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THE EFFECT OF ENDURANCE RUNNING ON TRAINING ADAPTATIONS IN WOMEN PARTICIPATING IN A WEIGHT LIFTING PROGRAM

by

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(ABSTRACT)

Twenty-five sedentary female volunteers, 18-30 years of age, were studied to determine the effects of an endurance running program on leg strength gains from a weight training program. Subjects were randomly assigned to one of three groups: a weight training group (W), a weight training plus running group (RW), or a control group (C). The subjects trained three days per week, approximately one hour per day, for nine weeks. The RW group ran for 25 min then weight trained for 30 min, whereas the W group weight trained for one hour. Subjects were tested for one-repetition maximum (1-RM) pre-training, at two week intervals during training, and post-training. Thigh girth (midpoint [MG] and 1.18 cm above the patella [AP]) and percent body fat were measured pre- and post-training, only. Body weight was measured weekly on a calibrated scale. Significant improvements in isotonic leg strength of 56% for W and 66% for RW were

observed, with no difference between the groups. W and RW also achieved a significantly greater isotonic leg strength than the C group. The experimental groups had a significantly greater posttest AP as compared to the C group. No significant differences were observed over the experimental period in MG, percent body fat and body weight of any of the groups. In conclusion, the running program used in the present study did not interfere with leg strength or girth gains achieved through weight training. These results are in contrast to those reported in other studies which found that aerobic training impaired strength gains.

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CHAPTER I

Introduction

Long distance running originated when Phidippides made his long distance trek from the city of Marathon to the city of Athens, Greece, during the Greco-Persian Wars in 490 B.C. (Encyclopedia Britannica, 1982). Although Phidippides' run was performed as a duty and not as sport, it can be viewed as an early representation of man's endurance capabilities.

Nonetheless, it took quite some time for running to become a popular activity in the United States. Not until the mid-1970's did the number of runners increase from the thousands in the 1960's, to hundreds of thousands (Williams, 1985). Both men and women women began pushing their bodies further and further, from 10 kilometer road races, to marathons, and even ultramarathons. Today, running continues to be a popular activity. It is currently estimated that 26 million people run and 42 million people walk (Mason, 1987).

Recently, weight lifting has increased its popularity in the United States. Such events as bodybuilding and power lifting have attracted greater number of male and female competitors each year (Hesson, 1985). In addition, weight lifting is practiced among various recreational and elite athletes to increase strength, improve physical fitness and performance, and reduce the number of injuries (Allsen, Harrison, & Vance, 1983; Fleck & Falkel, 1986).

Statement of the Problem

The physiological effects of running and weight lifting have been researched separately by a number of investigators. Long distance running is considered an aerobic endurance activity. Katch and Danielson (1976) define endurance as "the ability to maintain a specified high rate of physical work output for a relatively long period of time without fatigue". Its beneficial effects, such as an improved cardiovascular system, have been well documented (Andrew, Guzman, & Becklake, 1966; Clausen, 1969; Cooper, Purdy & White, 1974). However, skeletal muscle strength and size are not influenced by this type of activity (Holloszy & Booth, 1978).

Weight lifting, an anaerobic activity, results in increases in skeletal muscle strength and muscle cell hypertrophy with little or no increases in maximal oxygen uptake (Allen, Byrd & Smith, 1976; Hickson, 1980; Hurley et al., 1984). A few circuit weight training studies have shown some increases in cardiovascular indices, but not to the degree of an endurance-type activity (Gettman, Ayres, Pollock & Jackson, 1978).

Few researchers have studied the effects of the combination of an aerobic activity and weight training. Hickson (1980) and Dudley and Djamil (1985) have tested the effect of interval training combined with weight training compared to either training program alone. In Hickson's study, the weight training group improved their strength by 44% above baseline following the 10 week training period. The endurance trained group showed no significant change in strength. The combination group increased their strength by 25% above pre-test levels by the end of the 10 week period; however, this was less than their peak of 34% above baseline at week seven. Subjects in the combination group performed a high intensity weight training, running and cycling regimen, twice the work-out of the other groups. Thus, muscle fatigue may have accounted for the decrease in strength.

Dudley and Djamil (1985) performed a similar study for seven weeks. They strength trained their subjects on a Cybex isokinetic dynamometer. The aerobic training was performed on a cycle ergometer. The endurance trained group showed no significant increase in torque at any speed. The strength trained group showed significant increases in torque at all speeds. The combination group showed an impaired increase at fast speeds relative to the weight training only group.

Although both of the aforementioned studies showed that an endurance training program may hinder strength gains and peak torque, respectively, these researchers did not train their subjects with a true endurance training program. Hickson's subjects "ran as fast as they could for 40 minutes". This was accompanied by interval training on a bicycle ergometer and weight training at 80% of one repetition maximum. Dudley and Djamil's "endurance" training program consisted of five-five min sessions three times per week on a bicycle ergometer. It seems that these endurance training regimens are not truly "aerobic" nor are they realistic, as the general population does not usually partake in such rigorous training. Furthermore, the studies cannot be compared due to the differences in training. These inconsistensies in the literature accentuate the need for further research.

Females were chosen for this study since most researchers who have conducted weight training studies used male subjects. In addition, females on the average, have a greater percent body fat and lower metabolic rate than their male counterparts. The lower metabolic rate makes losing weight more difficult for many females. Therefore, an exercise routine, such as the one proposed in this study, could be beneficial to competitive and novice female weight lifters trying to achieve a lean body composition. However, if endurance running interferes with strength or muscle hypertrophy gain, this exercise would be avoided by competitive weight lifters.

The object of the present study was to compare the effect of aerobic training in combination with a weight training program on leg strength, thigh girth, percent body fat and body weight to the effect of weight training alone on these factors. The main question being investigated is: Does an aerobic activity, such as running, affect leg strength gains due to weight training?

Research Hypotheses

Ho: There is no difference between individuals who weight train for a total of one hour three times per week and those who combine weight training and an aerobic endurance activity for a total of one hour three times per week in:

1. body weight
2. percent body fat
3. isotonic leg strength (leg press and leg extension)
4. thigh girth (midpoint and 1.18 cm above the patella)

Significance of the Study

Presently, there is little information in the literature on the combined effects of aerobic exercise with a weight training program. Although some researchers have reported less strength gains in subjects who performed a combination training program compared to those who simply weight trained, it is still not clear whether this is a function of a different total work-out duration (Hickson, 1980).

The recreational and elite athlete may find the results of this study valuable to their present training regimen. Some elite weight lifters, for example, believe that an aerobic activity may decrease muscle strength and "definition". However, they are required to compete at a low percentage of body fat. A sound aerobic conditioning program has been shown to decrease percent body fat. The question remains whether this activity will also affect gains in muscle strength and muscle girth.

The significance of this study is to determine whether endurance exercise has a detrimental effect on leg strength gains achieved through a weight training program. If a detrimental effect is not noted, aerobic exercise should be encouraged to decrease cardiovascular disease risk and utilize body fat.

Delimitations

The following delimitations were imposed by the researcher:

1. Subjects were 30 female volunteers attending Virginia Polytechnic Institute and State University, aged 18-30.
2. All subjects had not been involved in a weight training program for at least six months.
3. All subjects had not been involved in an aerobic endurance program for at least six months (i.e., less than or equal to 30 minutes/week).
4. The dependent measures were leg strength, percent body fat, leg girth and body weight.
5. The training program was conducted three days per week for nine weeks.
6. The weight training program was performed on Universal and Nautilus weight training equipment.
7. The aerobic activity consisted of running for 30 minutes at 75% of the subjects' predicted maximum heart rate.

Limitations

The following limitation may have effected the outcome of this investigation.

1. The control group was not from the same population as the experimental groups.

Definitions and Symbols

Definitions and symbols that are essential to understanding this study are as follows:

1. Isotonic: A concentric muscle contraction which shortens the muscle and moves a load (Tuten, Moore, & Knight, 1983).
2. One Repetition Maximum (1-RM): The greatest amount of weight that a subject is able to lift just once on a weight training apparatus.
3. Repetition (Reps): A complete cycle of a weight training movement (Tuten et al., 1983).
4. Set: A set includes a specified number of repetitions, i. e. eight repetitions of leg extension.
5. Thigh Girth: Anthropometric measure of the midpoint of the right quadricep and 1.18 cm above the patella of the right quadricep.

Basic Assumptions

1. Subjects exhibited a maximal performance during all testing for 1-RM.
2. Subjects were able to accurately assess their heart rates while running.
3. Subjects did not include exercise regimens in their daily routine in addition to those performed for this study.
4. Subjects did not alter their diet throughout the study.

Summary

Aerobic exercise and weight lifting are two very distinct activities. The former improves cardiovascular fitness and utilizes fat, while the latter is clearly an anaerobic activity and increases muscular strength. However, there has been little research on the effects of an aerobic endurance activity on a weight training program. The studies conducted (Dudley & Djamil, 1985; Hickson, 1980) have chosen to combine interval-type training as the aerobic activity in conjunction with the weight training regimen.

Since women have only recently become involved in this traditionally male sport, little information exists concerning their responses to weight lifting. In addition, because of their higher body fat in relation to men, they have more of a motivation to incorporate a high-calorie burning activity into their exercise regime. This study will be conducted in order to assess if the addition of an aerobic endurance activity affects strength gains achieved by weight lifting in females.

CHAPTER II

REVIEW OF THE LITERATURE

Introduction

The adaptation to exercise is related to the type of training stimulus in which one partakes (Hickson, 1980). For example, an aerobic exercise, such as running, swimming, and cycling, results in increases in muscle mitochondria, muscle myoglobin, maximal oxygen uptake, and the capacity to perform prolonged work without an associated increase in strength or muscle hypertrophy (Holloszy & Booth, 1976). However, an anaerobic exercise, such as weight training, that involves heavy resistance, results in increases in strength and muscle cell hypertrophy (Costill, Coyle, Fink, Lesmes & Witzmann, 1979). Weight training shows little to no increase in maximal oxygen uptake (Hickson, 1980).

Although aerobic exercise and weight training differ dramatically in their physiological responses, incorporating both of these programs into an exercise regime may result in increased benefits than simply choosing one program over the other. Thus, an individual may increase muscle hypertrophy and/or muscular endurance while simultaneously increasing muscle myoglobin, muscle mitochondria, and maximal oxygen uptake.

In order to more fully understand the physiological changes that occur with the aforementioned exercise programs, the review of the literature is divided into five sections: exercise prescription, effects of aerobic conditioning, effects of weight training, effects of weight training accompanied by aerobic conditioning, and, differences in adaptation to exercise between males and females.

EXERCISE PRESCRIPTION

"An exercise prescription should designate the type, intensity, duration, frequency and progression of physical activity" (American College of Sports Medicine [ACSM], 1986). ACSM (1986) states that these five components are applicable to all persons, regardless of their age or disease status. The following sections describes the most appropriate exercise prescriptions for aerobic conditioning and weight training for the healthy population.

Aerobic Conditioning

Aerobic conditioning consists of those activities which require large muscle groups, are rhythmical in nature, and can be maintained for a prolonged period (ACSM, 1986). Activities such as long distance running, swimming, walking, and bicycling are considered aerobic (Williams, 1985).

In order to achieve cardiovascular benefits, the intensity of the training should correspond to 65-90% of an individual's maximal heart rate or, 50-85% of an individual's maximal oxygen uptake (ACSM, 1986). Exercising within these ranges assures that the heart is being stressed enough to become a more efficient pump at rest (deVries, 1980). The duration of the aerobic activity must last from 15-60 minutes. The duration of the exercise program is dependent upon the intensity of the exercise (ACSM, 1986). If the intensity is high, the length of time will be shortened, since it is difficult to exercise for long periods of time at high intensities (deVries, 1980).

The frequency of the exercise regime should be three to five days per week, with five days per week showing greater improvements in maximal oxygen uptake than three days (deVries, 1980; Sharkey, 1970). Finally, ACSM (1986) suggests that the rate of progression of the exercise may be achieved via an increase in intensity, an increase in duration or, a combination of the two. Individuals will observe the greatest improvements in their fitness levels during the first six to eight weeks of the exercise program (ACSM, 1986).

Most researchers agree with ACSM's exercise recommendations, however, some controversy exists on the combination of intensity, duration, and frequency that will produce the greatest improvements in maximal oxygen uptake

(VO2max). Boileau, Buskirk, Horstman, Mendez and Nicholas (1971) studied the effects of a running, jogging and walking program on lean and obese men. They were specifically interested in the frequency of an exercise program. Their subjects exercised 60 minutes per day, five days per week for nine weeks. Boileau et al. reported significant improvements in VO2max of 11.8% in the obese men and 14.2% in the lean subjects.

In another study on the frequency of exercise, Wilmore et al. (1980) researched the physiological alterations of a 20-week jogging and bicycling program in 38 sedentary volunteers. Their subjects trained three days per week, 30 minutes per day at 75% of their predicted maximum heart rate. Wilmore et al. reported a 13.3% and 14.8% increase for the joggers and bicyclers, respectively. Thus, Wilmore et al.'s training of three days per week produced similar increases in VO2max as did Boileau et al.'s program of five days per week. However, a direct comparison cannot be made since the length of the training programs differed.

Gettman et al. (1976) examined the physiological responses of three different running programs on 55 volunteer males. The subjects were placed in either a one-day, three-day, or five-day per week training program. The training regimens were 30 minutes per session for 20 weeks.

The subjects in the three-day and five-day groups had a significantly greater increase in VO2max of 13% and 17%, respectively than those who trained one-day per week who increased their VO2max by only 8%. The improvement in VO2max was directly related to the frequency of training.

Pollock, Cureton and Greninger (1969) compared the effects of a two day per week versus a four day per week walking, jogging or running program of 19 men. The subjects exercised for 30 minutes per session. Pollock et al. reported significant increases above baseline in VO2max for both groups. However, the four day per week group showed a 35% increase compared to a 17% increase in the two day per week group.

Another study comparing the frequency of training was conducted by Pollock, Miller, Linnerud and Cooper (1975). They compared running programs of two, three, and four days per week in 148 sedentary men. The results were similar to the aforementioned studies: the subjects in the two and three day per week groups increased their VO2max by 16% compared to the significantly greater increase of 22% observed in the four day per week group. Thus, the results of these studies favor exercise programs of four to five days per week.

The duration and intensity of an exercise program are equally as important as the frequency. Milesis et al. (1976)

researched the effects of 15, 30, and 45 minutes an endurance running program on 99 males. The subjects exercised at 85%-90% of their maximum heart rates for 20 weeks. Although the 15 minute group showed an 8.5% increase in VO2max, the 30 and 40 minute groups achieved significantly greater improvements of 16.1% and 16.8%, respectively. related to the duration of the exercise program. Gettman et al. (1976) also trained their subjects for 30 minutes per day at 85%-90% maximum heart rate for 20 weeks and reported similar results. Milesis et al. (1976) concluded that the magnitude of improvement in VO2max is directly related to the duration of the exercise program.

Although ACSM suggests a minimal intensity of 50% VO2max to elicit improvements in VO2max, Gaesser and Rich (1984) have observed increases in this factor with intensities as low as 45% VO2max. Gaesser and Rich (1984) compared the effects of a low intensity running program to a high intensity program. They randomly assigned 16 male subjects to one of two groups. The high intensity regimen consisted of a 25 minute run at 80%-90% VO2max. The low intensity program required the subjects to run 50 minutes at 45% VO2max. Both programs were three times per week. The high and low intensity groups showed significant improvements in VO2max of 18.7% and 15.1%, respectively. Since Gaesser and

Rich reported improvements in aerobic capacity at 45% VO2max, more research is required to investigate the effects of exercising at even lower percentages of VO2max.

Pollock et al. (1972) were not interested in the minimum threshold for increases in VO2max, but whether improvements are greatest at the highest work intensities. The subjects ran 45 minutes two days per week at either 80% or 90% of their maximum heart rate. Both groups improved significantly in aerobic capacity. The 80% group increased 14% in VO2max while the 90% group showed an improvement of 19%. Since there were no significant differences reported between the groups, the authors concluded that both exercise intensities were sufficient for improvements in VO2max.

