the interval weight training group.

3. There will be no significant difference in the pre-test and six-week post-test means for cardio-respiratory function within the circuit weight training group and within the interval weight training group.

4. There will be no significant difference in the six-week adjusted mean scores for strength between the circuit weight training group and the interval weight training group.

5. There will be no significant difference in the six-week adjusted mean scores for power between the circuit weight training group and the interval weight training group.

6. There will be no significant difference in the six-week adjusted mean scores for cardiorespiratory function between the circuit weight training group and the interval weight training group.

Treatment of the Data

Statistical analysis was carried out on data on the physical characteristics of the subjects and on the dynamic muscular strength, power and cardiorespiratory function tests.

1. The methods used to analyze data from physical characteristics tests involved determination of the means, standard deviations, and extreme values of the variables.

2. The t-test was computed on each dependent variable within each group to determine whether the changes which took place in each group were significant. Dependent variables present in this study were dynamic muscular strength, power and cardiorespiratory function measures.

3. The one-way analysis of covariance was used to determine differences in the means of test scores in strength, power and cardiorespiratory function between the experimental group and the control group. The pre-test values were used as the covariate and the post-test values were used as dependent variables.

4. The .05 level of significance was selected for all statistical conclusions.

5. Graphical analysis was used to demonstrate the relationship in a given set of test scores.

CHAPTER IV

ANALYSIS OF DATA

The basic problem of this study was to examine the relative effectiveness of interval weight training on the development of dynamic muscular strength, power and cardiorespiratory function.

The study lasted for a six-week experimental period and comprised two groups: a control group, which undertook a circuit weight training program, and an experimental group, which undertook an interval weight training program. Each subject was given a pre-test before the experimental period began and a post-test afterwards, with scores for each subject recorded. The raw data for all subjects are found in Appendix G.

Statistical Procedure

Since the results of each training were to be analyzed according to pre- and post-test control group research design procedures, both groups were given pre- and post- dynamic muscular strength, pre- and post-power and pre- and post-cardiorespiratory function tests. Two statistical procedures were used to analyze the data. A "t" test was used to determine if differences between pre- and post-test scores were significant, and an analysis of covariance was used to determine if there were any

significant differences between the control group and the experimental group.

Level of Significance

It is conventional in behavioral science research to use either a .05 or a .01 level of significance to determine the success of a hypothesis (88). The .05 level was selected to monitor this investigation because it seemed to allow sufficient variation to permit acceptance or rejection of the hypotheses.

Null Hypotheses

The following general null hypothesis was tested in this study:

1. Six weeks of interval weight training will result in no statistically significant improvement in dynamic muscular strength, power or cardio-respiratory function in college males.

The findings of the study will be discussed in order, according to the six sub hypotheses presented below.

Sub Hypothesis One

1. There will be no significant difference in the pre-test and post-test means for strength within the circuit weight training group and within the interval weight training group.

The results of the pre- and post-test means for dynamic muscular strength are presented in Table 7. At the end of the experimental period, both groups had achieved an increase in bench press strength and in squat strength, though the greater increase for both groups took place in the squat. The experimental group gained 8.375 kg (10%) in the bench press and 31.5 kg (26.3%) in the squat, whereas the control group gained 4.375 kg (5.7%) in the bench press and 12.25 kg (10.4%) in the squat.

The computed t-test values for the experimental group and the control group in the bench press were 3.360 and 2.606 respectively. The critical value of t at the .05 level of significance is 2.365. Thus both t-test values were statistically significant at the .05 level. The t-test value for the experimental group in the squat was 9.656. This value was significant at the .01 level. The t-test value for the control group in the squat was 2.938. This value was significant at the .05 level. Therefore, the null hypothesis was rejected.

Sub Hypothesis Two

2. There will be no significant difference in the pre-test and post-test means for power within the circuit weight training group and within the interval weight training group.

TABLE 7

Comparison of Difference between Mean Scores on Pre- and Post-Strength Test

Variable	Group	Pre Mean Score	Standard Deviation	Post Mean Score	Standard Deviation	Difference between Pre- and Post-Test	Computed t
Bench Press (kg)	Experimental	83.875	21.715	92.25	21.076	8.375	3.360*
	Control	76.5	25.145	80.875	20.932	4.375	2.606*
Squat (kg)	Experimental	119.875	17.748	151.375	19.449	31.5	9.656**
	Control	117.875	31.457	130.125	25.542	12.25	2.938*

N = 8

* Significant at the .05 level

** Significant at the .01 level

Table 8 shows that in the vertical jump test, both groups made a significant gain. The mean score for the experimental group increased from a pre-test level of 54.375 cm to a post-test level of 57.125 cm, a gain of 2.75 cm (5.1%). The control group also gained, with a 4.25 cm (7.7%) increase from the pre-test mean to the post-test mean. The computed values of t for the experimental and the control group were 4.438 and 5.194 respectively. Since these values were greater than the critical value (3.499) of t at the .01 level of significance, the null hypothesis was rejected.

Sub Hypothesis Three

3. There will be no significant difference in the pre-test and post-test means for cardiorespiratory function within the circuit weight training group and within the interval weight training group.

The results of changes in cardiorespiratory function for each group are presented in Table 9. According to this table, maximal oxygen uptake values, whether expressed in l/min or ml/kg/min, did not change significantly in either group. The values of t computed for maximum oxygen uptake of the experimental group and the control group were 0.721 and 0.965 respectively. These statistics indicate no significant difference at the .05 level for either group.

TABLE 8

Comparison of Difference between Mean Scores on Pre- and Post-Power Test

Variable	Group	Pre Mean	Standard Deviation	Post Mean	Standard Deviation	Difference between Pre- and Post-Test	Computed t
Vertical Jump (cm)	Experimental	54.375	4.069	57.125	5.853	2.75	4.438**
	Control	54.875	8.610	59.125	7.240	4.25	5.194**

N = 8

* Significant at the .05 level

** Significant at the .01 level

Table 9

Comparison of Difference between Mean Scores on Pre- and Post-Cardiorespiratory Function Test

Variable	Group	Pre Mean Score	Standard Deviation	Post Mean Score	Standard Deviation	Difference between Pre- and Post-test	Computed t
$\dot{V}O_2$ max (l/min)	Experimental	4.504	0.541	4.571	0.461	0.067	0.721
	Control	4.128	0.725	4.336	0.581	0.208	0.965
$\dot{V}O_2$ max (ml/kg/min)	Experimental	59.03	6.340	59.23	4.059	0.2	0.175
	Control	56.934	5.080	57.008	5.864	0.224	0.245
Max $\dot{V}e$ (BTPS) (l/min)	Experimental	130.848	15.270	134.506	13.604	3.658	1.274
	Control	126.453	20.885	123.053	23.210	-3.4	-0.824
Maximum Ventilatory Equivalent	Experimental	29.101	1.465	29.503	2.269	0.402	0.558
	Control	29.346	3.487	28.274	3.258	-1.092	-1.555

N = 8

* Signficant at the .05 level

Maximum ventilation (BTPS) and maximum ventilatory equivalent also did not change significantly. The t-test values of the experimental group and the control group in ventilation were 1.274 and -0.824 respectively. Neither of these t-test values was statistically significant at the .05 level. For maximum ventilatory equivalent, the t-test values of the experimental and the control group were 0.558 and -1.555 respectively. These values also show no significant difference at the .05 level. Therefore, the null hypothesis was retained.

