The Effects of a Circuit Weight Training Program on Body Composition, Muscular Endurance, and Muscular Strength in Untrained Females

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THE EFFECTS OF A CIRCUIT WEIGHT TRAINING PROGRAM
ON BODY COMPOSITION, MUSCULAR ENDURANCE, AND
MUSCULAR STRENGTH IN UNTRAINED FEMALES

by

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This thesis is approved as a creditable and independent investigation by a candidate for the degree, Master of Science, and is acceptable for meeting the thesis requirements for this degree. Acceptance of this thesis does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

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Abstract
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The effects of a circuit weight training (CWT) program on body composition, muscular endurance, and muscular strength in untrained females were examined. Seventeen untrained female subjects volunteered for either the experimental group (EG) (N=13) or the control group (CG) (N=4). All subjects were pre and posttested for total body weight (TBW), body density (BD), percent body fat (%BF), lean body weight (LBW), muscular endurance (ME), and muscular strength (MS). The EG participated in a CWT program, lifting a minimum of 40% of a one repetition maximum for 30 seconds (12-15 repetitions) at each station, and resting 40 seconds between stations. Lifts were made at eight stations for 3 circuits, 3 days per week, for 11 weeks. A Student's t test for correlated means and an analysis of variance were computed. The control group showed no significant change from pretest to posttest on any of the six variables measured (TBW, BD, %BF, LBW, ME, MS). The experimental group had no significant change in TBW but had a
significant change ($p<.05$) in BD, %BF, LBW, ME, and MS from pretest to posttest. There was no significant difference in TBW change between groups, but there was a significant difference in change for BD, %BF, LBW, ME, and MS between groups as a result of the CWT program implemented.
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# TABLE OF CONTENTS

LIST OF TABLES ........................................... vi

CHAPTER

I. INTRODUCTION ............................................. Page 1
   Statement of the Problem .................................. 1
   Statistical Hypotheses ..................................... 6
   Scope ...................................................... 7
   Limitations ............................................... 8
   Assumptions .............................................. 9
   Definition of Terms ...................................... 10
   Significance of the Study ................................ 11

II. REVIEW OF THE LITERATURE .............................. 15
   Underwater Weighing ...................................... 15
   Circuit Weight Training Procedures ...................... 20
   Circuit Weight Training and Physiological Changes .... 25
   Summary .................................................. 28

III. METHODS AND PROCEDURES ............................... 29
   Organization of the Study ................................ 29
   Data Collection ........................................... 33
   Total Body Weight ........................................ 35
   Vital Capacity ............................................ 35
   Estimated Residual Volume ................................ 36
   Underwater Weighing ...................................... 36
   Body Density .............................................. 38
   Percent Body Fat .......................................... 39
   Muscular Endurance ....................................... 39
   Muscular Strength ......................................... 40
   Data Analysis ............................................. 41

IV. RESULTS AND DISCUSSION ............................... 43
   Results ..................................................... 43
   Total Body Weight ........................................ 45
   Body Density .............................................. 45
   Percent Body Fat ......................................... 47
   Lean Body Weight .......................................... 48
   Muscular Endurance ....................................... 49
   Muscular Strength ......................................... 51
   Discussion ................................................ 54
TABLES

1. Descriptive Statistics for the Experimental Group ........................................ 44

2. Descriptive Statistics for the Control Group ................................................ 45

3. Summary for Analysis of Variance on Total Body Weight Change ......................... 46

4. Summary for Analysis of Variance on Body Density Change ............................... 48

5. Summary for Analysis of Variance on Percent Body Fat Change ........................ 49

6. Summary for Analysis of Variance on Lean Body Weight Change ........................ 51

7. Summary for Analysis of Variance on Muscular Endurance Change ...................... 52

8. Summary for Analysis of Variance on Muscular Strength Change ........................ 54
CHAPTER I

INTRODUCTION

Technological advances in the form of labor-saving devices have allowed us to live life comfortably and effortlessly. The modern American is typically confined to a chair throughout the average workday and goes home "exhausted", only to sit for several more hours in front of the television screen. Also with the availability and preparation of today's food, we can eat what we want when we want. As a result, our modern lifestyle seems to foster unfitness.

The results of our sedentary and indulgent lifestyle can be seen through the increase in obesity and heart related problems, particularly coronary disease (Getchell, 1979). Dr. Thomas Cureton (1969) noted that middle-aged characteristics have begun to reveal themselves in many Americans in their mid to late twenties. We have become inundated with a variety of health-related information from surveys, books, clinics, government reports, and the television media including but not limited to such topics as aerobic exercise and dance, jogging, and weight training. The popular physiological fitness
components gaining attention as a result of the abundance of health-related information include: body composition, cardiovascular endurance, muscular endurance and strength, and diet including caloric intake and expenditure (Corbin, Dowell, Lindsey, Tolson, 1983; Riley & Peterson, 1979).

As a result of the availability of health-related information in the last few years, our concern about fitness has increased. Consequently, we desire more knowledge about fitness and exercise programs. To counter the changes made by modern technology, exercise must be programmed into our daily lifestyle.

A recent survey indicated that 90% of all Americans believe that participation in some kind of regular physical activity is important (Corbin & Lindsey, 1979; Corbin et al., 1983). More people are now realizing the value of being physically active and feeling physically fit regardless of age or physical development. Regular exercise is necessary to develop and maintain an optimal level of health, performance, and appearance (Pollock, Wilmore, Fox 1978; DeVries, 1980; McIntrye, 1967; Berger, 1982).

The physically educated person recognizes the role of exercise and physical activity in daily life. A recent
survey indicated that 59% of American adults now participate in some form of regular physical exercise as compared with 24% twenty years ago (Harris & Associates, 1979). The data continue to support the notion that regular and vigorous physical activity is the best way to insure a long and productive life. Exercise is actually our cheapest and most enjoyable form of preventive medicine (Getchell, 1979).

Physical fitness is not an end in itself but a means to an end. It provides us with a basis for optimal physiological health and the capacity to enjoy a full life. Recently, total fitness or total well-being has emerged as a popular theme in the scholarly and popular literature (Cooper, 1982; Corbin & Lindsey, 1979). Dr. Kenneth Cooper (1982) identifies total well-being as more than just regular exercise or physical well-being, but also dietary, emotional, and spiritual well-being. The total well-being or wellness concept has achieved some notoriety in recent years as we have become increasingly aware of the benefits of exercise. As a result, various types of conditioning programs have surfaced in order to meet the demands of the consumer.

Women are becoming more interested and willing to participate in a variety of physical activities that can
provide a general conditioning effect. Societal values have changed sufficiently to allow women to participate in physical exercise free from the social stigma once attached to such participation. As a result, an area once dominated by men is now seeing increasing numbers of female participants. A conditioning activity that has gained popularity among women in recent years is weight training (Riley & Peterson, 1979). The misconceptions that were once associated with weight training are on the decline, particularly those associated with muscle hypertrophy in women. Several studies have indicated that muscle hypertrophy, at most, is only minimal for women involved in a weight training program (Brown & Wilmore, 1974; Mayhew & Gross, 1974; Sanders, 1976; Kelly, 1964; Larson, 1967).

An innovative type of training program developed by R. E. Morgans and G. T. Adams in 1953, at the University of Leeds, England, is circuit training (Morgan & Adams, 1961). Circuit training emphasizes total fitness through the development of strength, power, muscular endurance, speed, agility, neuromuscular coordination, flexibility, and cardiovascular endurance (Wilmore, 1982). Circuit training as identified by Wilmore (1982), is a formal type of training that requires the individual to go through a series of selected exercises or activities that are
performed in sequence or in a circuit. There are usually 6 to 10 stations in a circuit. The athlete performs a specific exercise at each station and then proceeds to the next station in the sequence or circuit. The premise underlying circuit training is to progress through the circuit as rapidly as possible, attempting to improve by decreasing the total time required to complete the circuit, by increasing the amount of work accomplished at each station, or via a combination of the two. Allen, Byrd, and Smith (1976), merged the circuit training concept with traditional weight training into a form of training now referred to as circuit weight training.