The aforementioned studies reported cardiorespiratory improvements at different frequencies, intensities and durations. The question remains: What combination would produce the most effective improvement in VO2max? Wenger and Bell (1986) reviewed many studies which have examined the interactions of intensity, frequency and duration of exercise training on VO2max. They concluded that intensity was the key factor to producing improvements in VO2max, "since increasing intensity up to 100% VO2max produces the greatest improvements across all frequencies, durations, program lengths and initial fitness levels" (Wenger & Bell, 1986).

They believe that the 90%-100% VO2max intensity is the most effective in producing cardiorespiratory improvements.

Wenger and Bell (1986) pointed out that the initial fitness level of the individual will interact with the exercise prescription in determining the improvement in VO2max. They reported significant increases in VO2max from two to six days per week in less fit individuals. However, when subjects' initial VO2max exceeded 50 ml/kg/min, two times per week was not sufficient, but, a four day per week program produced submaximal improvements in VO2max (Wenger & Bell, 1986).

An endurance program of 35 minutes has been shown to significantly improve VO2max. However, equal or greater improvements have been shown with exercise sessions exceeding 35 minutes, at intensities lower than 90% VO2max.

The conclusions made by Wenger and Bell were determined via a review of many studies. Although these conclusions provide an exercise prescription for the "best" improvements in VO2max, they certainly do not eliminate training regimens of differing frequencies, intensities or durations. However, to achieve the minimal threshold of improvement in VO2max, ACSM guidelines provide a solid basis for the novice aerobic exerciser.

Weight Training

There are several methods of weight training which have been shown to improve strength (Hesson, 1985). The DeLorme system consists of three sets of 10 repetitions on each weight training apparatus. The first set is performed at 50% of 10-repetition maximum (10-RM), the second set is performed at 75% of 10-RM, and the third set is performed at 100% of 10-RM.

Mayhew and Gross (1974) researched the effects of the DeLorme 10-RM method of weight training for nine weeks on females. Subjects increased their strength by 48% on the leg press apparatus, by 27% on the bench press, and by 39% on the arm curl exercise. The increase in strength was accompanied by a decrease in percent body fat and an increase in lean body mass.

Hunter (1985) conducted a weight training study that also used the DeLorme method on 24 males and 22 females. Subjects weight trained for a seven week period. Both the males and females showed significant strength gains on the bench press apparatus. Other researchers agree upon the use of the DeLorme method to increase strength (Allerheiligen et al., 1985). Allerheiligen et al. (1985) state it as "one of the best methods" to use to improve strength.

The pyramid method is another weight training program that has been shown to improve strength (Hesson, 1985). It is similar to the DeLorme method, however, the individual must "complete the pyramid". This means that after completing 10 repetitions at 100% of his 10-RM, the individual must then perform 75% and 50% of 10-RM, once again (Hesson, 1985). Allerheiligen et al. (1985) also support this method of strength training Allerheiligen et al. (1985) reported significant increases in leg strength of 30% following a 12 week weight training program using the pyramid method.

A third method of weight training that has become more widely accepted is the periodization model (Stone & O'Bryant, 1984). The periodization method is comprised of four phases or cycles. Each cycle lasts approximately four weeks. The first phase, the "adaptation" or "hypertrophy" phase is one of high volume and low intensity (Stone & O'Bryant, 1984). The individual performs two to three sets of eight to twelve repetitions at 60% of his one-repetition maximum (1-RM). The athlete trains from four to six days per week in this stage. This stage is an early preparation "designed to enable the athlete to adapt to his physiology so that he is better prepared to perform high intensity, high-quality strength-power training" (Stone & O'Bryant, 1984). During this phase, the athlete can expect a decrease in percent body fat and an increase in lean body mass (Stone & O'Bryant, 1984). The increase in muscle mass increases the athlete's potential to gain strength and power in the later stages of the weight training program (Stone & O'Bryant, 1984). Another important adapation acquired in this stage is the increase in short term endurance, which may be helpful in the reduction of fatigue in the later stages of training (Stone & O'Bryant, 1984).

The second stage of the model is entitled the "basic-strength" phase (Stone & O'Bryant, 1984). During this phase, the individual lifts three to four sets of four to six repetitions at 75% of his 1-RM. The athlete trains from four to six times per week. The gain in basic strength "provides the appropriate foundation for power specialization and further high intensity work (Stone & O'Bryant, 1984).

The third stage is the "strength-power" phase. In this stage, the individual performs three to five sets of two to three repetitions at 80%-85% of his 1-RM. It is low volume with very high intensity (Stone & O'Bryant, 1984). The athlete trains from three to four times per week. Finally, the "peaking-maintenance" stage consists of two to three sets of one to three repetitions at 85%-90% of an individual's

1-RM. The frequency of training during this stage is two to three times per week.

The periodization method of weight training is becoming the most accepted method of weight training. It significantly increases strength in both males and females (Allerheiligen et al., 1985). Allerheiligen et al. (1985) firmly state that "Gender-specific training is unnecessary! Muscle, blood, connective tissue, lung tissue, etc. are all made up of cells-cells without gender. There is absolutely no physiological reason to train women differently than men". It is a progressive-type of program that allows both the elite and novice weight lifter to achieve strength gains in a sensible manner.

Dunn and Halstead (1982) and Stone and O'Bryant (1984) firmly believe that the periodization model is the best program to increase skeletal muscle strength. Dunn and Halstead (1982) have reported considerable strength gains within four weeks in both males and females who incorporated the periodization model into their weight training regimen. Stone and O'Bryant (1984) reported significant increases in strength of 55% in subjects who performed the periodization model of strength training. This increase in strength exceeds both the DeLorme method and the pyramid method of weight training. "This training protocol allows for muscular recovery, facilitating muscular hypertrophy and strength better than other programs" (Dunn & Halstead, 1982).

All of the weight training programs discussed increase strength. However, controversy exists between the intensity and frequency of weight training that would elicit the greatest strength gains. Gilliam (1981) investigated the effects of frequency of weight training on muscle strength gains. Sixty-eight high school males were randomly assigned to one of five weight training groups, i.e. subjects trainied either one, two, three, four or five days per week for nine weeks. Significantly greater improvements in muscular strength were observed in the five day per week group as compared to the other groups. The one day per week group did not significantly increase strength, however, the two, three and four day per week groups showed a sequential pattern of improvement resulting from the increased training frequency. Nontheless, the five day per week group showed significant increases in strength above all groups. Gilliam (1981) concluded that "the more frequent the stress the greater the adaptation".

Hunter (1985) also performed a study on weight training frequencies. He compared a three day per week training program to a four day per week regimen. Subjects trained for seven weeks. His results were similar to Gilliam's, in that the four day per week group significantly increased their strength more than the three day per week group. Thus, the increased frequency of training alone, improves muscular strength, regardless of the training regimen (Hunter, 1985).

The intensity of a weight training program is equally important as the frequency. According to Stone and O'Bryant (1984), the greatest strength gains will occur at intensities of 75% - 90% of 1-RM. Withers (1970) investigated the effects of different weight training intensities and number of sets on 55 males. The groups exercised two days per week for nine weeks. Subjects were randomly assigned to one of the following groups: Group 1 performed three sets of 7-RM, Group 2 performed four sets of 5-RM, and Group 3 performed five sets of 3-RM. All the groups significantly increased strength, with no difference between groups. However, a slightly greater improvement was observed in Group 2.

Anderson and Kearney (1982) researched the effects of three resistance training programs on muscular strength and endurance. Forty- three males weight trained three times per week for nine weeks. The subjects were randomly assigned to a: high resistance, low repetition group, i.e. three sets of 6 to 8-RM, a medium resistance, medium repetition group, i.e. two sets, 30 to 40-RM, or a low resistance, high repetition group, i.e. one set of 100 to 150-RM. The high resistance, low repetition group showed a 20% increase in strength, which was significantly greater than the 8% and 5% increase achieved by the medium and low resistance groups, respectively. Nonetheless, the medium and low resistance groups significantly increased muscular endurance by 22% and 28%, respectively. Anderson and Kearney (1982) concluded that "human skeletal muscle makes both general and specific adaptations to a training stimulus, and that the balance of these adaptations is to some extent dependent upon the intensity and duration of the training protocol used".

In reviewing these studies, it seems the most appropriate method of increasing strength is a combination of high intensity, low volume workloads, three to five times per week, with five days per week showing the greatest improvements. Palmieri (1983) reviewed the concept of intensity and frequency. He stated that explosive strength has best been developed with a program of high weight with six repetitions or less (Palmieri, 1983). The high intensity provides the necessary stress to recruit the IIB motor units (Palmieri, 1983). The lower intensity, higher repetition type of weight training recruits less IIB motor units because there is less weight to move. Palmieri reported a lack of fast twitch muscle fiber hypertrophy in body builders due to their program of low weight, high repetitions. Conversely, power lifters, who perform high intensity, low volume workouts, show significantly larger fast twitch fibers (Palmieri, 1983). Thus, it is important to recruit IIB motor units to increase strength. This is achieved by a program of three to four sets, six or less repetitions, at 75% to 90% of 1-RM (Palmieri, 1983; Withers, 1970).

EFFECTS OF TRAINING

Aerobic Conditioning

In the 1960's, Kenneth Cooper, Ph.D., coined the term "aerobics" (Williams, 1985). Aerobic conditioning is defined as those exercises which are continuous, rhythmic, utilize fat, and enhance cardiovascular parameters (McArdle, Katch & Katch, 1986).

Numerous physiological changes occur with aerobic training. On the cellular level, Barnard, Edgerton and Peter (1970a) investigated the concentration of mitochondria in the gastrocnemius and plantaris muscles of Guinea pigs after an 18 week treadmill running program. They reported a significantly greater amount in both the size and number of mitochondria in the endurance-trained animals compared to their untrained counterparts. Furthermore, the trained skeletal muscle increased its capacity to generate adenosine triphosphate (ATP) aerobically by oxidative phosphorylation (Barnard et al., 1970a).

Studies have also reported an increase in the level of aerobic system enzymes. Baldwin, Winder and Holloszy (1975) studied the adaptation of actomyosin ATPase in male rats after an 18 week treadmill running program. The fundamental difference in actomyosin ATPase activity in fast and slow-twitch muscle fibers is that the actomyosin ATPase activity in fast-twitch muscle fibers is high; and, actomyosin ATPase activity in slow-twitch fibers is low. Nonetheless, certain fast-twitch muscle fibers can have a high respiratory capacity (Baldwin et al., 1975). For example, rodents possess three types of skeletal muscle fiber: fast-twitch red fibers, slow-twitch red fibers, and fast-twitch white fibers. The fast-twitch red fibers have a high respiratory capacity and a high actomyosin ATPase activity (Baldwin et al., 1975). The slow-twitch red fibers possess a moderately high oxidative capacity and a low actomyosin ATPase activity. And, finally, the fast-twitch white fibers have a low oxidative capacity and a high actomyosin ATPase activity. Baldwin et al. (1975) reported a 20% decrease of actomyosin ATPase activity in the fast-twitch red vastus muscle of the endurance-trained rats (1975). In contrast, the actomyosin ATPase activity of the slow-twitch red soleus muscle increased by 20%. They also reported a high correlation between actomyosin ATPase activity between the three types of skeletal muscle and in the heart muscle, in the exercise-trained rats (Baldwin et al., 1975).

Fitts and Holloszy (1977) researched the contractile property changes of the rat soleus muscle after a 20 week endurance training program, which consisted of treadmill running. They also reported a 20% increase of actomyosin ATPase activity in the slow-twitch red soleus of the trained animals. In addition, the muscles from the trained rats exhibited a greater resistance to fatigue compared to the untrained rats. The physiological consequences of this adaptation include a smaller decrease in high-energy phosphate concentration and a smaller increase in lactic acid concentration in the trained versus the untrained muscle during prolonged work (Fitts & Holloszy, 1977).

McArdle et al. (1986) reported an 80% increase in skeletal muscle myoglobin content in rats who underwent aerobic conditioning. Therefore, the quantity of oxygen within the cell at any one time is increased, which may facilitate oxygen diffusion into the mitochondria (McArdle et al., 1986). Since this increase in myoglobin has only been reported in animals, research on humans requires further investigation.

"Mitochondria from trained skeletal muscle have a greatly increased capacity to generate ATP aerobically by oxidative phosphorylation" (McArdle et al., 1986). Associated with the increased capacity for mitochondrial oxygen uptake, is an increase in both the size and number of mitochondria. Secondly, there is a possible twofold increase in the level of aerobic system enzymes (McArdle et al., 1986). The increased oxidative capacity of the mitochondria in trained muscle allows the muscle to exhibit a greater capability to oxidize carbohydrates (Wilmore, 1982).

Aerobic training produces metabolic adaptations in the different types of muscle fibers (Gollnick, Armstrong, Sauberg, Piehl & Saltin, 1972). In animals, endurance training has been shown to alter the metabolic characteristics of skeletal muscle by increasing the activity of some Krebs cycle enzymes, i.e., succinate dehydrogenase, mitochondrial protein concentration, and the ability to oxidize fat (Barnard, Edgerton & Peter, 1970b). However, this has not been thoroughly studied in humans. Gollnick et al. (1972) studied muscle fiber types in untrained versus trained men. Gollnick et al. (1972) reported an increased oxidative capacity of fast-twitch muscle fibers in the trained men. Thus, these fast-twitch fibers would be able to better utilize their glycogen stores aerobically and oxidize fatty acids. This adaptation would delay the onset of muscle fatigue as well as reduce lactate production during submaximal work that occurs after training (Gollnick et al., 1972).

Costill, Fink, Getchell, Ivy and Witzmann (1979) performed muscle biopsies of the gastrocnemius muscles in 13 men and 12 women distance runners and analyzed the activities of selected enzymes. Costill, Fink, et al. (1979) reported a significantly greater amount of succinate dehydrogenase in the male and female distance runners as compared to untrained males. However, the male runners possessed a significantly greater amount of succinate dehydrogenase than their female counterparts.

Aerobic exercise may also cause a "selective hypertrophy" of slow-twitch muscle fibers (Brooks & Fahey, 1985). Highly trained endurance athletes show larger slow-twitch fibers than fast-twitch fibers in the same muscle (McArdle et al., 1986). This hypertrophy is only apparent in the specific muscles used.

A muscle's capacity to mobilize and oxidize fat is increased with aerobic conditioning (Butterfield, 1982). Thus, at any submaximal work rate, a trained person utilizes more free fatty acids than an untrained individual (deVries, 1980). The increased lipid metabolism resulting from aerobic training allows muscle glycogen stores to be "spared" during work, therefore improving endurance by delaying the the onset of fatigue (Tremblay, Despres, & Bouchard, 1985). Thus, endurance training induces a reduction in adiposity by reducing fat cell size (Tremblay et al., 1985).

In addition to the cellular level improvements, aerobic conditioning exhibits various cardiovascular changes (Ross, 1982). The heart rate at rest will decrease as a result of endurance training (Wilmore, 1982). As an individual becomes more fit, his heart rate will be lower for submaximal work loads. The lower submaximal heart rate indicates that the heart is working more efficiently (Wilmore, 1982). Squire, Myers and Fried (1987) stated, "The best-known cardiovascular adaptation to exercise is a slower resting heart rate or training-induced bradycardia". Many researchers have documented a decrease in resting and submaximal heart rates due to aerobic training (Franklin, Hodgson & Buskirk, 1980; Metz & Alexander, 1971; Van Handel, Costill & Getchell, 1976). Heart rate response is even more significant in previously sedentary individuals (Van Handel et al., 1976). Furthermore, the more quickly an individual recovers from an exercise bout, i.e., heart rate returns to its resting value, the more aerobically fit is the individual. Thus, heart rate is a simple and convenient method to measure endurance training improvement (Allen, Byrd, & Smith, 1976; Katch & Danielson, 1976).