Sub Hypothesis Four

4. There will be no significant difference in the six-week adjusted mean scores for strength between the circuit weight training group and the interval weight training group.

Table 10 shows that the computed F values for the eight-week adjusted mean scores for strength in the bench press and in the squat between the control group and the experimental group were 3.514 and 16.177 respectively. The critical value of F at the .05 level of significance with degrees of freedom of 1 and 13 is 4.67. Thus the computed F value in the bench press was not statistically significant, while the computed F value in the squat was statistically significant at the .01 level. Since there was a significant difference between the two groups in the case of the squat, the null hypothesis was rejected.

TABLE 10

Analysis of Covariance for Adjusted Mean Scores for Strength

Variable	Source of Variation	df	SS	MS	F
Bench Press (kg)	Between	1	97.611	97.611	
	Within	13	361.123	27.779	3.514
	Total	14	458.734		
Squat (kg)	Between	1	1538.934	1538.934	
	Within	13	1236.714	95.132	16.177**
	Total	14	2775.648		

N = 8
* Significant at the .05 level
** Significant at the .01 level

Sub Hypothesis Five

5. There will be no significant difference in the six-week adjusted mean scores for power between the circuit weight training group and the interval weight training group.

It is shown in Table 11 that the computed F for the six-week adjusted mean scores for power between the control group and the experimental group was 2.609. This was less than the critical value of F, which is 4.67. Therefore, the null hypothesis was retained.

Sub Hypothesis Six

6. There will be no significant differences in the six-week adjusted mean scores for cardiorespiratory function between the circuit weight training group and the interval weight training group.

Table 12 shows the computed F values for the adjusted post mean scores for maximum oxygen uptake values between the control group and the experimental group. These were expressed in both l/min and ml/kg/min for both groups and were 0.013 and 0.125 respectively. Neither of these F values surpassed the critical value of F at the .05 level of significance with degrees of freedom of 1 and 13.

TABLE 11

Analysis of Covariance for Adjusted Mean Scores for Power

Variable	Source of Variation	df	SS	MS	F
Vertical Jump (cm)	Between	1	9.767	9.767	
	Within	13	48.664	3.743	2.609
	Total	14	58.430		

N = 8

* Significant at the .05 level

** Significant at the .01 level

TABLE 12

Analysis of Covariance for Adjusted Mean Scores for Cardiorespiratory Function

Variable	Source of Variation	df	SS	MS	F
$\dot{V}O_2$ max (l/min)	Between	1	0.002	0.002	0.013
	Within	13	2.024	0.156	
	Total	14			
$\dot{V}O_2$ max (ml/kg/min)	Between	1	0.849	0.849	0.125
	Within	13	88.268	6.790	
	Total	14			
Max $\dot{V}e$(BTPS) (l/min)	Between	1	88.130	88.130	0.897
	Within	13	1279.267	98.251	
	Total	14			
Maximum ventilatory equivalent	Between	1	8.038	8.038	2.065
	Within	13	50.600	3.892	
	Total	14			

N = 8
* Significant at the .05 level
** Significant at the .01 level

The computed F value of the adjusted post mean scores for maximum ventilation, as indicated in Table 6, was 0.897. For maximum ventilatory equivalent the computed F value for the adjusted post mean scores between the two groups was 2.065. Neither of these computed F values exceeded the critical F value of 4.67. Since none of the computed F values for cardiorespiratory function surpassed the critical value, the null hypothesis was retained.

Summary of Findings

The findings from this study may be summarized as follows:

1. There was a significant difference at the .05 level of significance between the pre-test and six-week post-test means for strength within the circuit weight training group and within the interval weight training group.

2. There was a significant difference at the .01 level of significance between the pre-test and six-week post-test means for power within the circuit weight training group and within the interval weight training group.

3. There was not a significant difference at the .05 level of significance between the pre-test and six-week post-test means for cardiorespiratory function within the circuit weight training group and within the interval weight training group.

4. There was not a significant difference at the .05 level of significance in the six-week adjusted mean scores for bench press strength between the circuit weight training group and the interval weight training group.

However, there was a significant difference at the .01 level of significance in the six-week adjusted mean scores for squat strength between the circuit weight training group and the interval weight training group.

5. There was not a significant difference at the .05 level of significance in the six-week adjusted mean scores for power between the circuit weight training group and the interval weight training group.

6. There was not a significant difference at the .05 level of significance in the six-week adjusted mean scores for cardiorespiratory function between the circuit weight training group and the interval weight training group.

Discussion

Both the circuit weight training group and the interval weight training group showed a significant increase in dynamic muscular strength and power during the six-week training period. However, the statistics indicate that the interval weight training was more effective in the development of squat strength than was the circuit weight training. This study also showed no

significant increase in cardiorespiratory function in either group. Figures 12, 13, 14, 15, 16 and 17 graphically display how the groups changed in dynamic muscular strength, power and cardiorespiratory function after the six-week experimental period.

Increase in Dynamic Muscular Strength

One of the findings of this study was the increase in dynamic muscular strength in the experimental group (8.375 kg in the bench press and 31.5 kg in the squat) and in the control group (4.375 kg in the bench press and 12.25 kg in the squat). The interval weight training program resulted in a 10% increase in bench press strength and a 26.3% increase in squat strength. The circuit weight training program showed a smaller increase in the bench press (5.7%) and in the squat (10.4%). This was expected since the interval weight training program used higher intensities (at least 60% of 1 RM) than did the circuit weight training program (40-60% of 1 RM).

It is likely that the increase of strength for both groups can be attributed not only to physiological adaptation but also to adaptations of the neuromuscular system. Overloading skeletal muscle results in strength increase accompanied by hypertrophy of the muscle involved (27, 94).