Circuit weight training involves a circuit or series of weight lifting stations, usually 6 to 10. Workloads range from 40 to 60% of the maximal amount of weight that can be lifted at one time—a one repetition maximum. The lifting period is approximately 30 seconds at each station with 15 to 60 seconds rest between stations. Usually two or three circuits are completed in the time span of 30 minutes or less. This type of training program can produce increases in VO$_{2\text{max}}$, muscular endurance, muscular strength, and flexibility, as well as changes in body composition (Gettman & Pollock, 1981).
The direction and magnitude of the aforementioned changes are dependent upon how the circuit weight training program is implemented. The available research on circuit weight training shows an inconsistency in the effects on women. The major areas of concern lie in body composition, strength, and muscular endurance (Mayhew & Gross, 1974; Gettman & Pollock, 1981). For the most part, the circuit weight training programs examined differed in program design. The number and types of stations, rest time between each station, number of repetitions, number of circuits, and the length of the program have all varied from one study to another.

The increasing interest among women in modifying body composition through weight training coupled with the inconsistency of findings in the literature regarding the benefits of such training make an investigation of circuit weight training as a means of modifying body composition, muscular endurance, and muscular strength timely.

**Statement of the Problem**

This study has as its main objective to determine whether body composition can be altered through the implementation of a circuit weight training program. More
specifically, the research will address what effects a circuit weight training program will have on body composition, (total body weight, body density, percent body fat, and lean body weight), muscular endurance, and muscular strength in untrained females.

**Statistical Hypotheses**

The specific null research hypotheses to be tested are as follows:

1. There will be no significant change in total body weight attributable to a circuit weight training program.

2. There will be no significant change in body density attributable to a circuit weight training program.

3. There will be no significant change in percent body fat attributable to a circuit weight training program.

4. There will be no significant change in lean body weight attributable to a circuit weight training program.

5. There will be no significant change in muscular endurance attributable to a circuit weight training program.
6. There will be no significant change in muscular strength attributable to a circuit weight training program.

Scope

This study seeks to examine the effects of a circuit weight training program on body composition, muscular endurance, and muscular strength in untrained females. The research was conducted during the spring semester of 1984 at South Dakota State University. The subjects in the experimental group (N=13) and control group (N=4) were volunteers from the female populations of South Dakota State University and the City of Brookings, South Dakota. All subjects were untrained, in that they had not been involved in more than 20 minutes of conditioning activity per week for the six months prior to the study.

A circuit weight training program, using a Universal Gym Machine, was implemented to determine the effects on total body weight, body density, percent body fat, lean body weight, muscular endurance, and muscular strength. The circuit weight training program consists of exercising three days per week at a minimum workload of 40% of one repetition maximum, lifting for 30 seconds at
each of the eight stations and resting 40 seconds between stations.

Equipment used to collect the data included:
(a) Toledo Scale, (b) Stead-Wells 10 liter spirometer,
(c) Universal Gym Machine, (d) underwater weighing tank,
(e) Chatillon 9 kilogram autopsy scale, (f) swing chair,
(g) snorkel and nose clip, and (h) Franz electronic metronome. The Stanley J. Marshall HPER Center at South Dakota State University, Brookings, South Dakota was the data collection site for this study.

Limitations

The following are set forth as possible limitations of this research:

1. Estimating residual volume from vital capacity may not represent a "true" measurement of residual volume (Katch & Katch, 1980).

2. The mechanical scale mechanism used for underwater weighing may give inconsistent readings (Katch & Katch, 1980).
Assumptions

For the purpose of this investigation, it is acknowledged that the following are assumptions on the part of the investigator:

1. All subjects were untrained, that is, they had engaged in less than 20 minutes of conditioning activity per week for six months prior to the investigation.

2. All subjects performed a maximum inspiration and expiration on the spirometer in determining vital capacity.

3. During the conditioning program, all subjects performed maximally during the 30 second lifting period.

4. Subjects in both the experimental and control groups maintained normal dietary habits.

5. Subjects in the experimental group were involved only in the prescribed exercise, the circuit weight training program.

6. All subjects abstained from food, drink, or smoking for at least two hours prior to underwater weighing.

7. All subjects eliminated waste from their bladders and bowels prior to underwater weighing.
8. All subjects were underwater weighed seven days prior to or following menstruation.

9. Subjects in the control group remained inactive for the duration of the study.

10. All subjects exerted maximal effort during the muscular endurance and muscular strength tests.

**Definition of Terms**

The following terms will be operationally defined for the purposes of this study:

**Body Composition**

Body composition is defined as the makeup of the human body including fat and lean tissue (Lamb, 1984).

**Body Density**

Body density is the weight of the body in grams per unit of body volume in milliliters (Lamb, 1984).

**Circuit Weight Training**

Circuit weight training is defined as a series of weight lifting stations completed in a consecutive manner within a specified amount of time (Allen et al., 1976).

**Fat Weight**

Fat weight is the amount of body weight composed of adipose tissue (McArdle, Katch, & Katch, 1981).
Lean Body Weight

Lean body weight is calculated as body weight minus fat weight (McArdle et al., 1981).

Percent Body Fat

Percent body fat is defined as the percentage of body weight that is composed of adipose tissue. Percent body fat can be determined from body density using the formula devised by Siri (1961). The equation for calculating percent body fat will be presented elsewhere in the paper.

Repetition Maximum

A repetition maximum is the maximum amount of weight that can be lifted in one repetition (Wilmore, 1982).

Residual Volume

Residual volume consists of the volume of air remaining in the lungs following a maximal expiration (Fox & Mathews, 1981).

Total Body Weight

Total body weight refers to the weight of the entire body including fat and lean tissue (Fox & Mathews, 1981).
Vital Capacity

Vital capacity represents the volume of air that can be maximally expired after a maximal inspiration (Fox & Mathews, 1981).

Significance of the Study

Circuit weight training is becoming a recognized and widely used general conditioning activity because of its attention to more than one fitness component (Wilmore, Parr, Girandola et al., 1978). Through circuit weight training it is possible to increase the caloric costs of exercise and produce improvements in more than one aspect of fitness (Katch & McArdle, 1983). A program of circuit weight training has been shown to affect muscular endurance, muscular strength, body composition, power, and cardiovascular endurance (Wilmore, Parr, Girandola et al., 1978; Wilmore, Parr, Ward et al., 1978). A variety of circuit weight training programs have been developed and their physiological benefits assessed, however the results have been inconclusive because of a variety of basic procedural inconsistencies among studies. As identified by Gettman & Pollock (1981), the major differences in circuit weight training programs lie in the amount of weight lifted
at each station, the number of stations included in a circuit, the number of circuits involved in the program, the amount of time or repetitions required during each lifting station, the amount of rest time between stations, and the total time involved to complete the specified number of stations and circuits. This factor coupled with the recent popularity of weight training among women and the desire to control and modify body composition were the principal motives behind this investigation.

The research will attempt to determine whether a circuit weight training program can alter body composition (total body weight, body density, percent body fat, lean body weight) and increase muscular endurance and muscular strength in untrained females. It is the hope of the investigator that the results of this study will provide some insight into conditioning, body composition, muscular endurance, and muscular strength as a result of the implementation of a circuit weight training program involving untrained females.
CHAPTER II

REVIEW OF THE LITERATURE

Rising awareness of the importance of body composition has stimulated interest in a variety of methods for controlling body composition. A method that has been studied recently is circuit weight training. What follows is a systematic review of research and writing which the author feels to be relevant to the study at hand. For ease of presentation, the review of literature has been divided into the following categories: (a) underwater weighing, (b) circuit weight training procedures, and (c) circuit weight training and physiological changes.

Underwater Weighing

Underwater weighing is one of the most widely used methods of determining body volume (Lamb, 1984). An accurate estimate of body composition can be obtained through underwater weighing (Wilmore, 1982). Body volume is equal to the loss of weight in water with appropriate temperature corrections for the density of the water (Katch & McArdle, 1983). Body volume is used to determine
body density from the relationship of mass to volume, i.e. density = mass/volume (Fox & Mathews, 1981).