Although heart rate provides a simple measure of cardiovascular adaptation resulting from exercise, researchers agree that stroke volume (SV) and cardiac output (Q) demonstrate the greatest improvements (Andrew, Guzman & Becklake, 1966; Clausen, 1969; Cooper, Purdy & White, 1974; Nadel, 1985). At rest, SV is higher following an endurance training program. SV is also greater at submaximal and maximal work loads (Nadel, 1985). This increase is attributed to a more complete filling of the heart, which results in a greater ventricular blood volume and improved cardiac contractility. The increased SV appears to allow the heart to beat at a slower rate, both at rest and submaximal levels of exercise (Wilmore, 1982). Nonetheless, the increase in SV during exercise plateaus at relatively low work loads (Sharkey, 1984). Since Q is a product of heart rate and SV, further increases in Q are due to an increased heart rate at higher workloads (Wilmore, 1982).

Ricci et al. (1982) reported an increase in the size of the left ventricular wall in adolescent boys following an eight week endurance training program. Morganroth (1975) reported larger left ventricles in trained athletes compared to non-athletes. This cardiac hypertrophy is a normal training adaptation that is characterized by an increase in the size of the left ventricular cavity, as well as by a thickening of its walls (Hickson, Foster, Pollock, Galassi & Rich, 1985). This indicates a greater ventricular muscle mass, and thus, contractility is increased, which reduces the volume of residual blood that remains following the contraction (deVries, 1980). However, with reduced training, this cardiac hypertrophy returns to control levels (Hickson et al., 1985).

Blood volume increases with endurance training. This is accomplished via an increase in both plasma volume and red cell volume (Nadel, 1985; Wilmore, 1982). Nadel (1985) states, "of all the adaptations to physical activity, the increase in absolute blood volume may well be the most important, because it provides major benefits in both oxygen and heat transport". This results in a greater SV than in the unfit state. The benefits of an increased blood volume are numerous: 1) it provides for a greater maximal Q; 2) it enables the heart rate to be lower at a given moderate Q; 3) there is a greater capacity to deliver oxygen to the contracting muscles, and 4) the increased blood volume enhances the body's ability to maintain a high skin blood flow in potentially compromising conditions, i.e., in the heat (Nadel, 1985).

Aerobic conditioning also improves VO2max (Brooks & Fahey, 1985). Bergh et al. (1978) reported a 5% to 20% increase in VO2max in trained and untrained individuals, respectively. Hickson, Bomze and Holloszy (1977) studied the effects of a 10 week strenuous program of endurance exercise on previously "very sedentary" males. They reported a 44% increase in VO2max. Hickson et al. (1977) concluded "It appears that aerobic work capacity can increase more rapidly and to a greater extent in response to training than has generally been thought". Thus, the more fit an individual becomes, the more difficult an improvement in VO2max. VO2max is regarded as the best criterion of cardiorespiratory endurance capacity or "physical fitness" (Wilmore, 1982).

Arteriovenous oxygen difference (a-vO2 difference) is another cardiovascular index which increases with training (Brooks & Fahey, 1985). The increase in the a-vO2 difference is the result of a more effective distribution of the cardiac output to working muscles as well as enhanced capacity of the trained muscle cells to extract and utilize oxygen (McArdle et al., 1986).

Van Handel et al. (1976) specifically studied circulatory adaptations to an endurance training program. Their subjects were seven men and seven women who had previously been sedentary. Van Handel et al. (1976) reported increases in the following: VO2max, Q, and a-vO2 difference. These adaptations were accompanied by a decrease in resting and submaximal heart rates. Since these cardiovascular changes were equivalent in both the men and women participating in the study, Van Handel et al. concluded, "there are no differences in the trainability of previously sedentary middle-aged men and women" (1976).

Finally, researchers have reported a decrease in both systolic and diastolic blood pressure during rest and submaximal exercise (Nadel, 1985). Kaufman, Hughson and Schaman (1987) studied the effects of exercise on recovery blood pressure in normotensive and hypertensive subjects. Following exercise training on a treadmill, both the normotensive and hypertensive subjects showed a decrease in both systolic and diastolic blood pressure. Only on the third session of testing did the diastolic blood pressure return to resting values in all subjects (Kaufman et al., 1987).

Along with its cardiovascular improvements, aerobic conditioning has been shown to decrease percent body fat. (McArdle et al., 1986). Many researchers report an improved body composition due to an aerobic training program (Brooks & Fahey, 1985; Nadel, 1985; Wilmore, 1982). However, aerobic endurance activities, such as running, have not been consistently shown to increase lean body mass (LBM) (Katch & Drumm, 1986). In a study by Boileau, Massey and Misner (1973), 21 men were randomly assigned to a weight training group, a jogging group or a control group. The experimental groups trained three days per week for 13 weeks. Each group exercised for 30 minutes per day. Boileau et al. (1973) reported a significant increase in LBM in the weight training group with no significant increase in LBM in the jogging group.

Cisar, Thorland, Johnson and Housh (1986) researched the effects of a 14 week endurance training program on 32 male volunteers. They reported significant decreases in body weight, relative fat and fat weight, with no change in LBM.

Wilmore, Royce, Girandola, Katch and Katch (1970) investigated the body composition changes in 55 men following a three day per week, 10 week program of jogging. The purpose of their study was to determine whether a jogging program was of sufficient intensity to produce body composition changes. They reported small but significant reductions in body weight and percent body fat, accompanied by a significant increase in body density. However, LBM remained unchanged.

Pavlou, Steffee, Lerman and Burrows (1985) studied the effects of dieting alone to exercise plus dieting in 72 obese males. The subjects were randomly assigned to one of eight treatment groups arranged in a 2x4 factorial design with exercise, non-exercise and four diets as the two factors. The exercise consisted of an aerobics program that was conducted three days per week for eight weeks. Subjects exercised at 70%-85% of their maximum heart rate. Pavlou et al. (1985) reported a decrease in LBM in the diet only group, with no significant change in LBM in the exercise plus diet group. Nonetheless, the exercise plus diet group possessed a significantly greater decrease in percent body fat than the diet only and control groups.

In contrast to the above studies, Moody, Wilmore, Girandola and Royce (1972) and Boileau et al. (1971) reported increases in LBM in their studies. Moody et al. (1972) trained 40 normal and obese high school girls in a walking, jogging, and running program for 15 weeks. The purpose of their study was to "assess the influence of long-term participation in a moderate exercise program on the body composition of normal and obese adolescent girls" (Moody et al., 1972). The obese group demonstrated significant decreases in body weight and relative fat, and increases in body density and LBM. The normal group showed an improved percent fat with no improvement in LBM, body density or body weight.

Boileau et al. (1971) researched the effects of a nine week running and walking program in 23 obese and lean college men. Their study showed that the obese men had a significant increase in LBM and a significant decrease in percent body fat. Although, the lean subjects showed a significant decrease in percent body fat, they did not significantly increase their LBM. The aforementioned studies seem to indicate that obese individuals have a greater tendency to increase their LBM with endurance exercise due to the greater amount of fat they possess prior to training. A possible explanation for the greater increase in LBM in the obese subjects may be attributed to the greater amount of body weight they have to move. Secondly, the lean subjects began at a lower percent fat which makes it more difficult to decrease it (Boileau et al., 1971).

Gettman, Ayres, Pollock and Jackson (1978) researched body composition changes in normal weight individuals in response to circuit weight training or running. Each group exercised three days per week for 20 weeks. Gettman et al. (1978)save reported a significant increase in LBM and a significant decrease in percent body fat in the running group. These changes were similar to those observed in the weight training group.

Although a few studies reported an increased LBM in their subjects following an endurance exercise program, most studies do not. It is most frequently observed that aerobic exercise produces a decrease in percent body fat with no change in LBM.

Weight Training

Muscular strength is defined as "the maximum force or tension level that can be produced by the muscle group" (Heyward, 1984). Although researchers agree on the definition of strength, conflict arises on the mechanism of strength gain. For many years it was assumed that strength gains were directly due to hypertrophy of the muscle, i.e., an increase in muscle size (Wilmore, 1982). Although hypertrophy occurs with weight training, gain in muscular strength may also be attributed to neuromuscular adaptations and possibly hyperplasia, an increase in the total number of muscle fibers.

It has been suggested that the great increase in maximal strength during the initial strength training program is primarily due to adaptations in the maximal neural activation (Hakkinen, 1985; Howard, Ritchie, Gater, Gater, & Enoka, 1985). These neural adaptations may be partially a result of an enhanced ability to recruit more fast-twitch motor units (Howard et al., 1985). Hypertrophic adaptations will accompany improved muscle strength during later conditioning (Howard et al., 1985). The former occurrence may be responsible for the reports of strength gain in the absence of measurable hypertrophy.

Research on animals has postulated that hyperplasia may be a factor in total muscle hypertrophy and strength gain (Gonyea, 1980). Gonyea (1980) studied cats who were trained to use their forepaw to move a heavy weight in order to get to their food. The intense strength training resulted in selected muscle fibers to split in half and increase in size. Although hyperplasia was discovered in the cat, it is not well-understood whether this actually occurs in humans (Wilmore, 1982).

Luthi et al. (1986) recently researched the effect of a six week heavy resistance training program on muscle fiber hypertrophy versus hyperplasia in untrained young males. They reported an increase in muscle fiber size with no change in number. Thus, it seems that the appropriate investigation to distinguish between hypertrophy and hyperplasia has been performed (Howard et al., 1985). Howard et al. (1986) stated, "since the issue of significance of strength is the amount of cross-sectional area, this debate on the existence of hyperplasia may be of little consequence. However, a genetically endowed greater number of muscle fibers may allow for greatest maximum hypertrophy".

McArdle et al. (1986) list the metabolic adaptations that occur with weight training and other anaerobic activities as: (1) increases in resting levels of anaerobic substrates; (2) increases in the quantity and activity of key enzymes controlling the anaerobic phase of glucose breakdown; and (3) increases in capacity for levels of blood lactic acid during all out exercise following anaerobic training.

MacDougall, Ward, Sale and Sutton (1977) studied nine healthy subjects under control conditions and following five months of heavy resistance training. The training resulted in significant increases of 39% in resting concentrations of muscle creatine, a 22% increase in creatine phosphate, an 18% increase in ATP and a 66% increase in glycogen. The authors concluded that there is a biochemical advantage to be gained from this form of training through an increase in muscle energy reserves.

Costill, Coyle, et al. (1979) researched the adaptations in skeletal muscle of five men following seven weeks of isokinetic strength training. They reported elevations in glycolytic and ATP-CP enzymes. The strength training program also elicited increases in the following enzymes: succinate dehydrogenase, malate dehydrogenase, lactate dehydrogenase, muscle phosphorylase, phosphofructokinase, creatine phosphokinase and myokinase. Costill, Coyle, et al. (1979) also reported significant changes in the percent of muscle area composed of fast glycolytic (FG) and fast oxidative glycolytic (FOG) fibers as a result of the strength training program.

Howard et al. (1985) and Palmieri (1983) did not report a conversion of fiber types (i.e., slow oxidative [SO] to FG) following 10 weeks of weight training. Researchers seem to agree that the FOG fibers will take on the characteristics of the type of training which an individual performs (Howard et al., 1985). For example, if one trains for endurance, the FOG fibers become more fatigue resistant, but there is no conversion of FOG fibers to SO (Palmieri, 1983). Thus, specificity of training is important in fiber recruitment type.

MacDougall et al. (1979) studied the mitochondrial volume density in six males following six months of an intense weight training program. They reported a 26% reduction in mitochondrial volume density and a 25% reduction in mitochondrial volume to myofibrillar volume ratio. They believed this reduction was due to an increase in total contractile protein through hypertrophy, without a proportional increase in mitochondrial volume. MacDougall et al. (1979) also reported significant increases in fiber area of 33% for fast twitch (FT) fibers and 27% for slow twitch (ST) fibers. MacDougall et al. (1979) concluded, "Since heavy resistance training leads to a deletion in mitochondrial density, it may be detrimental to endurance performance by decreasing oxidative potential per total muscle mass".

Accompanying its physiological adaptations, weight training has been shown to increase performance variables such as speed and strength (Pipes & Wilmore, 1975; Whitley & Smith, 1966). Whitley and Smith (1966) studied the effects of three different strength training programs on lateral arm speed. They utilized an isotonic-isometric lifting program versus a dynamic-overload lifting regime. They reported significant increases in speed of limb movement for both groups. Pipes and Wilmore (1975) reported similar improvements in limb speed with an isokinetic strength training program. Stone and Wilson (1985) reported improved running speed with subjects who incorporated a weight training program into their exercise regimen.

It is well documented that weight training increases strength (Brosmer, 1985; Hickson, 1980; Stone & Wilson, 1985). Although some controversy still exists, researchers are beginning to better understand the mechanism by which weight training increases strength. It seems that maximal strength of an untrained individual is increased during earlier weight training bouts via neural adaptations (Hakkinen, 1985). When the training is continued for a longer period of time, increases in strength are also due to hypertrophic factors. Hormonal changes may also be a factor in long-term strength improvements. Hakkinen (1985) reported increases in serum testosterone/cortisol ratio in his male subjects following intensive resistive weight training for 20 weeks. Stone, Byrd and Johnson (1984) also reported significant increases in testosterone in their male subjects following 12 weeks of weight training. Hypertrophy appears to be largely regulated by hormonal levels. The hormones cause hypertrophy by increasing actin, myosin, myofibrils, capillaries, ATP-PC and connective tissue (Allerheiligen et al., 1985). Since females possess a 10 times lower testosterone level than do males, increases in strength are largely due to neuromuscular recruitment and synchronization of motor unit firing (Cureton et al., 1985).

Cureton, Collins, Hill, McElhannon and Davis (1986) researched muscular strength and hypertrophy between males and females. After 16 weeks of a progressive-resistance weight lifting program, Cureton et al. (1986) reported significant increases in strength and muscle cell hypertrophy in the males and females with no significant differences between groups. They concluded that percentage changes in strength and muscle hypertrophy consequent to weight training were similar in males and females (Cureton et al., 1986).

Aside from increasing maximum skeletal muscle force output, weight training may also increase the strength of tendons and ligaments which could aid in the prevention of injuries (Dunn & Halstead, 1982; Stone & Wilson, 1985). Studies have shown that damaged ligaments regain strength at a faster rate if physical activity is performed after the injury (Fleck & Falkel, 1986). Fleck and Falkel (1986) reported a 31% reoccurence of tennis elbow in athletes who weight trained as compared to a 41% reoccurence in those who did not perform a weight training program. Thus, weight training may not only enhance an athlete's performance, but also reduce the risk of injury.

Stone and Wilson (1985) reported significant increases in LBM in both men and women following a 10 week weight training program. Hunter (1985) also reported significant decreases in percent body fat with increases in LBM in his study involving men and women who weight trained for seven weeks. Hunter (1985) reported a greater decrease in percent body fat in the women, which may have been attributed to a greater adiposity prior to training.

Wilmore et al. (1976) studied the effects of a circuit weight training (CWT) program on 13 college-aged females. The subjects completed a 12 week program of CWT for 25 minutes per day, three times per week. Wilmore et al. (1976) reported significant increases in LBM accompanied by significant decreases in relative, absolute, and subcutaneous fat. Wilmore, Parr, Girandola, et al. (1978) reported similar results a 10 week CWT program utilizing men and women The men and women showed significant improvements in LBM and percent body fat, with the women showing even greater improvements than the men.

Finally, Stone, Blessing, et al. (1982) investigated the physiological effects of a 12 week resistive training program on middle-aged untrained men. Their subjects possessed a significantly greater increase in LBM and a significantly greater decrease in percent body fat as compared to their baseline values.

Although it is well documented that weight training improves strength, there is conflicting evidence on its effect on aerobic capacity and cardiovascular indices (Hickson, 1980; Hurley et al., 1984). Hurley et al. (1984) studied the effects of a 16 week high intensity strength training program on cardiovascular function. Although the previously untrained subjects exhibited a 44% increase in muscular strength, VO2max did not change significantly. The lack of increase in VO2max, despite a sustained elevated heart rate during strength training, may be attributed to a relatively low VO2 (45% VO2max) elicited by this form of exercise. Hurley et al. (1984) concluded that sympathetic stimulation may have played an important role in the increases in heart rate without parallel increases in VO2 during strength training exercises (1984).