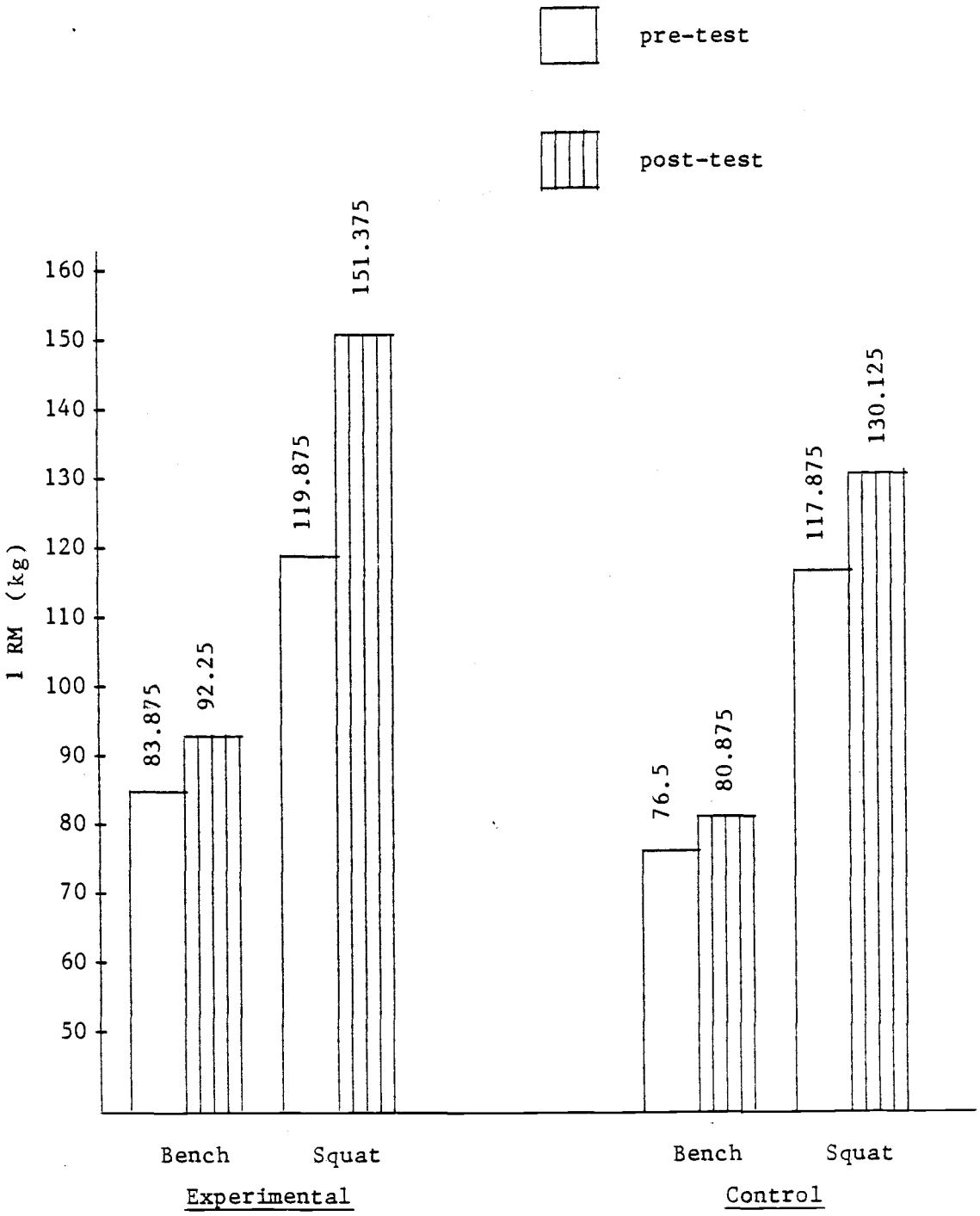

Figure 12. Changes in dynamic muscular strength

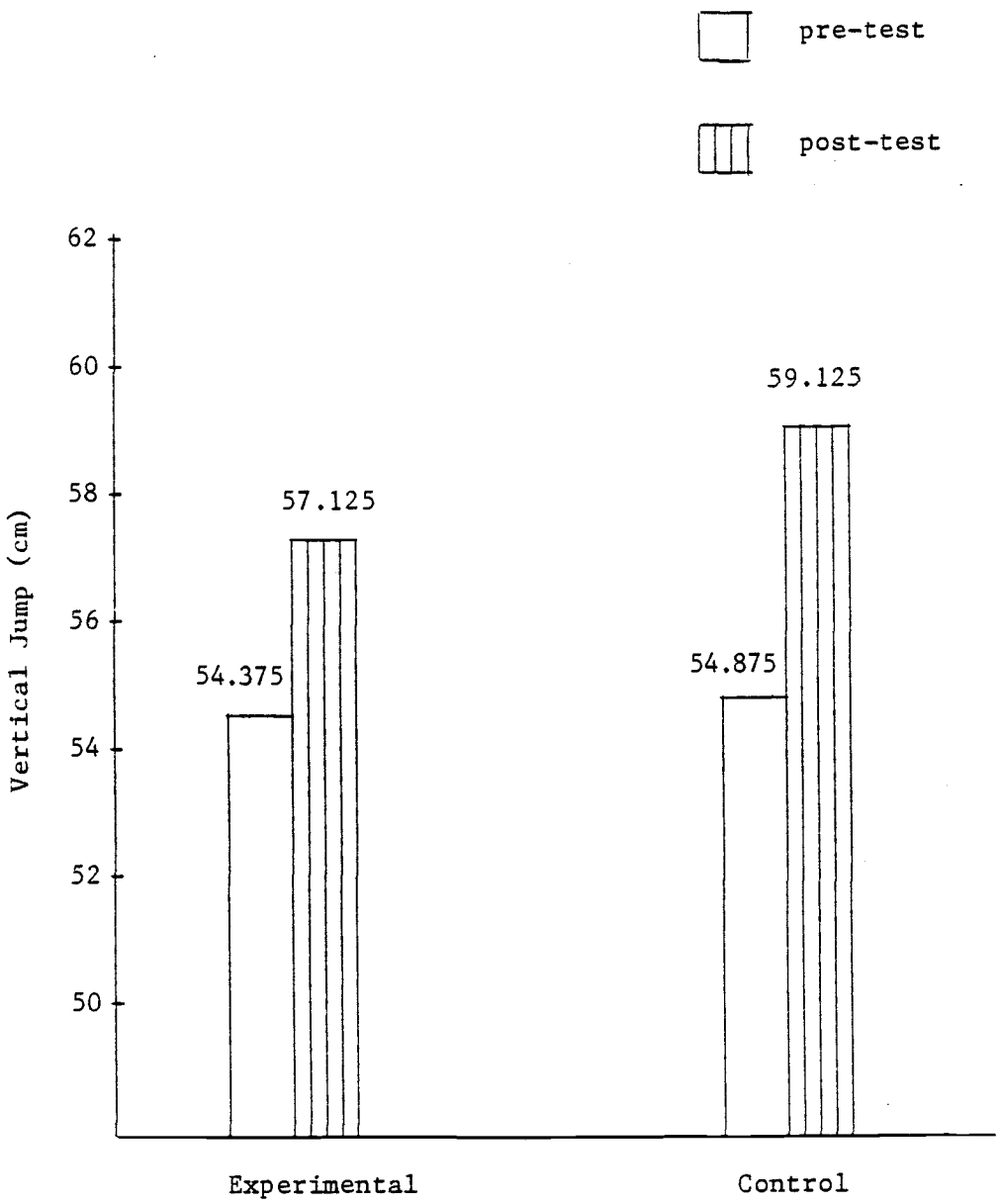

Figure 13. Changes in power.