Underwater weighing is based on Archimedes' Principle that an object immersed in a fluid loses an amount of weight equal to the weight of the fluid which is displaced (Fox & Mathews, 1981). When weighing an individual submerged, the total body volume in milliliters is equal to the loss of weight in water in grams. At 4°C there is a one-to-one ratio between volume and weight, that is to say, one gram of water assumes the volume of one milliliter (Michael, Burke, & Avakian, 1979). As the temperature of the water increases, volume increases as density decreases. Consequently, it becomes necessary to use a water correction factor to correct for the density of the water when weighing a submerged object (Michael et al., 1979).

Although underwater weighing is widely accepted as the "state-of-the-art" measurement tool for determining body density, Katch and Katch (1980) identified three problem areas that could affect body density scores. The first area of concern has to do with body weight. In a test-retest situation Katch and Katch (1980) found that only slight fluctuations in body weight occurred over a one to two hour period without exercise. As a result they
concluded that any observed fluctuations in body weight must be due to the inconsistency of the scale mechanism, observer error, or within-subject variation. To illustrate this the investigators pointed out that maintaining a constant residual volume of 1.2 liters and underwater weight of 5.0 kg from test to retest, a 0.5 kg difference in body weight in an individual weighing 70 kg would affect the computed density by only 1.3%. Heavier persons (100 kg range) would show an even smaller change, approximately 0.03% change in density and 0.2% change in computed body fat, indicating a relatively insignificant difference from a biological perspective.

The second problem area has to do with the difficulty in determining a "true" underwater weight. The difficulty lies in the ability of the subject to: (a) remove a maximum amount of air consistently from the lungs, and (b) remain motionless under the water for a period of 5 to 10 seconds after a maximum exhalation to permit accurate scale readings.

Researchers disagree on the number of trials necessary to obtain a stable measure as well as the means by which you determine the criterion measure of underwater weight. Several studies suggest that 10 trials provide an adequate approximation when using the mean of the last
3 trials, since there is a learning phenomenon associated with successive trials (Katch, 1969; Katch, Michael, & Horvath, 1967; Weltman & Katch, 1981; McArdle et al., 1981). Henry (1967) found that using the mean weight was more statistically sound than using the heaviest weight recorded. Katch (1969) concluded that 10 trials should be sufficient to provide an accurate approximation of underwater weight, however he reported that 40% of his subjects had not shown a leveling off of the learning curve at the end of those 10 trials. He suggested proceeding for an additional 5 trials or until the learning curve stabilized.

A different approach was noted by Wilmore (1969) and Wilmore and Behnke (1969). They suggested using three criteria for determining underwater weight: (a) select the highest obtained weight if it is observed more than twice, (b) select the second highest weight if it is observed more than once and the first criterion is not met, and (c) select the third highest weight if the first two criteria are not met. In addressing this concern, Katch and Katch (1980) concluded that using the average of the last three trials is a more dependable measure and should be used when residual volume is determined separately from underwater weighing.
The third problem area deals with obtaining an estimate of residual volume. The two methods of estimating residual volume that have been used extensively for the past 30 years are closed and open circuit oxygen or helium approaches (Wilmore, 1969b). Katch and Katch (1980) reported that determining residual volume from some percentage of vital capacity could result in error and overestimation of percent body fat. However, Wilmore (1969a) stated that this error is considered negligible for a normal population. In a study by Wilmore (1969a), 69 male and 128 female subjects were exposed to three different methods for estimating residual volume in calculating body density. For some of the subjects actual residual volume was measured by the closed-circuit oxygen dilution method. For another group estimated residual volume was determined from vital capacity using the constant value of 28% for females and 24% for males and multiplying by vital capacity. Finally, for the remaining subjects an estimated constant residual volume of 1000 ml for females and 1300 ml for males was used. The results of the study indicated that no statistically significant differences were found on the measures of body density using actual residual volume, estimated residual volume or constant residual volume.
Circuit Weight Training Procedures

Circuit weight training has modified the traditional strength training approach by deemphasizing heavy muscle overload (Wilmore, 1982). This makes it possible to increase the caloric cost of exercise, thus improving more than one aspect of fitness such as muscular endurance, muscular strength, body composition, cardiovascular endurance, and flexibility (Katch & Katch, 1983; McArdle et al., 1981; Wilmore, Parr, Girandola et al., 1978; Gettman, Ward & Hagan, 1982).

Gettman et al. (1982) identified in their study comparing a combined running and circuit weight training with a circuit weight training program that both programs were very effective and equal in the improvements observed for maximum aerobic power, strength, and body composition. Gettman, Ayers, Pollock, and Jackson (1978) concluded from their study on the effects of circuit weight training on strength, cardiorespiratory function, and body composition that their circuit weight training program was most specific in improving strength and changing body composition and produced only a small aerobic effect as measured on the treadmill running test.
Allen et al. (1976) identified through their study on the hemodynamic consequences of circuit weight training that not all types of exercise which elicit relatively high heart rates are of the same value in training the cardiovascular system. They indicated that their circuit weight training program appeared to have no effect on the cardiovascular system whatsoever. Conversely, Gettman and Pollock (1981) reported that circuit weight training can improve cardiorespiratory endurance, body composition and strength. It was also noted that circuit weight training does not develop a high level of aerobic fitness, but it can help maintain fitness.

Wilmore (1982) identified circuit weight training as a reversal of the slow and heavy traditional weight training program. Circuit weight training programs incorporate a reduced weight with short rest intervals between stations. A minimum of 6 weeks of circuit weight training is required before appreciable results are obtained (Fox & Mathews, 1981). It is generally agreed upon by most researchers in this field that a circuit weight training program of 10-15 weeks will produce measurable effects (Gettman & Pollock, 1981; Wilmore, Parr, Girandola et al., 1978).
The number of stations vary from study to study with the intent of exercising the major muscle groups of the body. The number of stations reported in the literature ranged from 6-8 (Wilmore, 1982), 6-15 (Fox & Mathews, 1981), 8-12 (Katch & McArdle, 1983), and 8-15 (McArdle et al., 1981). The idea behind involving more stations in a circuit weight training program is to increase the caloric energy expenditure making the workout more of an aerobic program (Wilmore, Parr, Ward et al., 1978). It appears that the fewer the stations in a circuit weight training program, the less effect there was on the cardio-respiratory system (Gettman & Pollock, 1981).

Some researchers advocate a particular number of repetitions ranging from 8-20 per station (Katch & McArdle, 1983; Gettman et al., 1978; Gettman, Culter, & Strathman, 1980; Gettman & Pollock, 1981; Gettman, 1978). The lower ranges of repetitions (8-12) appeared to have little effect on aerobic capacity, but when higher ranges of repetitions were implemented (15-20) some aerobic effects were evidenced (Gettman & Pollock, 1981; Gettman et al., 1978). Other researchers recommend operating within a specified time frame of 30 seconds for lifting at each station (Wilmore, 1982; McArdle et al., 1981; Wilmore, Parr, Girandola et al., 1978; Allen et al., 1976; Wilmore, Parr,
Ward et al., 1978). It was noted that allowing subjects to lift as many repetitions as possible within a 30 second time frame would tax each subject sufficiently to incorporate an aerobic effect that would create greater caloric energy expenditure (Wilmore, Parr, Girandola et al., 1978; Allen et al., 1976; Wilmore, Parr, Ward et al., 1978).

The amount of weight lifted at each station in a circuit weight training program is usually based on a one repetition maximum, ranging from 40-50% (Katch & McArdle, 1983), 40-55% (McArdle et al., 1981), to 40-60% (Wilmore, 1982). Higher percentages of a one repetition maximum (60% or greater) were found to elicit premature fatigue before each station could be completed (Wilmore, Parr, Girandola et al., 1978). A lower percentage of a one repetition maximum (below 40%) was found not to sufficiently tax subjects (Wilmore, Parr, Girandola et al., 1978). McArdle et al. (1981) reported that excessive weight contributes little to strength development. Excessive weight only increases the chances for muscle or joint injury.

The rest period between stations varied from study to study ranging anywhere from 15-60 seconds (Gettman & Pollock, 1981). Researchers agree that it is important to keep rest time to a minimum. Minimizing rest time between
stations forces the heart to maintain an elevated state as well as ensuring an aerobic effect throughout the circuit weight training program (Wilmore, Parr, Ward et al., 1978; Wilmore, Parr, Girandola et al., 1978; Gettman & Pollock, 1981).