Keul, Haralambie, Bruder and Gottstein (1978) researched the cardiovascular effects of specific weight lifting exercises in 15 experienced weight lifters. They reported no improvement in VO2max. Keul et al. (1978) concluded, "This type of training may be useful in the clinical rehabilitation of the locomotor system, but it lacks importance for prevention of rehabilitative therapy of the cardiovascular system".

Hickson, Rosenketter and Brown (1980) researched the effects of a heavy resistance training program on endurance and VO2max. Nine male subjects participated in this 10 week long study (five days per week). They weight trained only their lower limbs at an intensity of 80% of 1-RM. Although the strength training did not improve the subjects' VO2max, their short-term endurance was increased, as evidenced by a 47% increase in time to exhaustion on a bicycle ergometer at

80% of their VO2max. Blood samples also revealed a lower lactate concentration in the subjects, which may, in part, have accounted for the increase in short-term endurance.

Many researchers have studied the effects of a CWT program on cardiovascular indices (Gettman et al., 1978; Hempel & Wells, 1985) In circuit weight training, the individual lifts a weight which represents 40%-60% of his maximum strength for that lift as many times as possible in a defined period of time, i.e., 30 seconds (Wilmore, Parr, Girandola, et al., 1978). The individual only gets a short rest interval, i.e., 15 seconds, and then proceeds to the next lift.

Hempel and Wells (1985) studied the effects of the Nautilus Express Circuit (NEC) in ten men and eight women. Although the NEC appeared to stimulate the cardiovascular system, subjects did not demonstrate an improvement in VO2max.

Gettman et al. (1978) studied the effects of a 20 week CWT program on cardiorespiratory function. Subjects who performed the CWT had a significantly lower VO2max than subjects who were in a running group. It was concluded that the CWT program was specific in improving strength and changing body composition but produced only a minimal aerobic effect (Gettman et al., 1978).

In contrast, some researchers have reported an improved cardiovascular fitness in subjects who performed a CWT program (Gettman, Ward & Hagan, 1982; Wilmore, Parr, Girandola, et al., 1978). Wilmore, Parr, Girandola, et al. (1978) researched the efficacy of a 10 week CWT program on muscular strength, cardiovascular endurance and body composition in both males and females. Their subjects showed significant increases in strength and VO2max, and a decrease in percent body fat.

Gettman et al. (1982) studied the physiological effects of a 12 week CWT regimen on males and females. The CWT group showed a significant increase in VO2max and strength, with a subsequent decrease in percent body fat, compared to the control group.

Several researchers have reported a decrease in resting and submaximal heart rates with weight training (Fry, 1986; Stone & O'Bryant, 1984). Morganroth (1975) observed a number of athletes who weight trained. They reported a lower resting heart rate in the weight trained athletes than the average individual.

Kanakis and Hickson (1980) weight trained nine males five days per week for 10 weeks. Subjects only trained their lower limbs. Resting heart rates decreased from 65 beats per minute to a post-training heart rate of 53 beats per minute.

Stone et al. (1982) reported similar results in previously sedentary males. Their subjects, who weight trained for 10 weeks showed a decrease in resting heart rate from 85 to 74 beats per minute.

Some researchers have suggested an improved stroke volume and cardiac output with weight training (Kanakis & Hickson, 1980; Stone & O'Bryant, 1984). Kanakis and Hickson (1980) reported a slight increase in SV and Q, but no significant changes were observed in the dimensions of the left ventricle. This may be accounted for, in part, by an increase in the shortening of the left ventricle during contraction. The increase in SV and Q were not as great as those reported in aerobically trained individuals (Stone & O'Bryant, 1984).

Left ventricular hypertrophy has been reported in weight lifters (Kanakis & Hickson, 1980; Menapace et al., 1982; Ricci et al., 1982). Menapace et al. (1982) performed a study on 13 nationally ranked weight lifters who engaged in isometric exercise while weight lifting. Via echocardiography, they measured the thickness of the left ventricular wall and the ventricular septum. The weight lifters were compared with 10 normal subjects, eight patients with idiopathic hypertrophic subaortic stenosis (IHSS), and eight patients with asymmetric septal hypertrophy (ASH). The weight lifters had a larger septal thickness than the normal subjects but resembled the IHSS and ASH patients (Menapace eet al., 1982). Furthermore, the weight lifters possessed a larger left ventricular wall than the IHSS and ASH patients. Although the weight lifters met the criteria for hypertrophic cardiomyopathy, several tests revealed that they did not possess the disorder.

Left ventricular hypertrophy was another dependent measure in the Kanakis and Hickson (1980) study. The subjects, who weight trained for 10 weeks, showed a significant increase in left ventricular mass from 81.9 g to 92.3 g. This increase was similar to that seen in champion strength-trained athletes. The stimulus for the left ventricular hypertrophy was probably due to an increase in mean aortic pressure, which occurs as a result of weight training (Kanakis & Hickson, 1980).

Fleck, Bennett, Kraemer and Baechle (1985) compared the left ventricular mass of highly strength-trained individuals to sedentary controls. The strength-training group demonstrated a significantly greater left ventricular mass and intra-ventricular diastolic septal thickness than the controls.

Ricci et al. (1982) researched the effects of a 20 week strength training program on adolescent boys. They reported no significant changes in interventricular and left ventricular posterior wall thickness. However, a 4% increase in left ventricular mass proved to be significant. Ricci et al. (1982) stated, "These small increases in calculated left ventricular mass with short-term training are probably caused by small but insignificant increases in left ventricular internal diameter secondary to training bradycardia and to increased diastolic filling time rather than to true cardiac hypertrophy. Significant increases in aerobic capacity and in strength can occur without modification of left ventricular dimensions".

Little research has been conducted on the blood pressure response during isotonic weight training (McCarthy & Hunter, 1984). Wescott and Howes (1983) studied changes in blood pressure (BP) during isotonic weight training. They measured the subjects' BP by the auscultation method while the subjects performed the one arm bicep curl exercise with a 10-RM workload. They reported a similar BP response as seen with an aerobic endurance activity: a 34% increase in systolic BP and no change in diastolic BP. Wescott and Howes (1983) also reported that lighter weightloads had a less pronounced effect on systolic BP and may be preferable for individuals who possess a higher resting BP than the average.

In contrast to Westcott and Howes, MacDougall, et al. (1983) reported that both systolic and diastolic BP may increase much more dramatically in weight trainers than endurance athletes. They reported mean systolic and diastolic pressures of 355 and 282 mmHg, respectively in five bodybuilders performing leg press apparatus. MacDougall et al. measured their subjects directly, via catheterization, as compared to Wescott and Howes' auscultation method. Nonetheless, these differences indicate the much needed research in this area.

Weight Training Accompanied by Aerobic Conditioning

Aerobic conditioning programs and strength training regimens induce distinctly different adaptive responses when performed independently (Dudley & Djamil, 1985; Dudley & Fleck, 1987; Hickson, 1980). Aerobic conditioning greatly improves cardiovascular indices, while weight training increases strength and muscle mass (Dudley & Djamil, 1985; Dudley & Fleck, 1987). Specifically, "endurance training does not increase the force output ability of the muscle, and training for strength induces little or no increase in VO2max" (Dudley & Djamil, 1985). This statement emphasizes that the adaptive response to training is specific to the training stimulus (Dudley & Fleck, 1987).

Although it is well-documented that weight training is conducive to an aerobic activity, there is little known about the effects of an aerobic, endurance activity on strength gains due to weight training (Dudley & Djamil, 1985; Hickson, 1980; Houston & Thomson, 1977). However, Stone, Wilson, Rozenek and Newton (1984) stated that aerobic training "may interfere with the development of skeletal muscle strength and power". An early study by Martins and Sharkey (1966) researched the relationship of static and phasic strength and aerobic endurance. Although no significant relationships were reported between the variables, Martens and Sharkey (1966) stated, "It is clear that there is a need for more careful delineation of the above relationships" (i.e., strength and endurance).

In 1963, Jensen conducted a study that specifically investigated the effects of an aerobic exercise program accompanied by weight training. He chose five specific training methods: 1) swimming five days per week, 2) weight training five days per week, 3) swimming three days and weight lifting two days per week, 4) swimming two days and weight training three days per week and, 5) swimming and weight training five days per week. His study was conducted for six weeks and his dependent measure was swimming speed.

He reported significant improvements in speed in all five groups with no significant differences between groups.

Ono, Miyashita, and Asami (1976) researched the effects of long distance running on the vertical jump. Although the vertical jump is not a weight lifting technique, it utilizes the same energy system (i.e., ATP-PC) as does weight training (Ono et al., 1976). The male subjects ran 20 minutes per day for 18 weeks. The results revealed that prolonged running decreased the vertical jump height of the subjects. Ono et al. (1976) concluded that prolonged running, in the case of males aged 30-71 years, might cause restraining of explosive muscular contraction such as the vertical jump (1976).

Hickson (1980) investigated the effects of a weight training program in combination with an aerobic conditioning program. The purpose of his study was "to determine how individuals adapt to a combination of strength and endurance training as compared to the adaptations produced by either strength or endurance training separately" (Hickson, 1980). Hickson chose three groups composed of males and females: (1) an endurance training group, (2) a strength-training group, and (3) an endurance and strength training group (i.e., combination group). The endurance group performed interval training on a bicycle ergometer three days per week. The other three days consisted of continuous running "as fast as possible" for 40 minutes per day. The strength training group weight trained five days per week performing at a high volume and low intensity (i.e., five sets of five repetitions at 80% of 1-RM). The combination group performed the same exercise regimens at the same intensities as both the endurance and strength training groups.

Hickson reported an increase in VO2max in the combination and endurance group. He also reported a 25% increase in leg strength in the combination group and a 44% increase in the strength group. Although the combination group improved their strength by 25%, this was a decrease from their peak of 34% during week nine. Hickson reported a leveling off of strength gains for the combination group during weeks seven and eight, with a subsequent decrease during the ninth and tenth weeks. Although the subjects' strength was greater than at the beginning of the study, Hickson (1980) believed that the decrease in strength may have been due to their aerobic exercise regimen.

An alternative explanation for the decrease in strength may be that the combination group trained twice as long as the other two groups, causing more muscle fatigue. The high intensity running, i.e., "ran as fast as they could for 40 minutes", accompanied by interval training on a bicycle ergometer, as well as an intense weight training program (80%

1-RM), may have affected metabolic and physiological variables such as decreased muscle glycogen and/or broken down muscle tissue.

Gettman et al. (1982) researched the physiological effects of a program of combined running and weight lifting with a program of circuit weight training. Males and females participated in this 12 week, three days per week training program. The CWT group performed three circuits of 10 weight-training exercises at 40% of 1-RM (12-15 repetitions). The combination group performed 30 seconds of running following each 30 second CWT station. Total time for the CWT group was 22.5 minutes, whereas the combination group exercised a total of 30 minutes. Both the combination group and the CWT group demonstrated significant increases in strength and VO2max and a significant decrease in percent body fat, with no significant differences between groups. Gettman et al. (1982) concluded that one training program was not superior to the other, and thus, both the combination group and the CWT group were "effective in improving measures of physical fitness". Nonetheless, the running program was for such a short duration, and so similar to the CWT stations that the musculature may not have been challenged as with a progressive resistance program.

More recently, Dudley and Djamil (1985) investigated the influence of concurrent high-velocity isokinetic strength and endurance training on the force velocity relationship of human muscle. Twenty-two male and female subjects trained for seven weeks. The subjects were placed in one of three groups: (1) an endurance group, (2) a strength group, and (3) a combination group. The endurance training consisted of five-five minute sessions three times per week on a bicycle ergometer. The strength training consisted of 30 second sets of maximal knee extensions per day. This was performed on a Cybex II isokinetic loading dynamometer. The combination group performed the aforementioned exercises, alternating days of strength and endurance work-outs. The endurance group did not demonstrate improvement on any of the velocities of the dynamometer. The strength group showed significant improvements in all the velocities, while the combination group showed improvements at only the three slow speeds. From these results, Dudley and Djamil (1985) made two conclusions: (1) concurrent training for strength and endurance does not alter aerobic power induced by endurance training only (i.e., endurance and combination group increased their VO2max) and (2) concurrent training reduces the magnitude of increase in angle-specific maximal torque at fast, but not slow, velocities of contraction.

Although the reasons for the compromise in muscular strength and power with aerobic training are not well-understood, Stone, O'Bryant, Garhammer, McMillan and Rozenek (1984) list some speculations as to why this compromise occurs. Aerobic training may cause a reduction in myosin ATPase in Type IIB (FT) muscle fibers and in the concentrations of anaerobic enzymes. Thus, the muscle fibers and enzymes most important in strength training may decrease due to aerobic training. Secondly, aerobic training may produce an increase in skeletal muscle breakdown, which may result in a smaller muscle mass. "The increased catabolism may be influenced by the way aerobic exercise and training effects various hormones and proteolytic enzymes" (Stone, O'Bryant, et. al., 1984). The morphology of distance runners compared to weight trainers is quite different, and provides empirical support for this speculation. Stone, O'Bryant, et al. (1984) also believe it is possible that the mechanics of a typical endurance training program negatively affect the weight lifting - specific pattern of motor unit recruitment as well as whole muscle contraction. Finally, Stone, O'Bryant, et al. (1984) believe that the addition of an extra workout, i.e., running, may lead to "overtraining," regardless of the mechanism of compromise. In order to improve short-term endurance for weight trainers, Stone, O'Bryant, et al. (1984) suggest that the athlete perform some other type of anaerobic activity, i.e., sprint training, to expand this anaerobic capacity.

ADAPTATION DIFFERENCES TO EXERCISE BETWEEN MALES AND FEMALES

During the 1970's, the number of females participating in competitive and recreational athletics increased dramatically (Wilmore, 1982). This increase in participation lead a greater number of researchers to become more interested in comparing the physiological and performance changes between males and females (Wells & Plowman, 1983). The following sections discusses the similarities and differences of aerobic conditioning and weight training between the genders.

Aerobic Conditioning

Although men and women show the same relative improvement in aerobic capacity in response to aerobic training, absolute differences exist between them (McArdle et al., 1986). The average male has a 15%-30% greater VO2max than his female counterpart (McArdle et al., 1986). However, when VO2max is expressed relative to fat free weight, the males' values exceed the females' values by only 12%-15% (Wells & Plowman, 1983). McArdle et al. (1986) state that the differences in VO2max may be attributed to a smaller lean body mass and a lower blood hemoglobin concentration in women.

Cureton and Sparling (1980) investigated the metabolic responses of 10 male and 10 female distance runners to submaximal and maximal treadmill running. First, Cureton and Sparling (1980) studied the men and women at their natural weights. In addition, the males were tested on the treadmill with exogenous weight in order to equilibrate the extra weight due to the higher percent body fat of women. Even with the added weight, the men performed 32% better than the females in terms of treadmill time to exhaustion, and their VO2max was still significantly greater (Cureton & Sparling, 1980). Since equating the weight on the men decreased the differences in treadmill time by only 32%, the authors concluded that approximately one-third of the sex difference in distance running performance between men and women was due to the greater percent fat in women (Cureton & Sparling, 1980).

Drinkwater (1984) reported that when men and women train, using the same exercise prescription, there are no significant differences in training response. She reported a 15% increase in VO2max for men and a 14.2% increase in VO2max for women. In addition, submaximal and maximal heart rate and submaximal and maximal lactic acid concentration did not differ between the genders (Drinkwater, 1984).

Some researchers believe that the overt response to training between the sexes is similar, but the mechanism may be different (Drinkwater, 1984). It has been observed in one study that men increased their VO2max via increases in SV and maximal arterial-venous oxygen content difference (CaO2-CvO2 diff), whereas women increased their SV with no change in their CaO2-CvO2 diff (Eddy, Sparks & Adelizi, 1977). Nonetheless, when women were trained for seven weeks at a high intensity i.e. 70%-100% VO2max, they, too, showed an increase in CaO2-CvO2 diff (Eddy et al., 1977). Thus, " the stimulus for peripheral adaptation is a high-intensity exercise program, and that men and women respond equally to that stimulus" (Drinkwater, 1984).