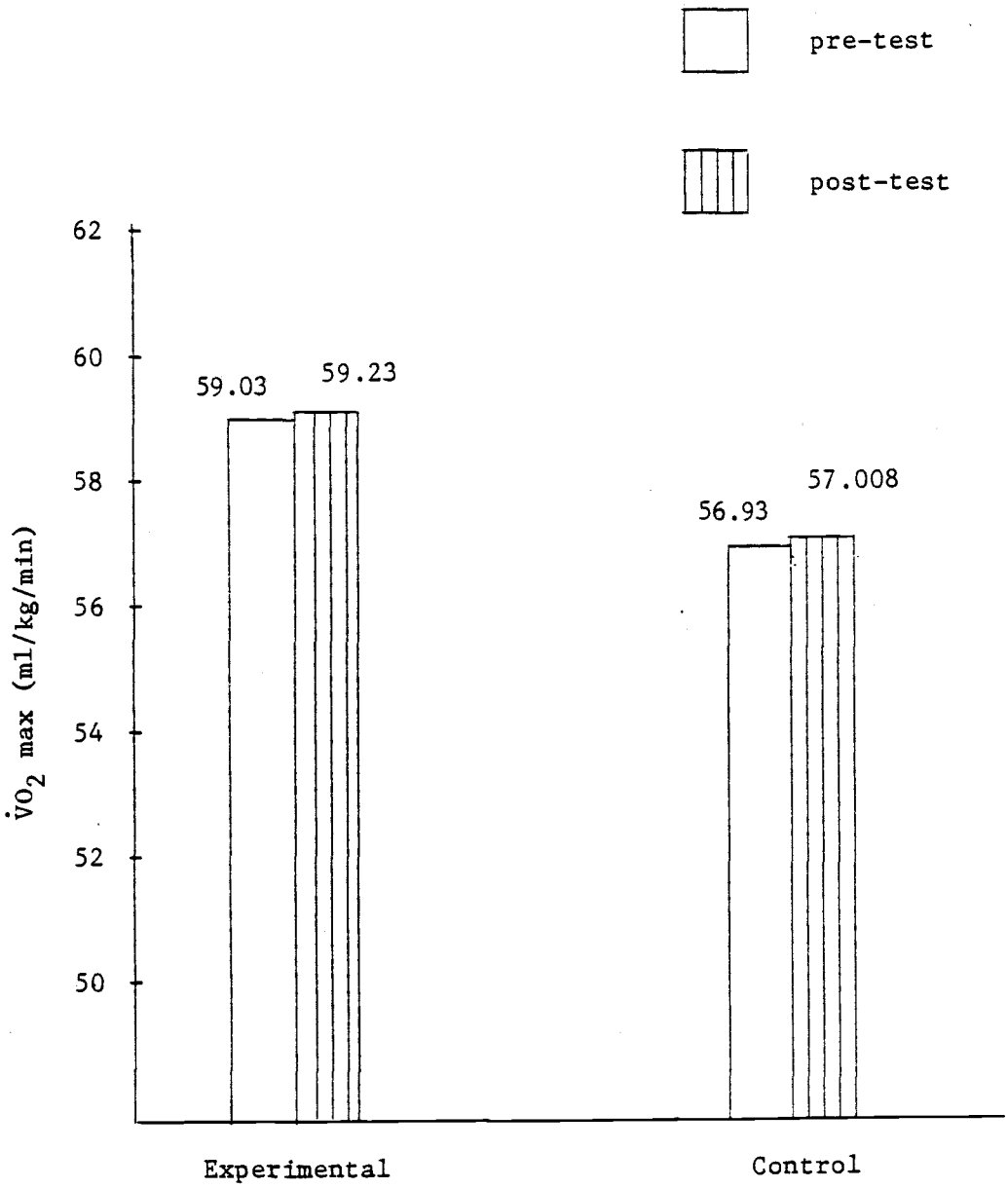

Figure 14. Changes in maximal oxygen uptake.