The number of circuits or sets generally consists of two or three (McArdle et al., 1981; Gettman & Pollock, 1981). Two circuits seem to be sufficient when identifying strength and muscular endurance gains, though the effect will be small. More pronounced results can be gained from a three circuit program including other possible benefits such as body composition and aerobic power changes (Gettman & Pollock, 1981; Wilmore, Parr, Girandola et al., 1978; Wilmore, Parr, Ward et al., 1978; Allen et al., 1976; Gettman et al., 1978; Gettman et al., 1980).

Fox and Mathews (1981) identified that any weight training program should consist of a minimum of three days of lifting per week. A two day per week lifting program, at best, could only provide maintenance of an already existing level of strength and muscular endurance.

The total time involved for a circuit weight training program is dependent upon the number of stations, lifting time, rest period, and the number of circuits. Completion time reported for circuit weight training programs
ranged between 20-34 minutes (McArdle et al., 1981; Gettman et al., 1980; Gettman & Pollock, 1981).

Circuit Weight Training And Physiological Changes

There is much evidence to indicate that circuit weight training will produce physiological changes. However, it is difficult to make substantive conclusions from the findings because of the diversity of the research. Fox and Mathews (1981) have indicated that the physiological effects from a circuit weight training program vary depending upon the design of the program. In a review of related research, Gettman and Pollock (1981) alluded to the difficulty of identifying specific physiological changes. Generally speaking, results indicated that aerobic capacity increased approximately 5%, lean body weight increased 1 to 3.2 kg, fat decreased 0.8 to 2.9%, while strength improved anywhere from 7 to 32%. It was concluded that improvements were dependent upon the work performed and not the equipment used (Gettman & Pollock, 1981).

Many studies have evidenced changes in body composition as a result of circuit weight training programs, however, in many instances they lack statistical significance. Lean body weight has been shown to increase while
fat weight decreases (Mayhew & Gross, 1974; Washington, 1978; Wilmore, 1974; Wilmore, Parr, Girandola et al., 1978; Wilmore, Parr, Ward et al., 1978; Gettman et al., 1980).

As a result of increases in lean body weight and decreases in fat weight, total body weight tends to remain rather constant. Gettman and Pollock (1981) reported that circuit weight training can be used to control body composition because it increases or maintains lean body weight while decreasing body fat depending upon the type of circuit weight training program implemented.

It is generally accepted that muscular endurance will increase through muscle training that incorporates high repetitions and relatively low resistance (Clarke, 1973). Yet, Wilmore (1982) suggests that there is a high correlation between strength and muscular endurance. This would suggest that programs of low repetition and high resistance will produce improvements in muscular endurance as well.

Changes in strength resulting from a circuit weight training program are rather common as an increase in resistance generally results in an increase in strength. Gettman and Pollock (1981) indicated, in their review of studies using circuit weight training programs, that strength increased anywhere from 7 to 32%. Most of the
circuit weight training studies used equipment similar to the Universal Gym because of the convenience of changing weight, however the type of equipment used does not seem to be a factor where strength gains are concerned. Buckbee (1981) supported this conjecture when he concluded from his study involving three types of training equipment (free weights, Universal Gym, Nautilus), that each produced gains in strength but no one system was shown to be superior.

Gettman and Pollock (1981) identified two advantages of using a circuit weight training program:

1. Circuit weight training programs attend to the major components of fitness.

2. Circuit weight training programs, with a three set workout, can be completed in less than 30 minutes.

Wilmore, Parr, Girandola et al., (1978) concluded that circuit weight training is a good general physical activity that attends to more than one component of fitness. Gettman et al., (1982) recognized circuit weight training as as effective means of improving physical fitness.
Summary

The review of the literature has indicated a lack of agreement among researchers in the area of circuit weight training procedures, physiological changes, and underwater weighing techniques. Circuit weight training procedures varied in the number of stations, amount of weight lifted, number of repetitions per station, lifting time per station, rest time between stations, and the number of sets completed. Physiological changes derived from circuit weight training programs varied. Lean body weight increased from 1 to 3.2 kg, fat decreased 0.8 to 2.9%, and strength gains of 7 to 32% were reported. Measurement procedures varied for determining vital capacity, residual volume, and "true" underwater weight.

Decisions to employ the procedures implemented in this study were based upon the accurateness of measurement procedures as reported in the literature, availability of equipment at South Dakota State University, and the time available for the research.
CHAPTER III

METHODS AND PROCEDURES

The purpose of this study was to determine the effects of a circuit weight training program on body composition (total body weight, body density, percent body fat, lean body weight), muscular endurance, and muscular strength in untrained females. For ease of discussion the methods and procedures pertaining to this study will be broken down into the following categories: (a) organization of the study, (b) data collection, and (c) data analysis.

Organization of the Study

The subjects involved in this study were female volunteers from the populations of South Dakota State University and the City of Brookings, South Dakota. Notices advertising for untrained females were placed throughout the SDSU campus in an attempt to acquire subjects for this study. Professors in various departments across campus also made announcements to their classes in an effort to obtain volunteers. This study was conducted
during the spring semester of 1984 at SDSU.

The study began with 21 subjects, 17 in the experimental group and 4 in the control group. Four subjects were lost from the experimental group during the 11 weeks of the study. One subject was injured outside of the study, another subject was absent excessively, and two other subjects lost interest in the study.

Each subject was required to meet two criteria in order to be accepted into this study. These criteria follow:

1. All subjects had to be untrained, that is to say they had not been involved in more than 20 minutes of conditioning activity per week for a period of six months immediately prior to the study.

2. All subjects agreed not to alter their lifestyles in any way during the period the study was being conducted. All subjects, both experimental and control, were required to maintain a "normal" lifestyle including physical activity, diet, and sleep patterns.

Each subject in the study received a pretest and posttest for body composition (total body weight, body density, percent body fat, lean body weight), muscular endurance, and muscular strength. The control group received no training for the 11 week period of the study.
The training program was introduced to the experimental group. A circuit weight training program was implemented for 11 weeks using a Universal Gym Machine. The circuit weight training was designed to include both concentric and eccentric muscular contractions to provide a program that would involve the major muscle groups of the body. The circuit weight training procedure consisted of eight stations on the Universal Gym Machine that were lifted in the following sequence: (a) double leg extension, (b) military press, (c) double leg curl, (d) biceps curl, (e) sit up, (f) latissimus pull, (g) seated leg extension, and (h) bench press. Subjects could begin at any of the eight stations but upon hearing the "change" command they had to move to the succeeding station in the above sequence.

Each subject in the experimental group had a minimum workload of 40% of a one repetition maximum for 30 seconds (12-15 repetitions) at each station and 40 seconds rest between stations. The subjects worked in pairs to allow for a maximum number of participants to be involved.

The circuit weight training program was conducted three days per week--generally Monday, Wednesday, and Friday. This pattern varied somewhat but no subject was permitted to lift on three consecutive days. The entire
program consisted of 32 minutes of lifting at eight stations for three sets.

A warm-up period of approximately five minutes at the beginning of each session included stretching and movement exercises for the major muscles of the body. The time sequence for the circuit weight training program was recorded on a cassette tape which included commands for starting and stopping at each station. To ensure that workloads were eliciting elevated heart rates, pulse rates were monitored and recorded for all subjects one day per week at the conclusion of each set. The subjects were required to make up any absences. Anyone missing three or more sessions without making them up was eliminated from the study.

Each subject determined her one repetition maximum at seven of the eight stations three times throughout the study. The first time occurred prior to the exercise program. The second and third measurements occurred after the fourth and eighth weeks respectively. If improvements in the one repetition maximum occurred at any of the seven stations tested, adjustments were made in the weight that they were lifting at that station. It should be noted here that because of the increments in weight on the Universal Gym Machine, each subject lifted at a weight that was as
close as possible to the 40% one repetition maximum criterion. The mean for all seven lifting stations was 48.6% of a one repetition maximum. The 40% one repetition maximum criterion was maintained, if possible, as a minimum workload. The workload at the sit-up station was also increased at the same time by increasing the incline of the sit-up board when the subject could consistently complete more than 15 repetitions in 30 seconds for all three sets.