Cunningham, McCrimmon and Vlach (1979) are in agreement with Eddy et al. (1977). Cunningham et al. (1979) trained two groups of women in either an interval training program (ITP) of 90% to 100% or a continuous training program (CTP) of 70% to 80% VO2max. Subjects trained four days per week for 12 weeks on a bicycle ergometer. Both groups increased VO2max by approximately 22%. However, the ITP significantly increased CaO2-CvO2 diff by 20% compared to an 8.9% increase in the CTP. Cunningham et al. (1979) concluded that women, like men, can increase CaO2-CvO2 diff if the exercise regimen is of sufficient intensity.

In a study on VO2max, Gimenez, Salinas, Servera and Kuntz (1981) trained sedentary men and women following a progressive and constant bicycle exercise. Their results were similar to Cureton and Sparling's (1980): the male subjects achieved a 25% greater VO2max than their female counterparts.

The concentration of hemoglobin in men is 10%-14% greater in men than in women (McArdle et al., 1986). The greater amount of hemoglobin allows the male to circulate more oxygen during exercise than the female (McArdle et al., 1986). This higher hemoglobin in males may be another explanation for the greater VO2max achieved by males. However, McArdle et al. (1986) state "that the differences in aerobic capacity between men and women are largely a function of the size of the contracting muscle mass, and not necessarily the result of inherent sex-related differences in oxygen transport and utilization". In addition, researchers have reported that when men compete against women possessing the same body fat, aerobic capacity and running economy, there are smaller differences between the sexes (McArdle et al., 1986).

Cardiovascularly, females possess a smaller SV than males for the equivalent submaximal workload (Wilmore, 1982). This is partially attributed to the female's smaller body size. To compensate for the smaller SV, females must achieve a greater heart rate at each workload (Wilmore, 1982).

Although women's SV is smaller than men's, they have a 5-10% larger Q at any submaximal VO2 than their male counterparts (Costill, 1986). The difference in Q may be due to the females' lower percentage of hemoglobin (McArdle et al., 1986).

Male and female endurance athletes possess the same percentage of ST and FT fibers (Costill, 1986). Researchers have reported a predominance of 60%-98% of ST muscle fibers in elite distance runners, with no differences between the genders (Costill, 1986). While there are no differences in the number of fibers, the average male has a 15% larger muscle fiber size than females (Costill,1986; Drinkwater, 1984; Nygaard, 1981). Men show a 9% increase in muscle fiber area between the age of 16-30, in contrast to an 8% decrease in the females' cross-sectional area (Costill, 1986).

Weight Training

Weight training has become increasingly popular among females (Williams, 1985). Although, in absolute terms, females possess two-thirds the strength of males, in relative terms they are equally capable of increasing their strength with a weight training program (Morrow & Hosler, 1981).

Researchers have only recently studied the effects of weight training in females. The main question is the mechanism of strength gains in females. It appears that women increase strength primarily via neurological mechanisms with less hypertrophy (Costill, 1986). Men, however, improve strength primarily by hypertrophy with neural factors playing a role in the early stages of the strength training program (Costill, 1986). The hypertrophy observed in men is attributed to a ten times greater amount of testosterone level in men as compared to women (Costill, 1986).

Weiss, Cureton and Thompson (1980) performed blood analyses on 20 men and women prior to and following a 30 minute weight lifting session. Prior to the weight lifting, the men possessed a ten times greater amount of testosterone than the women. Immediately following the exercise, testosterone was significantly increased in the men, but not the women. The results of this study may provide some insight for the increases in muscular strength observed in men over women (Weiss et al., 1980).

Westerlind, Byrnes, Freedson and Katch (1987) studied serum androgen levels in females following a 10 week hydraulic resistance exercise program. Subjects exercised three times per week in a maximal effort CWT program. Westerlind et al. (1987) reported no significant increases in androgen hormones, but the subjects did significantly increase their strength by 40%. They concluded that androgen hormones may not have played a role in the strength gains of their subjects. "The low levels of androgens in women may be responsible for preventing the same degree of muscular hypertrophy" (Mayhew & Gross, 1974).

In addition to a lower testosterone level, women possess a greater percent body fat than men (Dunn & Halstead, 1982). Dunn and Halstead (1982) stated that the "ten percent or so additional adipose tissue tends to obscure the visual definition of developed muscle in the female".

Although no evidence to date suggests that men have a greater number of muscle fibers than women, men do possess a greater cross sectional area per muscle fiber (Costill, 1986). This may be another factor inhibiting women from developing the same absolute muscle size observed in their male counterparts. Cureton et al. (1985) state that the ability of skeletal muscle to develop force is directly related to its cross-sectional area. Since the strength of a single muscle fiber is not affected by a person's sex, but is training-specific, the primary determinant of overall strength is the size of the muscle (Costill, 1986; Nygaard, 1981). Thus, the larger muscle has more contractile filaments, i.e. actin and myosin, and therefore, possesses a greater potential for force development when it is activated (Costill, 1986; Cureton et al., 1985). Accompanied with the ten times greater amount of testosterone, the greater muscle fiber size gives men an advantage to achieve a larger absolute muscle size (Costill, 1986).

Although, in absolute terms, females do not hypertrophy to the degree of their male counterparts, studies have reported relative increases in muscle mass with no significant differences between the genders (Cureton et al., 1986). Cureton et al. (1986) reported significant increases in strength of 30% in their male subjects and 40% in their female subjects with no significant differences between them following a 16 week weight lifting program. In addition to the strength increases, significant increases in muscle size of 16% in the males and 23% in the female subjects was observed, with no significant difference between the sexes. The similar increase in muscle mass may have been attributed to the equal training intensities for both groups (Drinkwater, 1984). Perhaps more studies are required that train females at greater intensities than previous investigations.

Wilmore (1974) conducted a study using the same resistive training program for his male and female subjects. His subjects trained two days per week, 40 minutes per day, for ten weeks. The men and women demonstrated similar relative increases in strength of 14% and 17%, respectively, with no significant differences between them. The men and women also showed a relative increase in muscle size of 19% and 21%, respectively. However, in absolute terms, the men showed a significantly greater amount of hypertrophy than the women (Wilmore, 1974).

Oyster (1979) trained college women athletes two days per week for seven weeks on a high resistance weight training program. The subjects significantly increased strength but showed a significant decrease in arm, chest and calf girth. Since a significant decrease in percent body fat was not shown in these subjects, there seems to be little explanation for the significantly decreased in girth. The author gave no postulation as to why the decrease occurred. However, the increase in strength with no evidence of muscle hypertrophy in these subjects, may have been primarily attributed to the neural adaptations often reported in women who weight train.

Morrow and Hosler (1981) compared muscular strength between untrained men and trained women athletes. They compared the two groups in terms of absolute and relative upper and lower body strength. Morrow and Hosler reported a 72% and 54% greater strength in their male subjects compared to their female subjects. These values represent the absolute and relative differences, respectively, in combined strength means of upper and lower body. Nonetheless, conclusive statements cannot be made since this was a cross sectional study and the authors did not impose a training protocol on their subjects.

In a review of a number of studies, Lewis, Kamon and Hodgson (1986) concluded that men and women have the same capacity to increase strength. However, women will show little change in total body weight and significantly less absolute muscle hypertrophy, which may be related to a lower amount of testosterone.

Summary

Aerobic conditioning, such as long distance running, cycling and swimming is quite distinct from anaerobic exercise, such as weight lifting and sprinting. An aerobic training program has been shown to improve such cardiovascular parameters as stroke volume, cardiac output as well as an increase in mitochondria (Brooks & Fahey, 1985; deVries, 1980; McArdle et al., 1986). Anaerobic training produces such physiological improvements as increases in the levels of anaerobic substrates and key enzymes, and muscle cell hypertrophy (Brooks & Fahey, 1985; McArdle et al., 1986). In addition to its physiological parameters, weight lifting also produces increases in skeletal muscle strength and running speed (Costill et al., 1979; Pipes and Wilmore, 1975).

Few studies, however, have specifically researched the effects of combining a weight training program with an aerobic exercise regime. Dudley and Djamil (1985) and Hickson (1980) have recently researched the effects of a combination training program. Dudley and Djamil used an isokinetic training method and reported improvements at only slow velocities with the combination group as compared to an improvement in slow and fast speeds with the weight training group. Hickson's subjects trained on free weights and isotonic apparatus. The combination group showed a 25% improvement in leg strength but not to the degree of the weight training group (44%).

Although not much literature exists on this combination training, it seems that running elicits a detrimental effect on weight lifting strength gains. However, more studies are required in this area before any conclusive statements can be made.

CHAPTER III

JOURNAL MANUSCRIPT

THE EFFECT OF ENDURANCE RUNNING ON TRAINING ADAPTATIONS IN WOMEN PARTICIPATING IN A WEIGHT LIFTING PROGRAM

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Dennis E. Hinkle

(abbreviated title for running head)
Effect of Endurance Running on Leg Strength

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ABSTRACT

Twenty-five sedentary female volunteers, 18-30 years of age, were studied to determine the effects of an endurance running program on leg strength gains from a weight training program. Subjects were randomly assigned to one of three groups: a weight training group (W), a weight training plus running group (RW), or a control group (C). The subjects trained three days per week, approximately one hour per day, for nine weeks. The RW group ran for 25 min then weight trained for 30 min, whereas the W group weight trained for one hour. Subjects were tested for one-repetition maximum (1-RM) pre-training, at two week intervals during training, and post-training. Thigh girth (midpoint [MG] and 1.18 cm above the patella [AP]) and percent body fat were measured pre- and post-training, only. Body weight was measured weekly on a calibrated scale. Significant improvements in isotonic leg strength of 56% for W and 66% for RW were observed, with no difference between the groups. W and RW also achieved a significantly greater isotonic leg strength than the C group. The experimental groups had a significantly greater posttest AP as compared to the C group. No significant differences were observed over the experimental period in MG, percent body fat and body weight of any of the groups. In conclusion, the running program

used in the present study did not interfere with leg strength or girth gains achieved through weight training. These results are in contrast to those reported in other studies which found that aerobic training impaired strength gains.

Introduction

The adaptation to exercise is related to the type of training stimulus in which one partakes (16). For example, an aerobic exercise, such as running, swimming, and cycling, results in increases in muscle mitochondria, muscle myoglobin, maximal oxygen uptake, and the capacity to perform prolonged work without an associated increase in strength or muscle hypertrophy (17). However, an anaerobic exercise, such as weight training, that involves heavy resistance, results in increases in strength and muscle cell hypertrophy (5). Weight training shows little to no increase in maximal oxygen uptake (16).

Although aerobic exercise and weight training differ dramatically in their physiological responses, incorporating both of these programs into an exercise regime may result in increased benefits than simply choosing one program over the other. Thus, an individual may increase muscle hypertrophy and/or muscular endurance while simultaneously increasing muscle myoglobin, muscle mitochondria, and maximal oxygen uptake.

Few researchers have studied the effects of the combination of an aerobic activity and weight training. Dudley and Djamil (9) and Hickson (16) have tested the effects of interval training combined with weight training compared to either training program alone. Although increases in strength were observed in the weight training plus endurance trained group, strength gains were not as great as the subjects in the weight training only group. Thus, these researchers concluded that endurance training impairs strength gains achieved through weight training.

These researchers used interval training for their subjects which would be expected to have a different influence than the constant intensity, endurance exercise used by many athletes. Therefore, their conclusions may not be valid with regard to endurance exercise. In addition, the interaction between strength and endurance training has not been examined in women. It was the purpose of this study to determine the effects of an endurance running program on weight training in women.

Methodology

Subjects

Prior to subject selection, permission was obtained from the Institutional Review Board for Research Involving Human Subjects to perform this study. The 18 experimental subjects who participated in this study were among volunteers who registered for a physical fitness activity course entitled "Bodybuilding and Fitness". These subjects were randomly assigned to one of two groups: weight lifting (W) or running and weight lifting (RW). The seven subjects in the control group were volunteers from leisure sports activity classes, i.e., bowling and golf, and thus, from the same general population. Criteria utilized for subject selection required the participants to be: (a) females, aged 18 - 30, (b) uninvolved in a weight training or a strenuous aerobic conditioning program for at least six months, (c) free of orthopedic problems, (d) free of high blood pressure (i.e., > 140/90 mm Hg), and (e) nonsmokers (i.e. never smoked or refrained from any smoking for six months or more)

Procedures

All subjects were given both a written and oral detailed explanation of the study, including its risks, benefits, and procedures, prior to any testing. Those subjects consenting to participate, completed a medical history questionnaire to ensure that none of them were at major risk in doing the exercise regimens (i.e. chest pain, breathing difficulties, myocardial infarction).

Subjects were pretested prior to the training for the following variables: isotonic leg strength (1-RM) on the Universal leg press and leg extension apparatus; percent body fat via hydrostatic weighing and skinfolds; and thigh girth. For reliability purposes, subjects were retested for the leg strength, skinfolds, and thigh girth approximately 72 hours from the initial measurements. The three day rest period was chosen because peak muscle soreness, which could have influenced muscle strength, has been reported in subjects at 24-48 hours post 1-RM testing (11). The reliability estimates ranged from r=.95 to r=.99. The subjects in the experimental groups were also pre- and posttested for the 12 min run. Although this was not a dependent measure of the study, it was performed to demonstrate that the running program was intense enough to elicit cardiovascular improvements.

For the measurement of 1-RM, the subjects were first given a warm-up of five repetitions at a submaximal weight of 90 lbs. The researcher then increased the weight by 20 to 40 lb. increments depending on the ease at which the subject lifted the previous weight. Three to five trials were performed, with a one min recovery time between trials. One-RM was recorded as the heaviest weight the subject could properly lift once. In order to observe strength increases and to readjust the weight lifting intensity prescription, new 1-RM's were calculated every two weeks throughout the nine week study. Thus, 1-RM measurements were made at weeks 0, 2, 4, 6, 8 and 9.

Subjects were weighed weekly to the nearest .25 kg on a calibrated scale. Hydrostatic weighing was performed as described by Katch and McArdle (22). The subjects were measured while supine on a mesh basket supported by four load cells, in a rectangular steel tank. Subjects' residual volume was measured by the oxygen dilution technique. This was performed as described by Wilmore, Vodak, Parr, Girandola and Billing (33).

Percent body fat via skinfold measures were recorded at three sites on the right side of the body: triceps, suprailiac, and quadriceps. Five measures were taken at each site and were used to calculate body fat as described by Jackson, Pollock and Ward (20). Midpoint thigh girth was also measured as described by Jackson et al. (20), with an added girth measure located 1.18 cm above the patella (AP).

The C group was measured for the same dependent variables as the experimental groups. However, they were only tested two times, at weeks 0 and 9 of the study.

<u>Experimental Procedures</u>

The experimental groups performed their workouts at the same time three days per week. W and RW performed the first two phases of the periodization model as described by Stone and O'Bryant (28) on Universal and Nautilus weight lifting apparatus. The periodization model was chosen since research has shown that periodization programs produce "superior strength and power development with relatively novice subjects" (3). Although Stone and O'Bryant's (28) model consists of four phases, only the first two, hypertrophy and basic-strength, were utilized because the investigator did not want to vary the work-out throughout the nine week training period. The hypertrophy or "adaptation phase" is a program of high volume and low intensity (i.e., high repetitions and low weights). The "basic-strength" phase is a program of moderate volume and high intensity (i.e., low number of repetitions with a greater workload).

For the first two weeks, W group's training consisted of eight to twelve repetitions at 60% of each subjects' 1-RM. Microcycles were also incorporated, i.e., on Mondays and Fridays subjects performed three sets of eight to twelve repetitions on the leg apparatus (Table 1) and two sets of eight to twelve repetitions on the arm apparatus (Table 1). On Wednesdays, the subjects performed three sets on the arm apparatus and two sets on the leg apparatus. Following the first two weeks of the "adaptation phase", subjects increased their intensity of weight lifted to 75% of 1-RM. The repetitions were decreased to four to six, and subjects performed four sets on the leg apparatus on Mondays and Fridays, and three sets on the arm apparatus. On Wednesdays, the subjects performed three sets of the leg equipment and four sets of the arm apparatus.