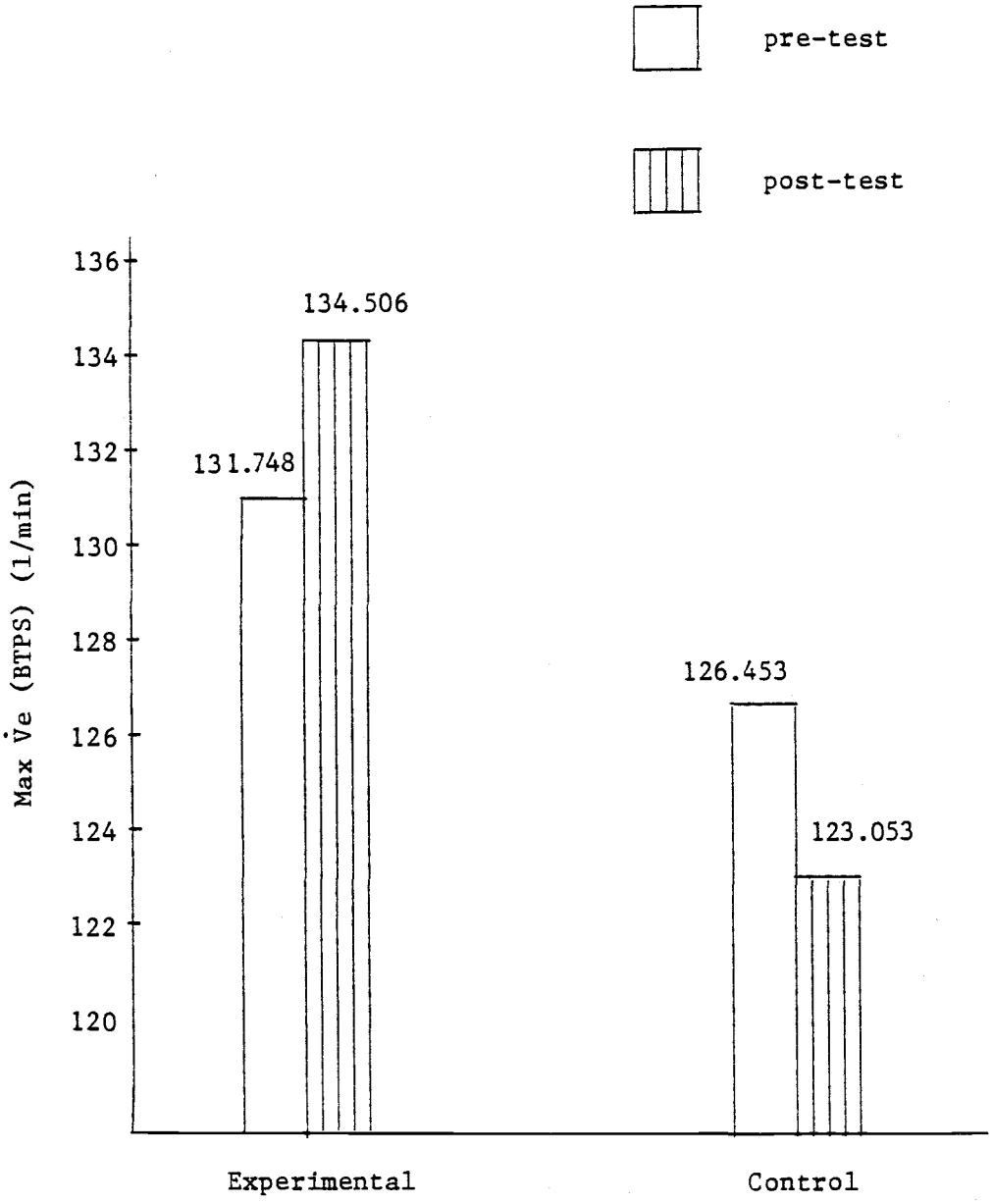

Figure 15. Changes in maximum ventilation (BTPS)