Data Collection

A trial run was conducted prior to the beginning of this investigation to determine the appropriate circuit weight training and underwater weighing procedures. Two female subjects were introduced to the circuit weight training program and the underwater weighing procedures. It was concluded that the circuit weight training program would consist of lifting at eight stations for three sets, while lifting for 30 seconds and resting for 40 seconds at each station. The underwater weighing procedure consisted of a minimum of 10 weighings (Katch & Katch, 1980; Jackson, Pollock, & Ward, 1980; Katch et al., 1967; Katch, 1969; Katch, 1968). A snorkel was used which allowed the subjects to remain underwater between trials. Not having the
subjects resurface after each trial resulted in less fluctuation of the scale and a more stable reading.

Each subject in the study was informed of the nature of the research and the procedures to be administered. An informed consent form for participation in a research study was required prior to participation (see Appendix A for complete proof). A medical clearance form was also required (see Appendix B for complete proof).

Prior to each measurement session, the subjects were given a detailed explanation of the testing procedures involving total body weight, vital capacity, underwater weighing, muscular endurance, and muscular strength. All subjects were instructed to wear a bathing suit for each body composition measurement. In an attempt to make all measurements as accurate as possible, the subjects were discouraged from eating, drinking, and smoking for a minimum of two hours prior to the administration of the body composition procedures (Jackson et al., 1980). Also the bladder and bowels were emptied prior to obtaining the body composition measurements (Robins, 1983). To avoid possible fluid retention problems as a result of menstruation, all subjects were tested at least seven days prior to or following menstruation (Jackson et al., 1980).
Data were gathered on the following variables: (a) total body weight, (b) vital capacity, (c) estimated residual volume, (d) underwater weight, (e) body density, (f) percent body fat, (g) lean body weight, (h) muscular endurance, and (i) muscular strength. A description of procedures used to gather the data follows:

**Total Body Weight**

A Toledo Scale, model 2831, was calibrated and used to determine total body weight. Total body weight was recorded to the nearest pound and converted to kilograms.

**Vital Capacity**

A Stead-Wells 10 liter spirometer was used to determine vital capacity. Vital capacity is the volume of air that can be maximally expired after a maximal inspiration (Fox & Mathews, 1981). The subject sat next to the spirometer, leaning forward in a position similar to the one assumed during the underwater weighing procedure. A nose clip was placed securely on the subject's nose. At this time the subject placed the mouth piece in her mouth and performed a maximal inspiration. At a point when the subject could no longer inspire, a maximal expiration was performed. Four to six trials were conducted recording
the highest obtained value (Wilmore, 1969). If there was
evidence of continual improvement with each successive
trial, up to five more trials were administered until a
stable measure of vital capacity was obtained. Vital
capacity was recorded to the nearest 50 ml.

**Estimated Residual Volume**

Residual volume is the amount of air remaining in
the lungs after a maximal expiration. For this study resi-
dual volume was estimated from a percentage (28%) of vital
capacity (Wilmore, 1969a). It was determined that any re-
sulting error in estimating residual volume from vital
capacity using Wilmore's method would be negligible given
the subjects under investigation. The correlation coeffi-
cient that was established by Wilmore between actual and
estimated residual volume determined from vital capacity
was $r = .875$ ($p<.0001$) for a comparable group of females
with an average age of 21.4 years.

**Underwater Weighing**

The underwater weighing procedure was conducted in
a metal tank 3 feet 2 inches by 5 feet long and 6 feet 6
inches deep. A Chatillon 9 kilogram autopsy scale was
supported overhead with a swing chair suspended from the
scale. The weight of the chair was recorded to the nearest 10 grams before each subject entered the water.

The water temperature was recorded to determine the density of the water (Michael et al., 1979). Density refers to weight per unit of volume. The density of water at 4° C is a one to one relationship, that is, one gram of water assumes one milliliter of volume. As the water temperature increases the density of water decreases and its volume increases. Because the water temperature had to be maintained at a comfortable but high density temperature for the subjects (30° C - 39° C), a water correction factor was used (Michael et al., 1979). The temperature was recorded prior to each underwater weighing procedure.

Each subject wore a bathing suit for all underwater weighing measurements. When the subject was in the water she was instructed to rub her body, suit, and hair with her hands to remove any air bubbles. The subject wore a nose clip and a snorkel. The snorkel was held in place using a head band. The subject sat on the chair and balanced her body by placing her arms around the outside of the ropes and held on to the ropes below the surface of the water. The subject would then submerge herself by leaning forward. The top of the snorkel was kept above the water by the researcher. The subject could breathe
normally through the snorkel until the scale stabilized.
The subject was then instructed to exhale as much air as
possible and remain still for 5-10 seconds. This pro-
cedure was repeated at least 10 times. Once the learning
curve had stabilized the mean of the final three trials was
taken as the subject's "true" underwater weight (Katch &
Katch, 1980).

**Body Density**

Body density is weight per unit of volume. Be-
cause fat tissue is less dense than lean body tissue,
body density can be determined through underwater weighing.
Because the density of water at 4°C is equal to one gram
of weight per one milliliter of volume, the weight a per-
son loses underwater is equal to the weight of the water
that would be displaced. Body density was calculated from
measurements obtained via underwater weighing. The den-
sity of the body was determined according to the Siri
formula (1961):
BD = \frac{\text{Wt. in Air}}{\text{Wt. in Air} - (\text{Wt. in Water} - \text{Chair Wt.}) - \text{RV}} - \text{Density of Water}

Where: \ BD = \text{body density (g/ml)} \\
\text{Wt. in Air} = \text{weight in air (g)} \\
\text{Wt. in Water} = \text{weight in water (g)} \\
\text{Density of Water} = \text{density of water using the water correction factor table (g/ml)} \\
\text{RV} = \text{residual volume (ml)}

Percent Body Fat

The percent body fat formula developed by Siri (1961) was used to calculate percent body fat:

\%BF = \frac{495}{BD} - 450

Fat weight was calculated by multiplying the percent of body fat by the body's weight in air. Lean body weight was determined by subtracting fat weight from the weight of the body in air.

Muscular Endurance

Muscular endurance was determined through procedures outlined by Anderson and Kearney (1982) for an absolute measurement on the bench press. An absolute
weight of 40 pounds was used as the workload. A Franz Electronic Metronome, model LM-FB-5, was calibrated and set to allow 40 repetitions to be completed within 60 seconds. The subject lifted in rhythm to the beat of the metronome with the aid of the instructor through "up" and "down" commands. When the subject could no longer continue or fell behind the beat of the metronome, the test was terminated. The number of repetitions completed represented the muscular endurance score.

**Muscular Strength**

Muscular strength was determined through procedures outlined by Anderson and Kearney (1982) using the bench press. Strength was assessed on the basis of each subject's one repetition maximum effort. The test began with a brief warm-up period. The subject then positioned herself on the bench in such a way that would allow her to push the weight upward. The hands were positioned on the inside portion of the handlebars. Each subject was strongly encouraged to exert a maximal effort on each trial. Each subject attempted to lift a weight on the first trial that they felt certain they could lift. The weight was increased after each successful trial until two consecutive unsuccessful trials occurred. The subject's
score consisted of the last successful lift. Three minutes of recovery time were allowed between each trial.

**Data Analysis**

The data were analyzed using the 10th release of the Statistical Package for the Social Sciences (SPSSX) on the IBM 3031 mainframe computer at South Dakota State University. Variables investigated included: (a) total body weight, (b) body density, (c) percent body fat, (d) lean body weight, (e) muscular endurance, and (f) muscular strength.

Initially, descriptive statistics included means, standard deviations, standard error of the mean, range, and maximum and minimum values were obtained for both experimental and control subjects. Following this a series of Student's t tests for correlated means were performed on both the experimental and control groups using the pretest and posttest values for the variables total body weight, body density, percent body fat, lean body weight, muscular endurance, and muscular strength.

The next procedure used was an analysis of variance for treatments. Before implementing this, however, it was necessary to affect a data transformation. For each
variable the pretest score was subtracted from the post-test score to create a new variable that reflected any changes which had occurred over the 11 week period. This procedure also had the added benefit of negating any between group differences which may have existed at the beginning of the experiment due to the inability to randomize the design. These "change" variables were used in the ANOVA procedure to identify treatment effects.