The RW group ran in an enclosed area for 25 min during the first half of their workout at 75% of their predicted maximum heart rate (Karvonnen method). Since the subjects were untrained, they initially ran/walked for 20 min the first two weeks. One-half of the subjects walked and ran

Table 1. Weight Training Apparatus Utilized

UNIVERSAL APPARATUS		NAUTILUS APPARATUS	
LOWER BODY		LOWER BODY	
	Leg Press		Calf Raises
	Leg Extension	UPPER BODY	
	Leg Curls		Chest Flies
	Calf Raises		Chest Press
UPPER BODY			Shoulder Flies
	Arm Curls		Military Press
	Bench Press		Abdominals
	Tricep Press		
	Shoulder Shrugs		
	Latissimus Dorsi Pull Down		
	Military Press		

approximately 50% of the 20 min during the first two weeks, until they progressed to running for 25 min by the fourth week. This run duration was sustained for the remainder of the study. Approximately two to three subjects continued to walk for short intervals during the fourth week, however, they eventually were able to run the entire time of 25 min by the fifth week. The second half of the program, RW performed the leg strengthening exercises and four pieces of the arm apparatus of their choice for 30 min. The same weight training protocol was applied as in the W group. All exercise sessions were monitored and each subject kept a record of her exact work-out for each session.

Statistical analyses included a repeated measures analysis of variance (ANOVA) for several of the dependent measures: body weight, leg press and leg extension. One repeated measures ANOVA was calculated on the weekly body weight and biweekly leg strength variables (W and RW only), while the second was done using only the pre- and posttest values (W, RW and C). In addition, a pre-posttest repeated measures ANOVA was performed on midpoint girth, 1.18 cm above the patella girth (AP), and percent body fat (skinfolds and hydrostatic weighing), for the W, RW, and C groups. Tukey post hoc tests were computed if significant interactions were found. Correlational analyses, using Pearson Product Moment

Correlations, were calculated on the pretest values and changes in all the dependent measures. The level of significance for the study was set apriori at .05. All data was analyzed using the Statistical Analysis System (SAS).

Results

Mean subject characteristics are found in Table 2. No significant differences were observed in the initial characteristics between any of the groups. The repeated measures ANOVA calculated on the 12 min run showed that the RW group performed a significantly greater number of laps (11.5±0.61) in the posttest than did the subjects in the W group (6.53±0.49). Thus, the running program used in this study was intense enough to elicit cardiovascular improvements.

Pre- and posttest and weekly body weight measures did not change significantly over time for all groups. Nonetheless, there was a trend for W to increase body weight and for RW to decrease body weight, which may have been related to the greater caloric expenditure by RW (Figure 1).

Percent body fat for all groups did not change significantly over time using either the skinfold or hydrostatic weighing method. Average percent body fat and lean body mass values may be found in Table 3.

Table 2. Subject Characteristics**

GROUP	N	WEIGHT (kg)	HEIGHT (cm)	AGE (yrs)
W	8	58.7±3.7	164.7±2.5	21.0±0.5
RW	10	62.0±2.9	165.5±2.2	20.1±0.3
C	7	58.7±4.2	162.0±2.2	24.3±1.5

** Values represent means ± SEM

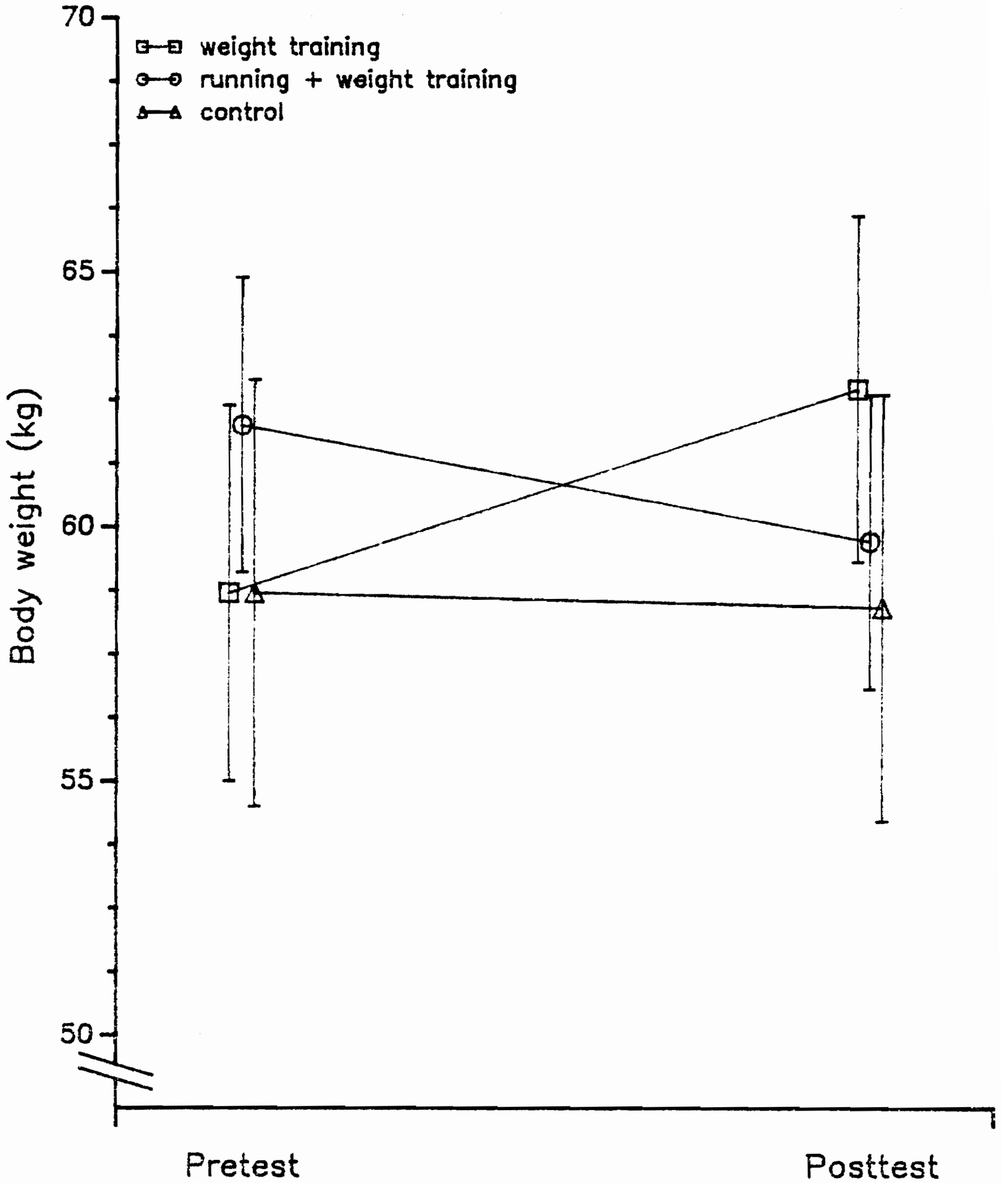

Figure 1. Pre– and posttest body weight measures (mean ± SEM).

Table 3. Percent Body Fat and LBM Values**

	GROUP		
	W	RW	C
N	8	10	7
HYDROSTATIC WEIGHING DATA (%)			
Pretest	25.4±3.5	24.5±1.9	22.5±2.9
Posttest	25.6±3.5	24.8±1.5	22.1±2.7
SKINFOLD DATA (%)			
Pretest	22.2±1.9	23.3±1.2	21.9±1.9
Posttest	22.9±1.8	23.2±1.3	21.7±2.0
LEAN BODY MASS DATA (kg)			
Pretest	43.1±1.3	46.6±1.6	45.1±2.6
Posttest	44.7±1.3	47.1±1.5	45.0±2.6

** Values represent means ± SEM

Increases in isotonic leg strength on the leg press apparatus for biweekly measures were significant over time for W and RW, with no significant difference between the groups over time (Figure 2). W increased their leg strength by 56% above baseline, and RW increased their leg strength by 67% above pretesting values by the end of the training period. The greatest increase in the biweekly values of leg press was 19.3% for W and 16.2% for RW. This occurred between weeks two and four of the training period. A Tukey post hoc test revealed that the significant increase in combined leg strength on the leg press apparatus began during week six of the training period. Statistical analysis using only the pre- and post-training calculations showed that W and RW achieved a significantly greater posttest leg strength on the leg press than the C group. This significant interaction betweeen groups over time is illustrated in Figure 3.

The W and RW groups also showed a significant increase in isotonic leg strength on the leg extension apparatus over time, with no significant difference between the groups over time on the biweekly leg strength values (Figure 4). The percent increases above pretesting values were similar to the increases for the leg press: W increased their leg strength by 55%, while RW increased their leg strength on the leg extension apparatus by 66%.

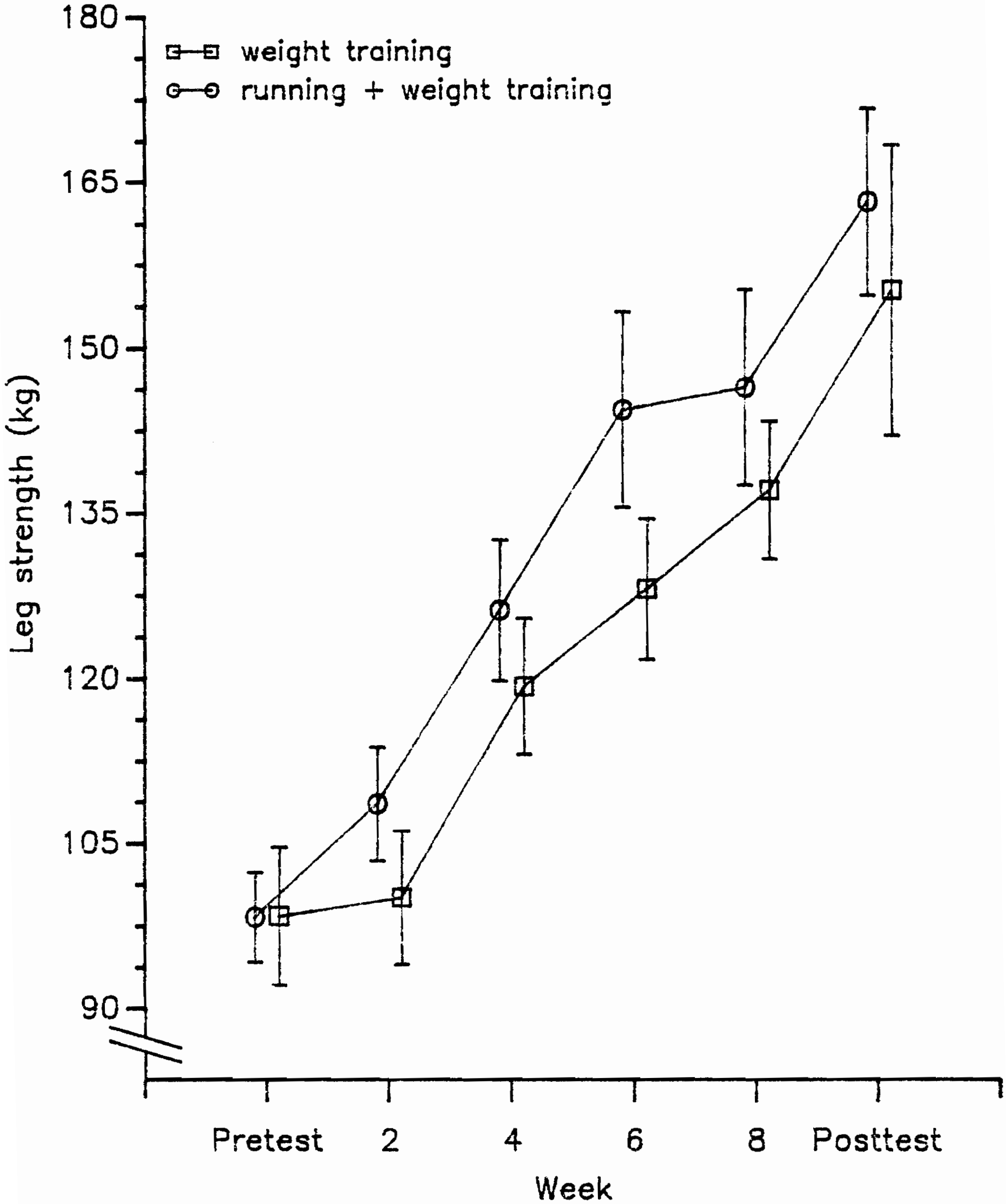

Figure 2. Biweekly 1−RM strength values on the leg press apparatus (mean ± SEM).

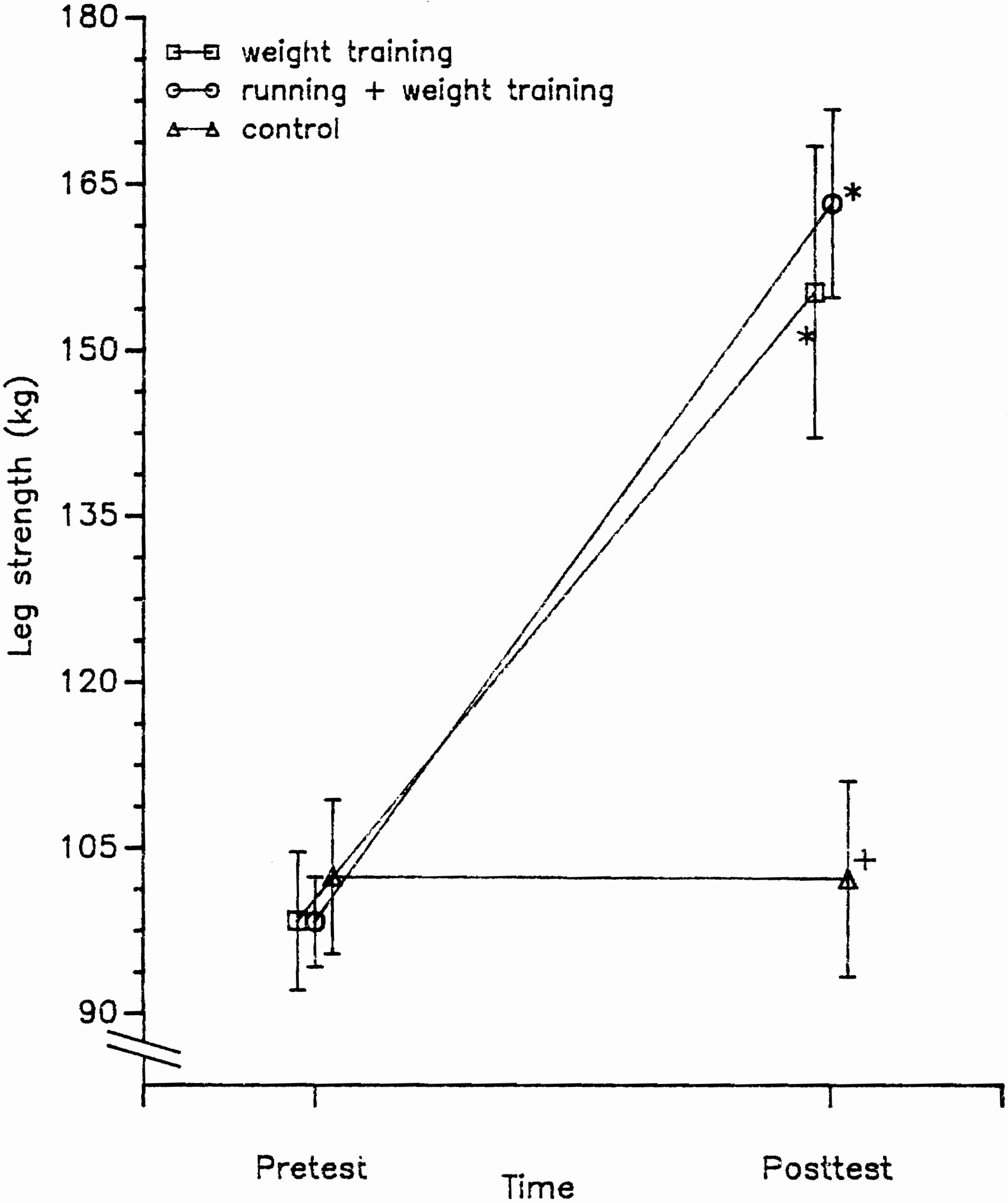

Figure 3. Pre– and posttest 1–RM leg strength values on the leg press apparatus (mean ± SEM).