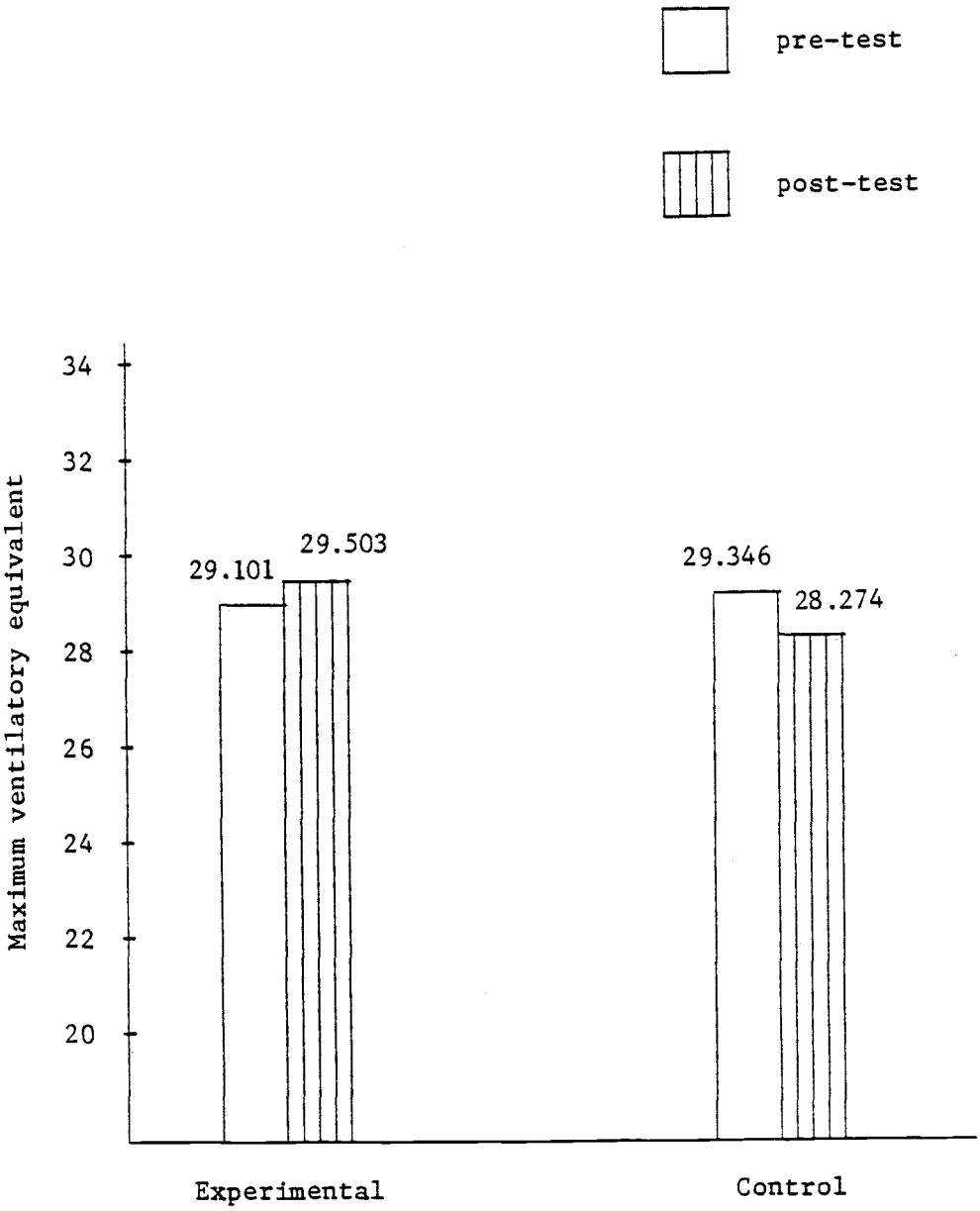

Figure 16. Changes in maximum ventilatory equivalent

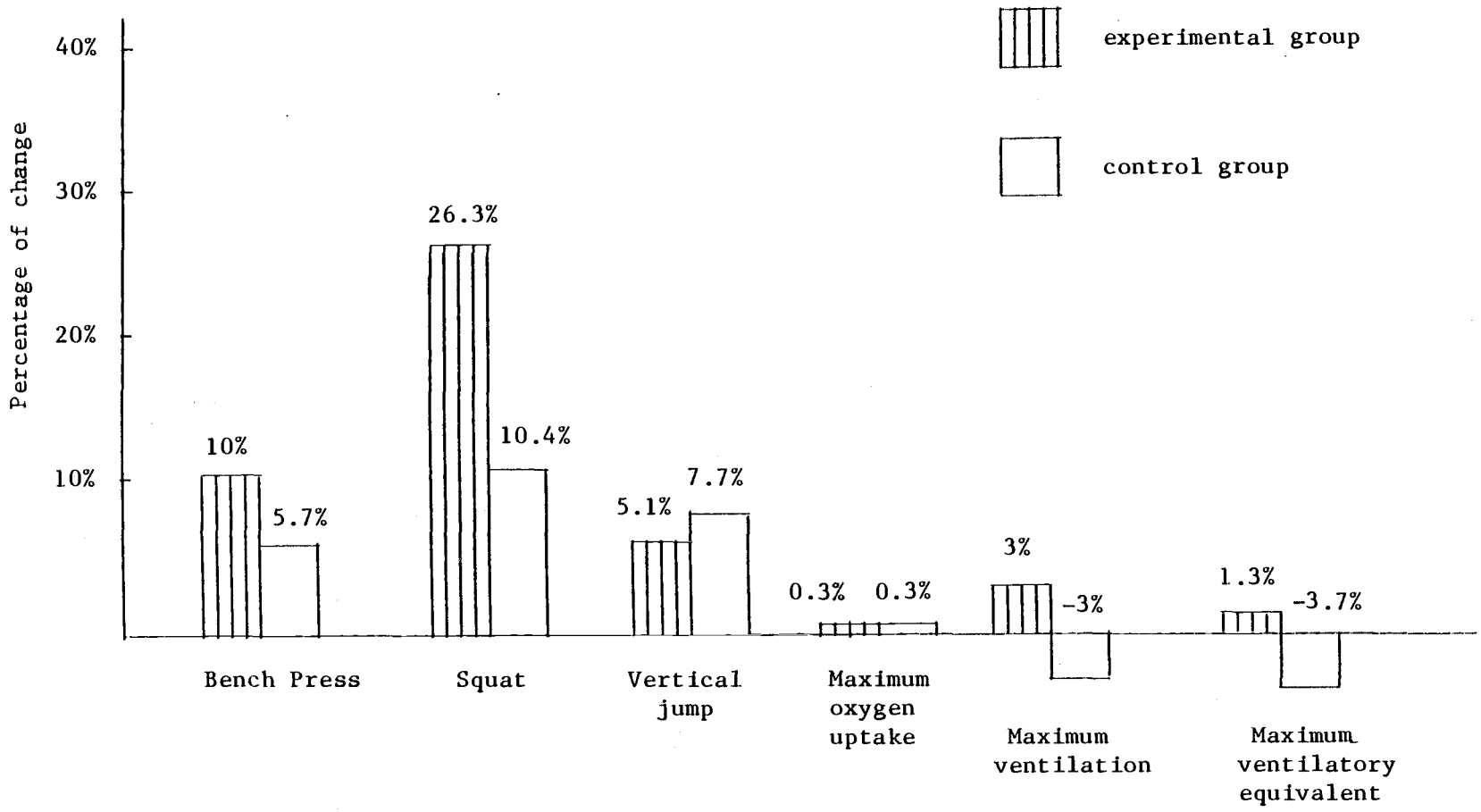

Figure 17. Comparison of change in dynamic muscular strength, power and cardiorespiratory function.

O'Shea and Wegner (78) state:

> Adaptation of the neuromuscular system to the stress of the power training program involves changes in the recruitment patterns of the motor units. Such a change would reflect an increase in spatial summation and a corresponding decrease in the nerve activation threshold due in part to greater facilitation of the synapse (p. 9).

Therefore, it is conceivable that increased neuromuscular efficiency improved the ability of muscles to adapt to the stimuli of the bench press and squat movements.

This study showed a greater increase in squat strength compared to bench press strength for both groups. The greater increase in the squat can be explained in the following way:

1. The body as a whole responds more effectively to training than does each individual part. Since the squat involves more major muscle groups than does the bench press, the squat may result in a greater strength increase.

2. The major muscle groups utilized in the bench press are smaller and weaker than the muscle groups used in the squat (96). The bench press develops strength for muscle groups such as the triceps, deltoids, pectorals, and latissimus dorsi (17). The squat movement develops muscular strength for the erector spinae, gluteus maximus and medius, tensor faciae latae, quadriceps, abdominals, hamstrings, and ankle flexors (71, 97, 102). The larger

muscle fibers brought into play by the squat movement are better able to adapt to the stresses of a training program.

3. Trainability of various muscle groups is different. Muscle groups utilized in the squat have greater trainability than muscle groups utilized in the bench press (49, 100).

This study also showed no statistically significant difference in bench press strength improvement between the interval weight training group and the circuit weight training group. However, there was a significant difference in squat strength improvement between the two groups. These findings may be explained by the three factors listed above and by the progressive overload principle, which was applied scientifically in the interval weight training program.

Increase in Power

The interval weight training program and the circuit weight training program both resulted in a significant increase in power, as measured by vertical jumping ability. However, the analysis of covariance showed that there was no significant difference in increase in power between the experimental group and the control group.

Since power can be thought of as muscular strength multiplied by limb velocity, the increase in power for

both groups can be attributed to: (1) an increase in muscular strength, (2) an increase in limb velocity, or (3) an increase in both muscular strength and limb velocity. No tests were made in this study to measure increase in limb velocity. However, both training programs did result in a significant increase in muscular strength, as measured by the bench press and the squat. Therefore the increase in power for both groups is at least partially due to the increase in muscular strength for both groups. The increase of power can also be explained by the fact that both training programs included the squat movement. According to O'Shea (75), the squat, together with the power clean, are the two most important basic weightlifting movements for power.

Cardiorespiratory Function

It is difficult to develop both aerobic and anaerobic power to high degrees in one specific type of training program. Hickson (52) reported that at the upper limits of strength development, aerobic training can inhibit strength gains. However, studies indicating that weight training produces an increase in cardiorespiratory endurance were cited in the review of literature (17, 51, 55, 69). In the present study it was expected that both the interval weight training program and the circuit weight training program would result in an increase in cardiorespiratory function.

However, the study showed that neither the interval weight training program nor the circuit weight training program had any significant effect on cardiorespiratory function. The results indicate that neither training program improved maximum oxygen uptake expressed either as liters per minute or as milliliters per kilogram per minute. These results, along with the finding of no significant change in respiratory function, suggest that interval weight training fails to produce adaptations in cardiorespiratory function.

It has been well-established that intensity, duration and frequency of exercise are essential components in stimulating cardiorespiratory adaptations in response to training (26). The American College of Sports Medicine (2) has made the following recommendations for the quantity and quality of exercise for developing and maintaining cardiorespiratory fitness and body composition.

1. Type of activity: Any activity that uses large muscle groups, that can be maintained continuously, and is rhythmical and aerobic in nature.

2. Intensity of conditioning: 60 to 90% of maximum heart rate or 50 to 75% of $\dot{V}O_2$ max.

3. Duration of conditioning: 15 to 60 minutes of continuous or discontinuous aerobic activity.

4. Frequency of conditioning: 3 to 5 days per week.

The intensity of exercise relative to $\dot{V}O_2$ max appears to be the most important factor in promoting gains in $\dot{V}O_2$ max (26). The fact that no significant increase in cardiorespiratory function was found in this study can be attributed to the following possible factors:

1. The subjects in the interval weight training group already had excellent cardiorespiratory function at the time of the initial test. The mean maximum oxygen uptake of the experimental group was 4.504 l/min (59.03 ml/kg/min) which, according to Astrand's (4) categorization (Table 13) of maximum oxygen uptake levels, was in the "high" category (57+ ml/kg/min). Among eight subjects in the experimental group, two subjects already had very high values of $\dot{V}O_2$ max (68.05 ml/kg/min and 68.95 ml/kg/min), while the subject with the lowest $\dot{V}O_2$ max registered 51.13 ml/kg/min. It is reasonable to assume that improvements in cardiorespiratory function made in only a six-week interval weight training program might not be significant for a group that begins at such a high level of cardiorespiratory function.