For all analyses an alpha level of .05 was pre-selected. Significance of the $F$ and $t$ statistics were determined using a standard table of values.
CHAPTER IV

RESULTS AND DISCUSSION

This chapter presents a discussion of the results concerning the effects of a circuit weight training program on body composition, muscular endurance, and muscular strength in untrained females. The untrained females were volunteers from the Brookings community and SDSU population. Subjects volunteered for either the experimental group (N=13) or the control group (N=4). The mean age for all subjects was 22.7 years. Average weight for the subjects was 61.5 kg and 167.7 cm was the mean height. The raw data on which the statistical analyses were based are presented in Appendix C.

Total body weight, body density, percent body fat, lean body weight, muscular endurance, and muscular strength were the six variables measured. Each variable was analyzed using a t-test for correlated means and an analysis of variance. The significance level of alpha<.05 was used for all comparisons. Table 1 includes descriptive statistics for the experimental group, while Table 2 contains descriptive statistics for the control group.
TABLE 1

Descriptive Statistics for the Experimental Group (N=13)

<table>
<thead>
<tr>
<th>Variables</th>
<th>Pretest</th>
<th></th>
<th></th>
<th>Posttest</th>
<th></th>
<th></th>
<th>Mean</th>
<th>Diff.</th>
<th>t</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td></td>
<td>Mean</td>
<td>SD</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TBW (kg)</td>
<td>61.50</td>
<td>7.79</td>
<td></td>
<td>62.03</td>
<td>8.42</td>
<td></td>
<td>+0.53</td>
<td>+1.02</td>
<td></td>
</tr>
<tr>
<td>BD (g/ml)</td>
<td>1.035</td>
<td>0.011</td>
<td></td>
<td>1.039</td>
<td>0.012</td>
<td></td>
<td>+0.004</td>
<td>+4.56***</td>
<td></td>
</tr>
<tr>
<td>%BF</td>
<td>28.20</td>
<td>5.34</td>
<td></td>
<td>26.64</td>
<td>5.41</td>
<td></td>
<td>-1.56</td>
<td>-4.82***</td>
<td></td>
</tr>
<tr>
<td>LBW (kg)</td>
<td>43.92</td>
<td>4.30</td>
<td></td>
<td>45.21</td>
<td>4.32</td>
<td></td>
<td>+1.29</td>
<td>+3.59**</td>
<td></td>
</tr>
<tr>
<td>ME (reps)</td>
<td>35.39</td>
<td>9.12</td>
<td></td>
<td>47.09</td>
<td>10.60</td>
<td></td>
<td>+11.70</td>
<td>+7.35***</td>
<td></td>
</tr>
<tr>
<td>MS (kg)</td>
<td>36.36</td>
<td>6.16</td>
<td></td>
<td>39.87</td>
<td>5.78</td>
<td></td>
<td>+3.51</td>
<td>+6.35***</td>
<td></td>
</tr>
</tbody>
</table>

* < .05  
** < .01  
*** < .001

Note. TBW = total body weight, BD = body density,  
%BF = percent body fat, LBW = lean body weight,  
ME = muscular endurance, MS = muscular strength,  
reps = repetitions.
TABLE 2

Descriptive Statistics for the Control Group (N=4)

<table>
<thead>
<tr>
<th>Variables</th>
<th>Pretest</th>
<th>Posttest</th>
<th>Mean Diff.</th>
<th>t</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>TBW (kg)</td>
<td>56.70</td>
<td>8.25</td>
<td>56.48</td>
<td>10.01</td>
</tr>
<tr>
<td>BD (g/ml)</td>
<td>1.038</td>
<td>0.009</td>
<td>1.037</td>
<td>0.009</td>
</tr>
<tr>
<td>%BF</td>
<td>27.09</td>
<td>4.31</td>
<td>27.51</td>
<td>4.70</td>
</tr>
<tr>
<td>LBW (kg)</td>
<td>41.13</td>
<td>3.94</td>
<td>40.60</td>
<td>4.72</td>
</tr>
<tr>
<td>ME (reps)</td>
<td>22.75</td>
<td>5.12</td>
<td>23.00</td>
<td>2.58</td>
</tr>
<tr>
<td>MS (kg)</td>
<td>30.65</td>
<td>2.30</td>
<td>31.23</td>
<td>3.45</td>
</tr>
</tbody>
</table>

Note. TBW = total body weight, BD = body density, %BF = percent body fat, LBW = lean body weight, ME = muscular endurance, MS = muscular strength, reps = repetitions.

Results

Total Body Weight

Data analysis was performed on the total body weight variable expressed in kilograms. The mean of the pretest total body weight variable for the experimental group was 61.5 kg with a standard deviation of 7.79 kg. These values increased to 62.03 and 8.42 kg, respectively
at posttest. The \( t \) test for correlated means for the experimental group revealed a \( t \) value (\( df=12 \)) of +1.02 which was not a significant change from pretest to posttest (\( p>.05 \)). The control group had a pretest mean of 56.7 kg with a standard deviation of 8.25 kg for total body weight. The posttest mean and standard deviation for total body weight were 56.48 kg and 10.01 kg, respectively. The \( t \) test for correlated means for the control group revealed a \( t \) value (\( df=3 \)) of -0.20 for total body weight which was not a significant change from pretest to posttest (\( p>.05 \)). The analysis of variance, summarized in Table 3, showed no significant difference between the experimental and control groups in terms of total body weight change from pre to posttest. (\( F=0.457; df=1,15; p>.05 \)).

**TABLE 3**

Summary for Analysis of Variance on Total Body Weight Change

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>( F )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Groups</td>
<td>1.747</td>
<td>1</td>
<td>1.747</td>
<td>0.457</td>
</tr>
<tr>
<td>Within Groups</td>
<td>57.335</td>
<td>15</td>
<td>3.822</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>59.082</td>
<td>16</td>
<td>3.693</td>
<td></td>
</tr>
</tbody>
</table>
Body Density

The mean pretest value for body density for the experimental group measured in grams per milliliter was 1.035 with a standard deviation of 0.011. The posttest mean was 1.039 and the standard deviation was 0.012. The t test for correlated means indicated a significant increase with a t value (df=12) of 4.56 (p=.001). The pretest mean and standard deviation for the control group on body density was 1.038 g/ml and 0.009 g/ml, respectively. The posttest mean for body density was 1.037 g/ml with a standard deviation of 0.009 g/ml. The control group revealed a t value (df=3) of -0.50 for body density from the t test for correlated means. This was not a significant change at the .05 alpha level. The analysis of variance on mean body density change, presented in Table 4, showed a significant difference between experimental and control groups (F=6.921; df=1,15; p=.019).
TABLE 4
Summary for Analysis of Variance on Body Density Change

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Groups</td>
<td>.0000485</td>
<td>1</td>
<td>.0000485</td>
<td>6.921*</td>
</tr>
<tr>
<td>Within Groups</td>
<td>.000105</td>
<td>15</td>
<td>.000007</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>.000154</td>
<td>16</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*p<.05

Percent Body Fat

The pretest mean for percent body fat for the experimental group was 28.2 with a standard deviation of 5.34. The posttest mean and standard deviation were 26.64 and 5.41, respectively. The t value of -4.82 (df=12) indicated that the change was significant (p=.0001). The pretest mean and standard deviation for the control group for percent body fat were 27.09 and 4.31, respectively. The posttest mean was 27.51 and the standard deviation was 4.7. The t test for correlated means for the control group resulted in +0.61 (df=3) for percent body fat which was not a significant change from pretest to posttest.
(p>.05). The calculated F ratio (8.192; df=1,15; p<.05) from the analysis of variance on mean percent body fat change, presented in Table 5, showed a significant difference between experimental and control groups from pre to posttest.