* Indicates significant difference from pretest.
+ Indicates significant difference from weight training and running + weight training at the same point in time.

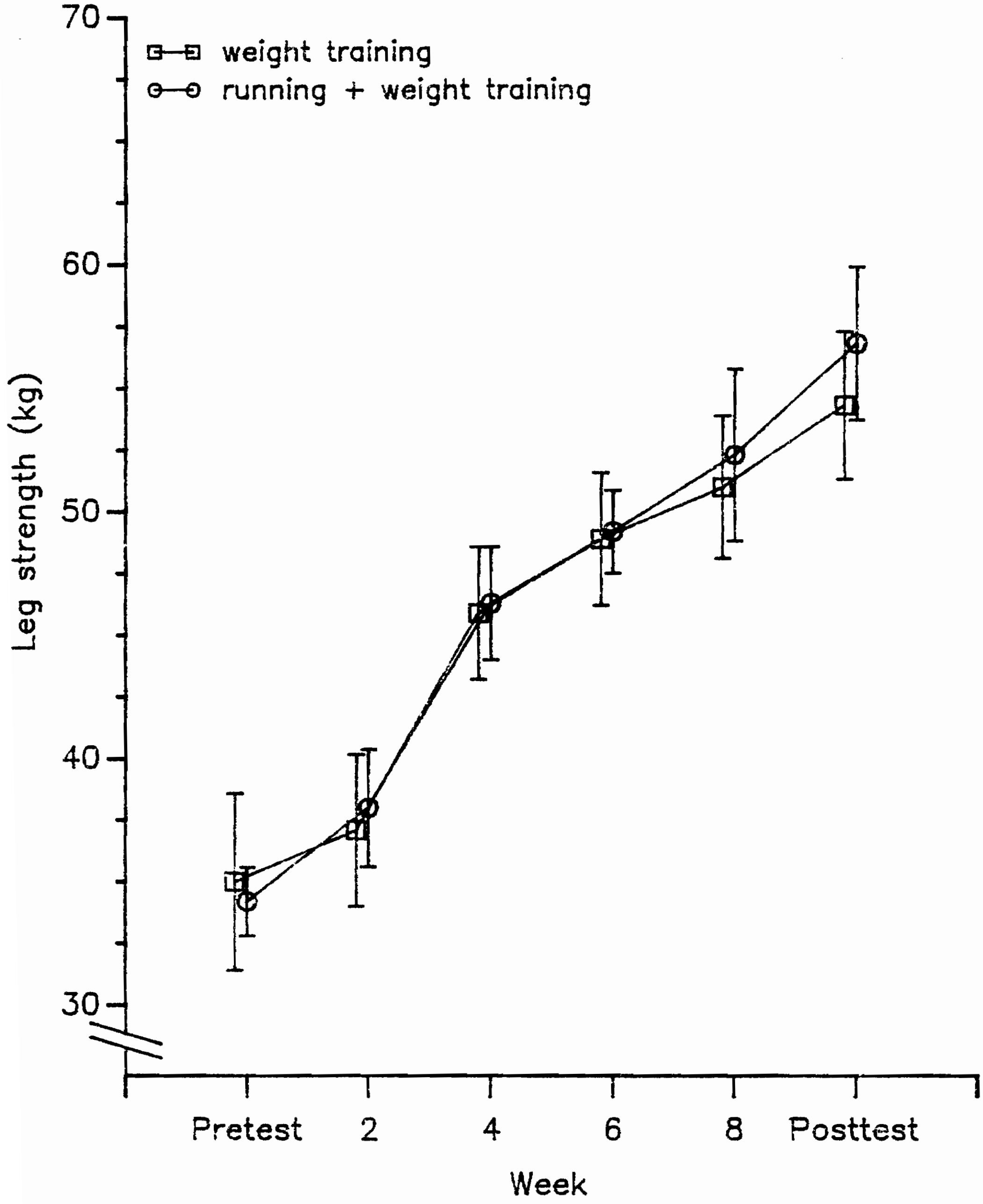

Figure 4. Biweekly 1-RM strength retest values on leg extension (mean ± SEM).

As on the leg press, the greatest increase on the leg extension apparatus occurred between weeks two and four, with W increasing by 23.4% and RW showing a 21.7% increase in leg stength. A Tukey post hoc test revealed that the experimental groups significantly increased their leg strength during week four of the training program. As on the leg press, W and RW achieved a significantly greater posttest leg strength on the leg extension than the C group. This significant interaction between groups over time is illustrated in Figure 5.

Midpoint thigh girth did not show a significant increase between groups over time (Table 4) nor a significant time effect. Although no significant time effect was revealed for AP, there was a significant interaction between groups over time. Figure 6 illustrates this interaction.

The results of the pretest correlational analyses may be found in Table 5. As expected, the correlational analyses revealed significant correlations between such variables as body weight and percent body fat. Moderate correlations were revealed between such variables as leg press and body weight and between leg press and leg extension.

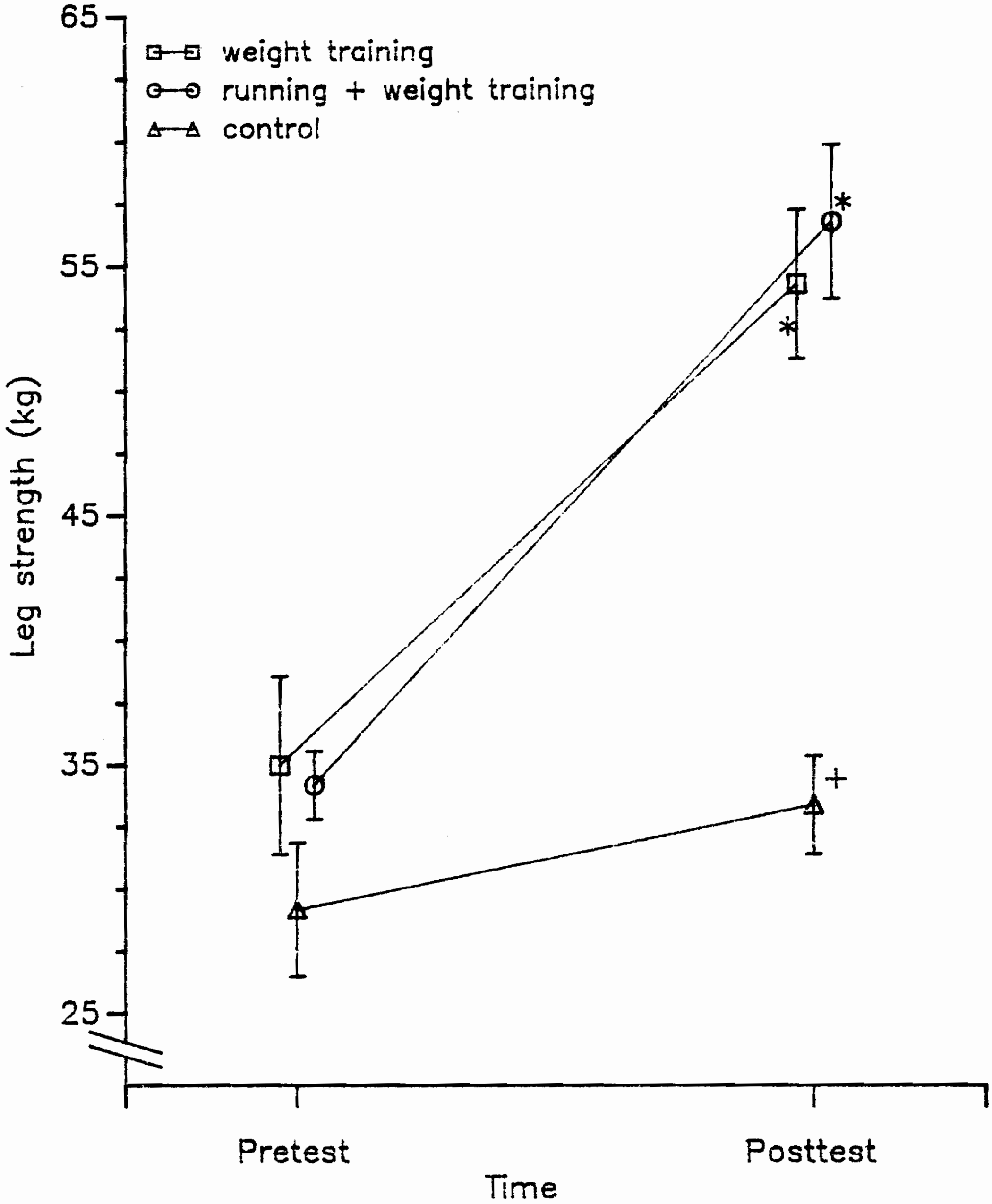

Figure 5. Pre– and posttest 1–RM leg strength values on the leg extension apparatus (mean ± SEM).

* Indicates significant difference from pretest.

+ Indicates significant difference from weight training and running + weight training at the same point in time.

Table 4. Midpoint Thigh Girth Measurements (cm)**

		GROUP	
	W	RW	C
N	8	10	7
Pretest	55.9±2.8	57.2±1.2	56.1±2.0
Posttest	56.1±2.5	56.9±1.2	55.6±1.7

** Values represent means ± SEM

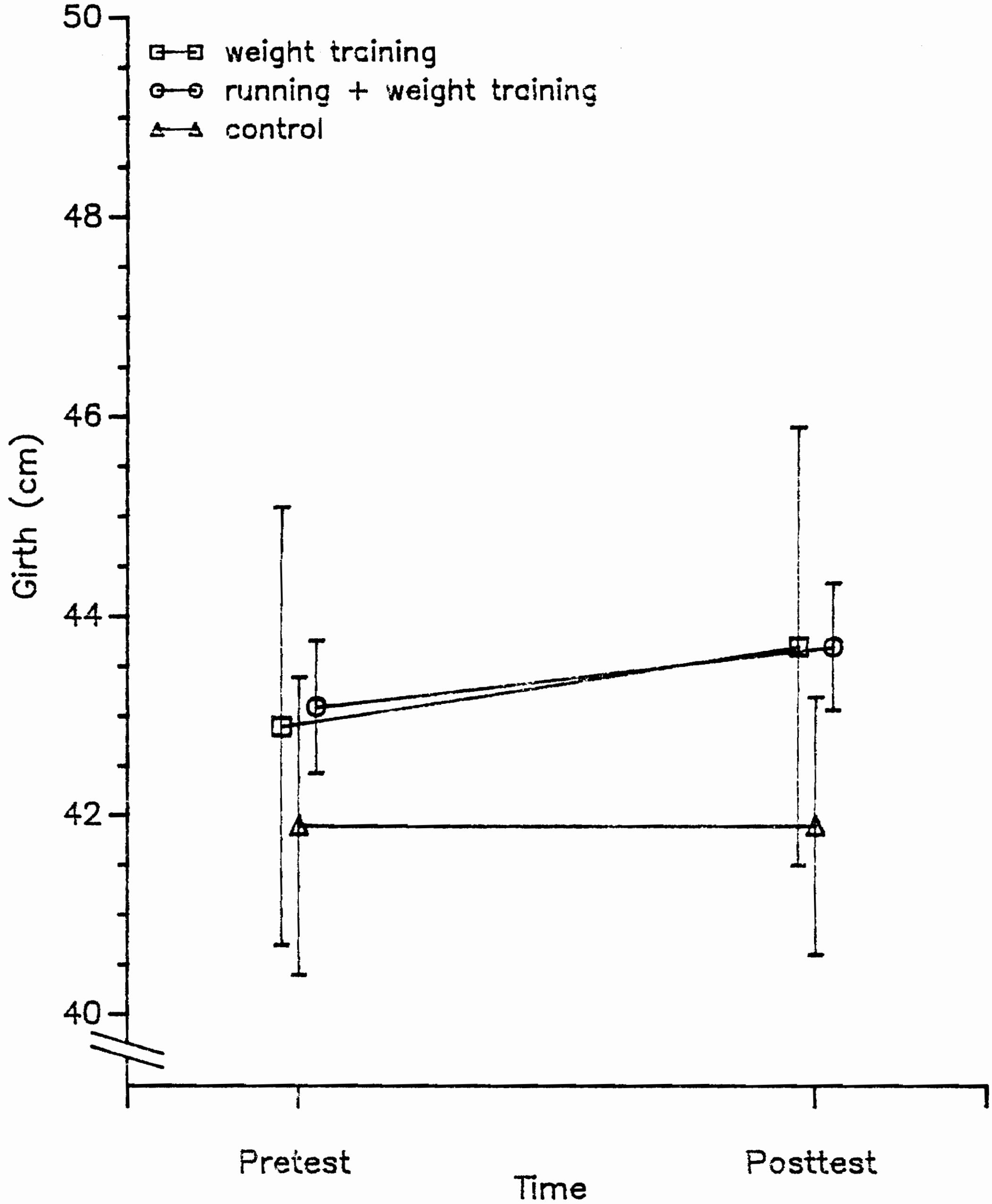

Figure 6. Pre– and posttest girth measures 1.18 cm above the patella (mean ± SEM).

Table 5. Correlational Analyses on Pretest Variables**

	LEG PRESS	LEG EXT.	BODY WEIGHT	% FAT	MG	AP	LBM
LEG PRESS	1.00 0.00	0.54 0.02	0.64 0.00	0.42 0.08	0.60 0.00	0.65 0.00	0.42 0.09
LEG EXT.	0.54 0.02	1.00 0.00	0.22 0.37	0.19 0.44	0.24 0.33	0.26 0.29	0.18 0.48
BODY WEIGHT	0.64 0.00	0.22 0.37	1.00 0.00	0.89 0.00	0.85 0.00	0.76 0.00	0.71 0.00
% FAT	0.42 0.08	0.19 0.44	0.89 0.00	1.00 0.00	0.86 0.00	0.71 0.01	0.54 0.02
MG	0.60 0.00	0.24 0.33	0.85 0.00	0.86 0.00	1.00 0.00	0.93 0.00	0.37 0.13
AP	0.65 0.00	0.26 0.29	0.76 0.00	0.71 0.00	0.93 0.00	1.00 0.00	0.36 0.15
LBM	0.42 0.09	0.18 0.48	0.71 0.00	0.54 0.02	0.37 0.13	0.36 0.15	1.00 0.00

** Numbers represent Pearson Product Moment Correlations with level of significance
LEG EXT.: Leg Extension; % FAT: Percent Fat; MG: Midpoint Thigh Girth; AP: Girth 1.18 cm Above the Patella; LBM: Lean Body Mass

When the initial measures were correlated with the changes that occurred in the dependent variables over the training period, a significant correlation ($p < .05$) was observed between initial leg press 1-RM and initial LBM ($r = .51$) and between the increase in leg extension 1-RM and initial LBM ($r = .51$). Thus, those subjects with initially high LBM's showed a greater improvement in leg extension strength. Other correlations that were significant were between initial body weight and the increase in leg press 1-RM ($r = .49$) and between initial body weight and the increase in leg extension 1-RM ($r = .58$).

Discussion

Body weight and percent body fat did not significantly decrease in response to weight training alone or the combination of running and weight training in this study. Although some studies have reported significant changes in body weight and percent body fat in females with weight training (19, 31), others have not observed changes in these parameters (24, 26). Following a seven week weight training of either three or four days per week, Hunter (19) reported a decrease in percent body fat and an increase in LBM, with no change in body weight. Wilmore (31) also reported an increase in LBM and a decrease in percent body fat of 1.9% and 9.3%, respectively, in his female subjects who weight trained for 10 weeks. However, as in Hunter's (19) study, body weight remained unchanged.