It is worth noting that at the beginning of the experiment the mean maximum oxygen uptake for the control group was in the upper end of the "good" category

TABLE 13

Norms for Maximal O_2 Consumption
(Aerobic Working Capacity)*

Women

Age	Low	Fair	Average	Good	High
20-29	1.69	1.70-1.99	2.00-2.49	2.50-2.79	2.80+
	28	29-34	35-43	44-48	49+
30-39	1.59	1.60-1.89	1.90-2.39	2.40-2.69	2.70+
	27	28-33	34-41	42-47	48+
40-49	1.49	1.50-1.79	1.80-2.29	2.30-2.59	2.60+
	25	26-31	32-40	41-45	46+
50-65	1.29	1.30-1.59	1.60-2.09	2.10-2.39	2.40+
	21	22-28	29-36	37-41	42+

Men

Age	Low	Fair	Average	Good	High
20-29	2.79	2.80-3.09	3.10-3.69	3.70-3.99	4.00+
	38	39-43	44-51	52-56	57+
30-39	2.49	2.50-2.79	2.80-3.39	3.40-3.69	3.70+
	34	35-39	40-47	48-51	52+
40-49	2.19	2.20-2.49	2.50-3.09	3.10-3.39	3.40+
	30	31-35	36-43	44-47	48+
50-59	1.89	1.90-2.19	2.20-2.79	2.80-3.09	3.10+
	25	26-31	32-39	40-43	44+
60-69	1.59	1.60-1.89	1.90-2.49	2.50-2.79	2.80+
	21	22-26	27-35	36-39	40+

*Upper figure = liters per minute
Lower figure = milliliters of O_2 per kilogarm body weight

(52-56 ml/kg/min) according to Astrand's classification. The value of $\dot{V}O_2$ max for this group was 4.128 l/min (56.934 ml/kg/min), with the the highest value being 62.48 ml/kg/min and the lowest being 47.59 ml/kg/min. The fact that the circuit weight training program also showed no significant increase in cardiorespiratory function, which differs from results previously reported in the literature (42, 43, 44, 45), may also be at least partially due to the high initial cardiorespiratory function for the control group.

2. The intensity of the interval weight training might not have been enough to stimulate cardiorespiratory adaptations.

3. The duration of the interval weight training might not have been enough to bring about an increase in cardiorespiratory function. The work-relief interval, consisting of rope jumping, was just 15 minutes in length.

4. The frequency of training (2 times per week) might not have been enough to stimulate cardiorespiratory function.

Although interval weight training did not result in a significant increase in cardiorespiratory function in this study, the experimental group did show a small amount of increase in maximum oxygen uptake (59.03 to 59.23 ml/kg/min). However, the two subjects who began

with very high values of $\dot{V}O_2$ max (68.05 ml/kg/min, 68.95 ml/kg/min), decreased their maximum oxygen uptake after the experiment (68.05 to 63.59 ml/kg/min, 68.95 to 64.77 ml/kg/min). These two subjects showed an increase in both strength and body weight (73 to 75 kg and 73 to 75 kg). This could be the result of the decrease in maximum oxygen uptake. It is also worth noting that if the scores of these two subjects are disregarded, the experimental group increased its maximum oxygen uptake from 55.87 to 57.59 ml/kg/min (3.1%).

The study indicated no significant difference in maximum ventilation between the interval weight training group and the circuit weight training group. While the experimental group showed an increase in maximum ventilation (130.848 to 134.806 l/min) after the six week training period, the control group had a decrease in maximum ventilation (126.483 to 123.053 l/min). The experimental group also had an increased maximum ventilatory equivalent (29.101 to 29.503), while the control group showed a decrease (29.346 to 28.274). Robinson (90) contends that a factor in the increase in maximum ventilation with training is the increase in strength and endurance of the respiratory muscles. Accepting this explanation, the training effects of a six-week interval weight training program on maximum ventilation and maximum ventilatory equivalent would be

dependent, at least in part, on the increased strength and endurance of the thoracic, abdominal, and diaphragm muscles. However, the training adaptations of ventilation for the control group were unexpected, and the causes for the decreases in maximum ventilation and maximum ventilatory equivalent in this group remain undetermined.

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

The purpose of this study was to determine the relative effectiveness of interval weight training on the development of dynamic muscular strength, power and cardiorespiratory function.

A search of the literature revealed a number of studies published in the area of weight training for strength, power and cardiorespiratory endurance. However, no studies were found in the area of interval weight training and its effects on the development of dynamic muscular strength, power and cardiorespiratory function.

This investigation was conducted during the spring term of the 1986 academic year. All training was done in the weight training room of the Department of Physical Education at Oregon State University, Corvallis, Oregon. The subjects consisted of sixteen male students who had registered in the intermediate weight training class.

The pre- and post-test control group research design was employed for this study. The subjects were randomly assigned to either the experimental group (interval weight training program) or the control group (circuit weight training program). Training was limited to sixty minutes

twice a week and continued for six weeks. Subjects in the experimental group followed an interval weight training program. Subjects in the control group followed a circuit weight training program.

All subjects were tested for dynamic muscular strength, power and cardiorespiratory function prior to the six-week training period. The subjects were re-tested following the six-week period. One repetition maximum for the bench press and for the squat were used as a strength test. The vertical jump test was used as a power criterion. Cardiorespiratory function was tested using the running protocol graded exercise testing.

The amount of change in each group from pre-test to post-test was determined for each dependent variable. Initial and final means within each group were analyzed by the "t" test for related samples. The one-way analysis of covariance was used to determine significant differences between group mean scores. The .05 level of significance was used as the critical level for retention or rejection of the null hypotheses for the study.

As a result of the analysis, the following findings are reported:

1. There was a significant difference in the pre-test and post-test means for strength within the circuit weight training group and within the interval weight training group.

2. There was a significant difference in the pre-test and post-test means for power within the circuit weight training group and within the interval weight training group.

3. There was no significant difference in the pre-test and post-test means for cardiorespiratory function within the circuit weight training group and within the interval weight training group.

4. There was a significant difference in the six-week adjusted mean scores for squat strength between the circuit weight training group and the interval weight training group.

There was no significant difference in the six-week adjusted mean scores for bench press strength between the circuit weight training group and the interval weight training group.

5. There was no significant difference in the six-week adjusted mean scores for power between the circuit weight training group and the interval weight training group.

6. There was no significant difference in the six-week adjusted mean scores for cardiorespiratory function between the circuit weight training group and the interval weight training group.

Conclusions

Within the limitations of the sample and procedure in this study, the following conclusions seem justified:

1. Six weeks of interval weight training produces significant increases in strength and power.

2. Six weeks of interval weight training is superior to circuit weight training for producing squat strength.

3. Six weeks of interval weight training does not produce a statistically significant improvement in cardiorespiratory function.

Recommendations

On the basis of the results of this study, the following recommendations are made for future investigations.