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Groups</td>
<td>12.022</td>
<td>1</td>
<td>12.022</td>
<td>8.192*</td>
</tr>
<tr>
<td>Within Groups</td>
<td>22.013</td>
<td>15</td>
<td>1.468</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>34.036</td>
<td>16</td>
<td>2.127</td>
<td></td>
</tr>
</tbody>
</table>

*p<.05

Lean Body Weight

Lean body weight was measured in kilograms. The mean value obtained during pretest data collection for the experimental group was 43.92 kg with a standard deviation of 4.3 kg. The posttest mean and standard deviation increased to 45.21 and 4.32 kg, respectively. The t
test for correlated means yielded a $t$ value of +3.59 (df=12) which was significant at the .004 level. The pretest data collected on the control group revealed a mean of 41.13 kg and a standard deviation of 3.94 kg for lean body weight. The posttest mean and standard deviation for lean body weight was 40.6 kg and 4.72 kg, respectively. The $t$ test for correlated means from the control group resulted in a $t$ value of -1.22 (df=3) for lean body weight. No significant change resulted from pretest to posttest ($p>.05$).

The analysis of variance applied to the lean body weight change variable produced a $F$ ratio of 6.766 (df=1,15), which was a significant difference ($p=.02$) between experimental and control groups from pre to posttest. Table 6 presents the analysis of variance summary for the lean body weight change variable.
TABLE 6
Summary for Analysis of Variance on Lean Body Weight Change

<table>
<thead>
<tr>
<th>Source of Variance</th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Groups</td>
<td>10.102</td>
<td>1</td>
<td>10.102</td>
<td>6.766*</td>
</tr>
<tr>
<td>Within Groups</td>
<td>22.397</td>
<td>15</td>
<td>1.493</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>32.499</td>
<td>16</td>
<td>2.031</td>
<td></td>
</tr>
</tbody>
</table>

*p<.05

Muscular Endurance

Muscular endurance was expressed as the maximum number of repetitions lifted in rhythm to the beat of a metronome. The mean and standard deviation for pretest results for muscular endurance were 35.39 and 9.12, respectively for the experimental group. The posttest mean increased to 47.08 with a standard deviation of 10.6. A t value of +7.35 (df=12) from the t test for correlated means revealed that a significant increase (p=.0001) had occurred in muscular endurance from pretest to posttest. The control group had a pretest mean and standard deviation of 22.75 and 5.12, respectively for muscular endurance.
The posttest mean for muscular endurance was 23.0 with a standard deviation of 2.58 for the control group. The t test for correlated mean for the control group revealed a t value (df=3) of +0.15 which was not a significant change from pretest to posttest (p>.05). Again, the computation of the analysis of variance on muscular endurance change showed a significant increase (p=.002) between experimental and control groups from pretest to posttest. The calculated F ratio for muscular endurance change was 14.051 (df=1,15). Table 7 presents the results of the analysis of variance on muscular endurance change.

TABLE 7
Summary for Analysis of Variance on Muscular Endurance Change

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Groups</td>
<td>400.481</td>
<td>1</td>
<td>400.481</td>
<td>14.051*</td>
</tr>
<tr>
<td>Within Groups</td>
<td>427.519</td>
<td>15</td>
<td>28.501</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>828.000</td>
<td>16</td>
<td>51.750</td>
<td></td>
</tr>
</tbody>
</table>

*p<.05
Muscular Strength

Muscular strength was measured in kilograms. The pretest mean for the experimental group was 36.36 kg with a standard deviation of 6.16 kg. The posttest mean was 39.87 kg with a standard deviation of 5.78 kg. The computation of the t test for correlated means revealed a t value of +6.35 (df=12) that was a significant increase at the .0001 level. The control group pretest mean for muscular strength was 30.65 kg with a standard deviation of 2.3 kg. The posttest mean and standard deviation for muscular strength of the control group was 31.23 kg and 3.45 kg, respectively. The t test for correlated means for the control group on muscular strength resulted in a t value of +1.00 (df=3) which indicated no significant change at the alpha level of .05 from pretest to posttest.

The analysis of variance yielded an F ratio of 7.660 (df=1,15) which indicated a significant difference (p=.014) between the experimental and control groups in terms of muscular strength change from pre to posttest. The results of the analysis of variance for muscular strength change are presented in Table 8.
TABLE 8
Summary for Analysis of Variance on Muscular Strength Change

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Groups</td>
<td>26.308</td>
<td>1</td>
<td>26.308</td>
<td>7.660*</td>
</tr>
<tr>
<td>Within Groups</td>
<td>51.517</td>
<td>15</td>
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*p<.05

Discussion

The intent of this study was to determine the effects of a circuit weight training program on six variables (total body weight, body density, percent body fat, lean body weight, muscular endurance, and muscular strength). The circuit weight training program was approached from the standpoint of a general conditioning activity that would attend primarily to muscular endurance while also altering body composition. The following discussion focuses on the six variables investigated.
Total body weight did not change significantly through the 11 weeks of this investigation. Though a significant increase in lean body weight and a significant decrease in fat weight resulted, the changes offset one another resulting in an insignificant mean difference of +0.5308 kg for the experimental group. This finding supports the results of Wilmore, Parr, Girandola et al. (1978) that total body weight in the females tested did not change significantly as a result of a circuit weight training. Their program involved 10 stations, 3 circuits, 3 days per week, at 40-55% of one repetition maximum, for a 10 week program. Similarly, Gettman et al. (1982) reported that no significant change was noted in total body weight in the females tested as a result of their 12 week circuit weight training program, 3 days per week, consisting of 10 stations, 3 circuits, at 40% of one repetition maximum. In a review of circuit weight training literature, Gettman and Pollock (1981) noted similar results when compared with this study, indicating that total body weight tended to remain unchanged throughout a circuit weight training program. They also indicated that circuit weight training could be used as a weight-control program, although, when compared with aerobic training programs, the changes in total body weight may not be as apparent because
the increases in lean body weight and the losses in body fat may offset each other. The present study did not examine changes in aerobic fitness.

A significant change ($p < .05$) was observed in body density for the experimental group as a result of the circuit weight training program. Body density changes result in modifications of percent body fat and lean body weight. As body density increases, lean body weight increases and fat weight decreases. Lamb (1984) indicated that as body density increases, lean body weight becomes a greater percentage of total body weight. With a mean resistance in this study of 48.6% of one repetition maximum (8 stations, 3 circuits, 3 days per week for 11 weeks) for the experimental group, body density was shown to increase significantly as a result of the circuit weight training program implemented. As a result of the significant increase in body density, a proportional change in percent body fat revealed a significant decrease ($p < .05$) as a result of the circuit weight training program. And lean body weight also had a significant increase ($p < .05$) in conjunction with the body density variable. The 1.2923 kg increase in lean body weight from the experimental group can be directly attributable to the circuit weight training program. With an increase in physical
activity beyond what the experimental subjects were normally accustomed, the additional weight of the workload helped to develop the musculature of the subjects and therefore, produce an elevated lean body weight over the 11 week training period. As in previously mention studies on circuit weight training involving females, Gettman and Pollock (1981), Gettman et al. (1982), and Wilmore, Parr, Girandola et al. (1978), lean body weight was shown to increase significantly while significant decreases were reported in percent body fat. The results of this investigation would tend to support these findings.

Muscular endurance, as a result of the circuit weight training program, increased significantly \((p<.05)\). The difference between the pretest and posttest measures revealed a mean increase in muscular endurance of 11.6923 repetitions. The increase of 33% in muscular endurance from the 11 week circuit weight training period indicated that muscular endurance can increase substantially in the circuit weight training program implemented in this study. Anderson and Kearney (1982) also reported that absolute muscular endurance can increase significantly as evidenced in their study consisting of weight training 3 days per week for 9 weeks.
The final variable examined, muscular strength, exhibited a significant increase (p<.05) attributable to the circuit weight training program in this study. The untrained females in the experimental group experienced an average muscular strength increase of 9.6% in the bench press over the 11 week training period. Gettman and Pollock's (1981) results are consistent with the findings of this study that circuit weight training programs can be expected to elicit substantial increases in muscular strength. The increases in muscular strength (9-44%), from weight training as noted by Gettman and Pollock (1981) are generally higher than the increase found in this study. The circuit weight training program was not specifically developed for muscular strength improvement, but attends more to muscular endurance. Both Gettman et al. (1982) and Wilmore, Parr, Girandola et al. (1978), reviewed earlier in this discussion, reported increases in muscular strength as a result of their individual circuit weight training programs.

This study suggests that the circuit weight training program implemented in this study will significantly effect body composition, muscular endurance, and muscular strength in untrained females. Gettman & Pollock (1981) suggested several fitness aspects concerning circuit weight
training:  (a) circuit weight training places less orthopedic stress on the legs than other aerobic activities, 
(b) circuit weight training elicits only modest increases (5%) in \( \dot{V}O_2 \) max versus traditional aerobic activities, 
(c) circuit weight training requires an anaerobic intensity that may be too high for beginners to tolerate, but if programs are designed to minimize initial soreness and maintain low exercise intensities, circuit weight training can be useful to most individuals, (d) circuit weight training compares favorably with traditional weight training programs for strength development, and (e) although circuit weight training does not develop high aerobic fitness, it can help maintain fitness. Given the population and number of subjects in the present study, the results would seem to support the conjecture that circuit weight training can offer positive changes that can increase certain aspects of fitness. With alterations in body composition, such as increases in body density and lean body weight and decreases in percent body fat, increases in muscular endurance, and increases in muscular strength, the circuit weight training program implemented in this study can produce significant changes over a relatively short period of time (11 weeks at 32 minutes per day, 3 days per week). This study would support the finding of
Wilmore, Parr, Girandola et al. (1978) and Gettman and Pollock (1981) that circuit weight training is a good general conditioning activity attending to more than one component of fitness.
CHAPTER V

SUMMARY AND CONCLUSIONS

The purpose of this study was to determine the effects of a circuit weight training program on body composition, muscular endurance, and muscular strength in untrained females. Prior to presenting the conclusions the reader should be cautioned against generalizing from the results beyond the scope of this study given the limited representation in both the experimental and control groups.

Summary

Seventeen untrained females participated in this study conducted during the spring semester of 1984 at South Dakota State University. The subjects volunteered for either the experimental group (N=13) or the control group (N=4). The subjects were volunteers from the populations of South Dakota State University and the City of Brookings, South Dakota. All subjects were pretested for total body weight, body density, percent body fat, lean body weight, muscular endurance, and muscular strength. The control group received no treatment for the 11 weeks
of the study. The experimental group participated in a circuit weight training program consisting of exercising three days per week at a minimum workload of 40% of one repetition maximum, lifting 30 seconds at each of the eight stations and resting 40 seconds between stations. Three sets were completed in approximately 32 minutes. Posttest measurements were obtained at the end of the 11 week training period for the same six variables measured during pretesting.

A series of Student's t tests for correlated means were performed on the experimental and control groups using the pretest and posttest values for the six variables measured (total body weight, body density, percent body fat, lean body weight, muscular endurance, and muscular strength). An analysis of variance was also performed on the differences between pretest and posttest values for each of the six variables to see if a difference existed between groups.

A summary of the results follows:

1. There was no significant change in total body weight as a result of the circuit weight training program for the experimental group.

2. Body density increased significantly in the experimental group as a result of the circuit weight
training program.

3. A significant decrease occurred in percent body fat as a result of the circuit weight training program in the experimental group.

4. Lean body weight for the experimental group increased significantly as a result of the circuit weight training program.

5. There was a significant increase in muscular endurance in the experimental group from pretest to posttest as a result of the circuit weight training program.

6. Muscular strength increased significantly in the experimental group as a result of the circuit weight training program.

7. There was no significant change in any of the six variables measured (total body weight, body density, percent body fat, lean body weight, muscular endurance and muscular strength) from pretest to posttest for the control group as a result of the circuit weight training program.

8. Total body weight change was not significantly different for the experimental and control groups as a result of the circuit weight training program.

9. Body density change was significantly different as a result of the circuit weight training program when
experimental and control groups were compared.

10. A significant difference was observed between the experimental and control groups in percent body fat change as a result of the circuit weight training program.

11. When experimental and control groups were compared, a significant difference was evident in lean body weight change as a result of the circuit weight training program.

12. In a comparison of experimental and control groups, a significant difference resulted in muscular endurance change as a result of the circuit weight training program.

13. Muscular strength change was significantly different as a result of the circuit weight training program when experimental and control groups were compared.

Conclusions

The following conclusions are drawn from data collected during the 1984 spring semester from 17 untrained females from the Brookings community and SDSU population. Once again, because of the small number of subjects participating in this study, the reader is
cautioned against generalizing beyond this group of individuals.

1. This circuit weight training program will not significantly alter total body weight in untrained females.

2. This circuit weight training program will significantly increase body density in untrained females.

3. This circuit weight training program will significantly decrease percent body fat in untrained females.

4. This circuit weight training program will significantly increase lean body weight in untrained females.

5. This circuit weight training program will significantly increase muscular endurance in untrained females.

6. This circuit weight training program will significantly increase muscular strength in untrained females.

**Implication for Future Research**

Those involved in physical education and athletics as well as those interested in developing and maintaining
physical fitness may find circuit weight training to be advantageous for increasing body density, lean body weight, muscular endurance, and muscular strength and decreasing percent body fat. The primary advantage of a circuit weight training program similar to this one lies in the fact that, because circuit weight training attends to more than one component of fitness, individuals could obtain the general physical activity they require with a 32 minute workout three days per week.

For researchers interested in exploring this fertile area the following comments are offered. These recommendations, observations, and questions have arisen out of this investigation.

This investigation only obtained data at pretest and posttest. It would be of interest to determine at what time during the study differences began to surface. This could be done by obtaining additional measures at predetermined intervals between the pre and posttest.

This study used a minimum of a 40% of one repetition maximum in determining the weight lifted at each station. It would be of interest to investigate lower repetition maximums to determine the minimum workload necessary to induce a significant change. It may be that a lower workload would produce similar significant changes.
Since this study involved limited participation, it would be of interest to replicate this study with increased participation in both experimental and control groups. This would provide additional support for this research as well as the area of circuit weight training.

This study investigated the effects of circuit weight training on six variables in untrained females. It would be of interest to investigate the effects on other variables such as anaerobic and aerobic power. Perhaps it might be the case that such variables would also change as a result of circuit weight training.

Since this study investigated only untrained females, it would be of interest to examine the results using untrained males. The comparisons between the sexes would provide a more accurate picture for populations other than those examined in this study.

More investigation needs to be conducted concerning circuit weight training programs of high/low intensity, different rest/exercise ratios, and varying types of stations. This type of evaluation would provide valuable and more comprehensive information, beyond the scope of this investigation, concerning physiological changes.
REFERENCES


Appendix A

CONSENT FOR PARTICIPATION IN A RESEARCH STUDY

I, __________________________ state that I am at least eighteen (18) years of age and wish to participate in a research project being conducted by Stephen M. Woodden. I understand that the purpose of this study is to determine the effects of a circuit weight training program on body composition, muscular endurance, and muscular strength in untrained females. The study consists of an experimental group and a control group. Both groups will be measured at the beginning of the study and at the end for total body weight, body density, percent body fat, lean body weight, muscular endurance, and muscular strength. The experimental group will lift weights for 11 consecutive weeks, 3 days per week for approximately one hour each session. The control group will agree to have no change from their normal amount of physical activity for the 11 week period. The body composition measurements obtained through underwater weighing will require approximately one hour on each of the 2 days that measurements are taken. I have been informed of the procedure for circuit weight training, and I understand what is required of me. I acknowledge that my
participation in this study is on a voluntary basis and that I may withdraw from this study at any time. I understand that all results of this study will be kept confidential and that I may obtain my personal results if I so desire. I freely and voluntarily agree to participate in this research study.

Signature of volunteer ____________________________

Date ___________________
Appendix B

MEDICAL CLEARANCE

Are you currently being treated for any medical disorder?
If so, what? ____________________________________________

Do you have any musculo-skeletal problems that could be aggrevated by this activity? ____________________________

Signature of volunteer __________________________________

Date ________________
### Appendix C

**RAW DATA**

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Note. Group 1=experimental; Group 2=control; HT=height, cm; PRTBW=pretest total body weight, kg; POTBW=posttest total body weight, kg; PRBD=pretest body density, g/ml; POBD=posttest body density, g/ml; PRBF=pretest percent body fat; POTBF=posttest percent body fat; PRLBW=pretest lean body weight, kg; POLBW=posttest lean body weight, kg; PRME=pretest muscular endurance, no. of reps; POME=posttest muscular endurance, no. of reps; PRMS=pretest muscular strength, kg; POMS=posttest muscular strength, kg.