1. The effect on the development of dynamic muscular strength, power and cardiorespiratory function of an interval weight training program which employs three or more workouts per week should be investigated.

2. A study similar to the present study, but using a large sample representing various age groups and including female subjects, is suggested.

3. A study similar to the present study, but consisting of subjects who have low initial values of maximum oxygen

uptake, is suggested in order to further investigate cardiorespiratory function effects of interval weight training.

4. A study similar to the present study, but using different types of work-relief intervals and differently timed work-relief intervals, is suggested.

5. An investigation is suggested to determine to what extent interval weight training can be utilized by world class athletes.

6. A study to determine the effects of interval weight training on maximal anaerobic power and capacity in athletes is suggested.

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APPENDICES

APPENDIX A

SAMPLE WORKOUTS

Interval Weight Training Program
Phase 3 (May 12-23)

Training Protocol

Bench Press - Increase load to 70 percent of your 1 RM. Reduce reps to 5.
Squat - Increase load to 80 percent of your 1 RM. Reduce reps to 5.
Record resting heart rate.

Training Outline

Warm-up: 3 minutes of rope jumping.

Bench Press

Set 1: 50% of 1 RM 15 reps
Rope jump 2 min.
Rest 1 1/2'

Set 2: 70% of 1 RM 4-5 reps
Rope jump 2'
Rest 1 1/2'

Set 3: 70% of 1 RM 4-5 reps
Rope jump 2'
Rest 1 1/2'

Set 4: 50% of 1 RM 15 reps (narrow grip)
Rest 5'

Squat

Set 1: 60% of 1 RM 15 reps
Rope jump 1 1/2'
Rest 2'

Set 2: 80% of 1 RM 4-5 reps
Rope jump 1 1/2'
Rest 2'

Set 3: 80% of 1 RM 4-5 reps
Rope jump 1 1/2'
Rest 2'

Set 4: 60% of 1 RM 15 reps
Rest 5'

Circuit Training

14-15 reps - 30 second rest between exercises

Curls	Dumbell exercises
Lat-machine	Sit-ups

Rope jump 1 1/2', Rest 2'
Repeat circuit twice, end of workout

**IT IS VERY IMPORTANT THAT YOU STICK CLOSELY TO THE ALLOTED TIME FOR THE REST PERIODS.

APPENDIX B

SAMPLE WORKOUT
(CIRCUIT WEIGHT TRAINING PROGRAM)

Exercise	% body weight	Reps
1. Squat	75	15
2. Lock-knee Deadlifts	50	12
3. Bench Press (narrow grip)	60	15
4. Leg Extension	40	20
5. Toe Raise	25	25
6. Seated Dumbbell Curl	20	15
7. Front Squat	60	15
8. Leg Curl	30	15
9. Sit Ups		40
10. Leg Press	60-70	15
11. Hack Squat	50	15
12. Ladder Walk	-	1

APPENDIX C

INFORMED CONSENT RELEASE

In consideration of the benefits to be derived and the data to be generated, the undersigned, a student of Oregon State University, agrees to participate in the research project, "The Effects of Six Weeks of Interval Weight Training on Strength, Power, and Cardiovascular Function," under the direction of J. P. O'Shea, Professor of Physical Education, Oregon State University.

The undersigned states that he or she has read an outline of the proposed study, including the possible risks and benefits, and is participating voluntarily and consents to following the testing and training program outlined. The undersigned also agrees to the use of the data generated as the above agencies may desire.

At any time during the study, if circumstances should arise and the undersigned cannot complete the study, he or she is free to discontinue.

_____

Participant

_____

Date

APPENDIX D

AGE AND PHYSICAL CHARACTERISTICS OF THE SUBJECTS

Experimental Group

Subject	Age	Height (cm)	Weight (kg)
1	20	174	90
2	19	176	65
3	20	191	84
4	20	182	75
5	18	184	73
6	20	179	75
7	19	179	78
8	21	174	79

Control Group

Subject	Age	Height (cm)	Weight (kg)
1	18	182	87
2	19	175	82
3	19	177	74
4	18	180	83
5	26	178	72
6	19	173	62
7	25	174	75
8	19	178	74

APPENDIX E

RAW DATA FOR THE WEIGHT LIFTING GROUPS

The Control Group

Subject	Test	Bench (kg)	Squat (kg)	Vertical Jump (cm)	Max VO_2 (l/min)	Max VO_2 (ml/kg/min)	Max Ve (BTPS)	Maximal Ventilatory Equivalent
1	Pre	125	143	58	5.08	58.69	153.74	30.26
	Post	120	134	61	4.86	55.98	147.75	30.4
2	Pre	100	170	59	4.31	52.03	142.39	33.66
	Post	100	180	64	4.06	49.35	130.73	32.2
3	Pre	75	107	58	4.23	58.5	128.43	30.36
	Post	82	116	61	4.66	62.72	144.97	31.11
4	Pre	68	130	54	5.14	62.48	122.82	23.89
	Post	75	136	57	5.12	61.55	134.18	26.21
5	Pre	70	93	51	3.95	55.35	124.72	31.57
	Post	77	114	53	4.18	57.84	122.81	29.38
6	Pre	43	66	37	3.55	56.19	85.59	24.11
	Post	52	93	46	3.6	58.24	79.29	22.03
7	Pre	70	118	67	3.71	47.59	113.47	30.58
	Post	73	143	70	3.55	47.48	99.06	27.9
8	Pre	61	116	55	4.63	62.88	140.46	30.34
	Post	68	125	61	4.66	62.9	125.63	26.96

APPENDIX E - Continued

The Experimental Group

Subject	Test	Bench (kg)	Squat (kg)	Vertical Jump (cm)	Max VO_2 (l/min)	Max VO_2 (ml/kg/min)	Max Ve (BTPS)	Maximal Ventilatory Equivalent
1	Pre	95	148	53	4.52	51.13	131.92	29.19
	Post	102	170	56	4.9	54.44	144.73	29.46
2	Pre	61	100	57	3.44	54.26	100.91	29.33
	Post	70	123	60	3.61	55.16	114.63	31.95
3	Pre	77	107	58	4.91	57.08	138.88	28.29
	Post	91	141	61	4.96	60.12	130.85	26.38
4	Pre	77	116	56	4.98	68.05	146.14	29.35
	Post	91	139	57	4.74	63.59	155.52	32.81
5	Pre	82	109	49	5.03	68.59	149.7	29.96
	Post	84	143	50	4.74	64.77	146.79	30.97
6	Pre	132	145	59	4.2	56.78	125.77	29.95
	Post	136	177	65	4.15	55	121.89	29.39
7	Pre	70	111	48	4.75	59.64	123.46	25.99
	Post	73	145	52	4.32	62.02	129.45	26.86
8	Pre	77	123	55	4.2	56.35	130	30.95
	Post	100	173	56	4.65	58.79	132.19	28.43