In contrast to these studies, and in agreement with the present study, Mayhew and Gross (24) and Oyster (26) did not observe significant decreases in percent body fat in their female subjects who weight trained. Although there seems to be more evidence that women do achieve positive changes in percent body fat with weight training, it has not been consistently reported. Thus, the results of no significant changes in W and RW in the present study are not unusual. Significant changes in percent body fat may not have been observed in the present study since the average pre-training percent fat for all groups was 23.3% (average of skinfolds and hydrostatic weighing). Brown and Wilmore (2) reported significant decreases in percent fat in their obese but not lean subjects. This was not observed in the present study. Therefore, the lower average initial percent fat of the subjects in the present study may have been a reason for no significant changes in this area. Secondly, since the subjects were previously sedentary, it would seem that body weight would significantly decrease with the exercise regimen. However, the subjects may have increased their caloric intake during the study, which may have kept their body weight and percent fat constant. Nonetheless, the nonsignificant changes in body weight and percent fat have been reported elsewhere (19, 26).

In the present study, isotonic leg strength was significantly increased in the experimental groups, with no significant difference between groups. Others (2, 16) have reported increases in strength from a weight training program, and from the combination of weight training and endurance running. The percentage increases in the present study are comparable to those reported by others who weight trained their subjects for similar durations and intensities (12, 13, 28). Nonetheless, the studies comparing weight training versus weight training plus an endurance exercise, have reported impaired strength gains in their previously sedentary subjects in the weight training plus endurance exercise group, i.e. combination group (9, 16). Hickson (16) reported a 25% increase in leg strength in his combination group and a 44% increase in leg strength in the weight training group. Although the combination group showed an increase in strength above baseline, it was a decrease from their peak of 34% at week seven of the training period. Hickson (16) believed that the decrease in strength may have been due to their aerobic exercise regimen. Stone, Wilson, Rozenek and Newton (29) have presented some possible mechanisms which may explain how aerobic exercise may interfere with strength gains. First, aerobic exercise may cause the myosin ATPase in the fast twitch (FT) muscles to decrease. Secondly, Stone et al. (29) state that aerobic training may reduce the concentration of anaerobic enzymes necessary for weight training. Finally, Stone et al. (29) state that the addition of an endurance exercise program to a weight training program may lead to overtraining. Perhaps this is what occurred in Hickson's (16) study. Since the combination group exercised twice as long as the weight training group, their decreased performance on the 1-RM test may have been secondary to muscle glycogen depletion and fatigue, rather than a true decrease in strength. With this in mind, the researcher of this study chose to design the workouts to be of similar duration for the experimental groups. The consequence of maintaining duration of exercise is that the caloric expenditure was not identical for the treatments. The mean of each of the caloric expenditures of weight lifting for females as calculated by Hempel and Wells (14) and Hickson, Buono, Wilmore and Constable (15) is 6.5 kcals/min. Thus, one hour of weight training would utilize approximately 390 kcal. The caloric cost of running eight min per mile for 25 min is estimated to be 250 kcal for a 60 kg woman (27). Therefore, RW was estimated to spend 445 kcal/h as compared to approximately 400 kcal/h for W. Since these are estimated values, true caloric expenditure for each subject would vary according to factors such as body weight and initial fitness.

It is possible that significant differences in isotonic leg strength were not observed between W and RW in the present study because of the similar duration and caloric cost of the exercise sessions for these groups. The similar duration may have kept the amount of muscle glycogen depletion between the groups equal, thus, possibly reducing the amount of muscle fatigue that may have come into play had RW exercised twice as long as W. Secondly, the workouts were three days per week compared to Hickson's (16) program of six days per week. The subjects in the present study had recovery periods of one to two days between workouts. Gettman et al. (13) compared the effects of 30 sec running bouts performed between each 30 sec circuit weight training station for 30 min to 22.5 min of circuit weight training alone on 41 males and 36 females. As in the present study, their subjects trained three days per week. Gettman et al. (13) reported significant gains in strength for both groups, with no significant difference between groups. The similar duration of the exercise programs combined with a greater recovery time between exercise sessions, may have been a key factor in explaining the lack of interference of running with weight training in Gettman et al.'s (13) study as well as in the present study. Nonetheless, direct comparisons between the present study and Gettman et al.'s (13) study cannot be made since their subjects performed a circuit weight training program and not the low repetition, high intensity strength training program in the present study.

Dudley and Djamil (9) researched the influence of high-velocity isokinetic strength and endurance training on the force-velocity relationship of human muscle. The endurance group did not demonstrate improvement on any of the seven velocities tested on the dynamometer. The strength group showed significant improvements in all the velocities, while the combination group showed improvements at only the three slow speeds. Dudley and Djamil (9) concluded that concurrent aerobic and strength training reduces the amount of increase in maximal torque at fast, but not slow velocities of contraction.

Although Dudley and Djamil's (9) combination group exercised more frequently than their weight training group, the training was performed on alternate days, i.e. cycled three days and weight lifted three days. Thus, the argument that muscle fatigue caused the reduction in strength gain may not be approprate for their study. However, both Dudley and Djamil (9) and Hickson (16) interval trained their subjects by having them perform six five-min sessions, at near VO2max, on the bicycle ergometer, three days per week. In addition, Hickson (16) required his subjects to run "as fast as possible" for 40 min the other three days of their six day per week workout. These training regimens are in contrast to the 25 min running program at 75% predicted maximum heart rate for the subjects in the present study. Interval training primarily utilizes anaerobic fuels such as creatine phosphate (CP), adenosine triphosphate (ATP) and glycogen (23). This is in contrast to the high fat utilization seen in aerobic-type activities such as long distance running (32). The subjects in Hickson's (16) study may have performed their weight training regimen, an anaerobic activity, following this possible depletion of anaerobic fuels. However, since CP and ATP are replenished rather quickly, a depletion in glycogen stores may be another explanation of the impaired strength gains reported in both Dudley and Djamil's (9) and Hickson's (16) studies (25). It is possible that their subjects experienced chronic glycogen depletion, which has been reported following bouts of intense endurance and resistive-type training (10). This chronic glycogen depletion may have reduced the strength training capabilities of the combination groups in both studies. Houston, Marrin, Green and Thomson (18) researched the effects of rapid weight loss in collegiate wrestlers. They reported a chronic glycogen depletion in these wrestlers that may have been secondary to their rapid weight loss. Houston et al. (18) reported that if the initial level of muscle glycogen is reduced, it may lead to "premature fatigue", and thus, a decreased performance, which may have occurred in both Dudley and Djamil's (9) and Hickson's (16) studies.

Another possibility that may explain the impaired strength gains in Dudley and Djamil's (9) and Hickson's (16) studies may be that their subjects were suffering from muscle soreness. Muscle soreness has been reported in subjects from 12 to 48 hours following a bout of heavy resistance training, heavy endurance running or interval training (11, 32). Thus, in both Dudley and Djamil's (9) and Hickson's (16) studies, the subjects in the combination group may have shown an impaired performance. However, isokinetic training, utilized in Dudley and Djamil's (9) study, produces little or no muscle soreness following exhaustive exercise bouts because it uses only concentric contractions (32). Nonetheless, this does not eliminate the possibility that Dudley and Djamil's (9) subjects suffered from muscle soreness following the five five-min sessions on the ergometer. Thus, if the subjects in their combination group suffered from muscle soreness, they may not have performed at 100% on the 1-RM strength tests and on the days that they weight trained, possibly impairing their ability to improve at fast velocities on the Cybex.

In the present study, the subjects in the RW group exercised at a comfortable pace, 75% of predicted maximum heart rate, which has been documented to increase VO2max (1). The pace and duration of the running portion of the RW group's regimen is associated with the utilization of fat as its primary fuel. It is unlikely that muscle glycogen became depleted with this duration of exercise (30). Therefore, when the RW group performed their 1-RM tests, their muscle glycogen may not have been as depleted as in the other studies. Furthermore, since the experimental groups in the present study exercised three days per week, muscle soreness may not have been as great, due to the one to two day recovery period between exercise sessions.

In the present investigation, no increases were observed in midpoint girth, but the experimental groups showed a significantly greater posttest AP than the C group. Cureton, Collins, Hill, McElhannon and Davis (6) reported significant increases in relative hypertrophy in both their male and female subjects following a weight training program. However, others have reported either decreases in chest, arm and calf girth in females, or no change in girth in females, but an increase in males, following a weight training program (2, 21, 24, 26). These inconsistencies in the literature concerning girth may be due to different strength training programs. Oyster's (26) subjects performed high resistance weight training on Nautilus two days per week for seven weeks. Her subjects showed a decrease in girth in the chest arm and calf. Katch and Drumm (21) and Mayhew and Gross (24) exercised their subjects on a circuit weight training program for three days per week for 10 weeks. They reported no significant changes in thigh girth for their female subjects. Finally, Brown and Wilmore (2) weight trained their subjects three days a week for 10 weeks at 80% of 1-RM, which is similar to the program used in the present study. Again, they reported no change in girth in their female subjects.

If the weight training regimen was different for the aforementioned studies, what could explain the nonsignificant change in girth? It may be related to the neural adaptations that occur in females who weight train. It appears that women increase strength primarily via neurological mechanisms with less hypertrophy of the muscle (4). Men, however, increase strength primarily via hypertrophy, which is attributed to their ten times greater amount of testosterone compared to women, as well as their larger muscle fiber size, which has a greater ability to develop force due to its greater number of contractile filaments (4, 7). This is not to say that females will not or do not hypertrophy. Studies have reported that, given the same training intensity, females will increase strength and show muscle hypertrophy to the same extent as their male counterparts, when both are expressed relative to initial muscle size (7, 8). The subjects in the present and other studies may not have shown an increase in midpoint thigh girth with a significant increase in strength because of a greater neural adaptation and/or their initial fitness level. Since they were previously sedentary, it may require a longer period of time before significant hypertrophy in specific girth measurements may be observed. Further research in comparing strength and hypertrophy gains between males and females is required to provide a better understanding of the associated mechanisms in females.

From the results of the present study, the researcher concluded that a low level endurance running program that accompanies a moderate intensity weight training regimen, is not detrimental to leg strength gains in young adult females. However, the exercise regimen did not significantly change body weight, percent body fat or thigh girth. Although the present study reported no differences in strength gains between the W and RW groups, other studies that have investigated the effects of an endurance exercise on weight training have reported impaired strength gains of the subjects in the combination group. An explanation for differences in results is unclear. However, the aerobic exercise regimens in the previous studies were performed at high intensities, which may have caused chronic muscle glycogen depletion, muscle soreness, and/or local muscle fatigue. Further study is required to determine whether other intensities and durations of aerobic exercise interfere with strength gains in women.

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CHAPTER IV

Summary and Research Recommendations

Summary

This study was conducted to assess alterations in leg strength, thigh girth, percent body fat and body weight following a program of weight training and weight training combined with a running program.

Three groups of females, 18-30 yrs. of age, participated in this nine week exercise program. The three groups were as follows: (1) weight training group (W), (2) weight training plus running group (RW) and (3) control group (C). The two experimental groups exercised three times per week, with each session lasting approximately one hour for both groups. The RW group ran for 25 min at a heart rate of 75% of their predicted maximum heart rate. The second half of their workout included weight training at 60% of their 1-RM for the first two weeks of the study, and 75% of their 1-RM for the remainder of the study. The RW group performed the exact same leg apparatus program as the W group, and performed as much of an arm workout as time allowed. The W group exercised for one hour at the same percentages as the RW group. However, they performed all the arm apparatus exercises available.

Statistical Analysis System (SAS) Institute's computer package was used to conduct the statistical analyses. A repeated measures ANOVA was computed for biweekly leg strength measures and weekly body weight measures for W and RW only. A repeated measures ANOVA was also conducted to measure pre- and posttest values of leg strength, thigh girth, percent body fat and body weight for W, RW and C. A Tukey post hoc test was computed if significant interactions were found.

Pretest measures of all the dependent variables revealed no significant differences between any of the groups. Posttest values revealed no significant change in midpoint thigh girth, percent body fat and body weight between groups over time. Weekly body weight did not significantly change bewteen W and RW over time. Posttest measures of 1.18 cm above the patella girth (AP) revealed a significant interaction between the groups over time.

Increases in isotonic leg strength on the leg press and the leg extension apparatus for biweekly measures were significant over time for W and RW, with no significant difference between groups over time. W increased their leg strength by 56% above baseline, and RW increased their isotonic leg strength by 67% above pretesting values by the end of the training period. A Tukey post hoc test revealed that the significant increase in the combined leg strength values began at week six of the training period on the leg press and week four on the leg extension apparatus. Statistical analysis using only the pre- and post-training calculations showed that W and RW achieved a significantly greater leg strength than the C group, following the training period. There was a significant interaction between groups over time in this variable.

Research Implications

The results of this study contribute information regarding adaptations that occur when a running program is combined with a weight training regime. Since an increase in leg strength was achieved by both the W and RW groups, it is suggested that combining a low intensity running program with a weight training program may provide increased benefits than either program alone. Although no improvements were observed in percent body fat, thigh girth and body weight, it does not exclude the possibility of these variables improving if the duration and frequency of the exercise regimens were increased. Secondly, diet was not controlled in this study, and thus, the subjects may have increased their caloric intake, which may have affected the results of the study.

The significant increase in leg strength, without a subsequent increase in midpoint thigh girth, may be appealing to young adult females, in that many women do not wish to significantly increase their muscle mass. The addition of an aerobic conditioning program, as the one used in this study, may provide cardiovascular benefits along with the strength gains achieved via weight training.

Future Research Recommendations

Although the present study reported no significant differences in strength gains between W and RW, other studies have reported impaired strength gains for the subjects in the running plus weight lifting group, i.e. combination group (Dudley & Djamil, 1985; Hickson, 1980). However, these researchers interval trained their subjects on the bicycle ergometer at near VO2max. This is in contrast to the present study's lower intensity endurance running regimen at 75% heart rate reserve. There are many unanswered questions as to why Dudley and Djamil (1985) and Hickson (1980) observed impaired strength gains in there combination groups.

Stone, Wilson, Rozenek and Newton (1984) have presented some possible mechanisms which may explain how aerobic exercise may interfere with strength gains. First, aerobic exercise may cause the myosin ATPase in the fast twitch (FT) muscles to decrease. Baldwin, Winder and Holloszy (1975) reported a 20% decrease in myosin ATPase activity in the FT red vastus muscle of their rats who trained 18 weeks, 2 hours per day. This was accompanied by a 20% increase in the myosin ATPase activity of the slow twitch (ST) red soleus muscle of the their endurance trained rodents.

Barnard, Edgerton and Peter (1970b) trained Guinea pigs for up to 21 weeks at 20 min per day, five days per week. Although the trained rodents showed a significantly greater percentage of ST fibers, no significant differences were observed in myosin ATPase activity in either their ST or FT fibers. Thus, a decrease in ATPase activity in FT fibers may only occur if the endurance exercise duration is two hours or greater. However, it would be unlikely that this would have occurred in Dudley and Djamil's (1985) and Hickson's (1980) studies due to the interval training performed by the subjects. There would seem to be an increase in myosin ATPase since the subjects primarily utilized FT fibers while interval training. Nonetheless, more research is required that studies any changes in myosin ATPase activity with aerobic and anaerobic training.

Secondly, Stone et al. (1984) state that aerobic training may reduce the concentration of anaerobic enzymes necessary for weight training. Some researchers have measured aerobic and anaerobic enzymes following endurance training (Gollnick, Armstrong, Sauberg, Piehl and Saltin, 1972; Costill, Fink, Getchell, Ivy & Witzmann, 1979). Gollnick et al. (1972) reported a significant increase in succinate dehydrogenase (SDH) and other Krebs cycle enzymes and mitochondrial protein concentration in the ST and FT fibers of their endurance trained men. Costill et al. (1979) also reported a significantly greater amount of SDH in both the ST and FT fibers in their male and female distance runners than their untrained subjects. Since these researchers reported an increased oxidative capacity in the FT fibers of their endurance trained subjects, it may alter the contractile properties of the FT fibers, which is of great importance in a weight lifting activity. Thus, Stone et al.'s (1984) theory may be valid. However, the increase in the aerobic enzymes may be beneficial, since the muscle fiber becomes more fatigue- resistant, with less lactic acid build-up (Costill et al., 1979). Therefore, further research on the adaptability of FT fibers to endurance training is required to observe its effects on weight training strength gains.

Another possibilty as to why these researchers observed strength impairments in their combination groups may be related to the types of muscle fibers recruited during their cycling exercise. ST fibers may have primarily been recruited during the cycling , thus, causing a "selective hypertrophy" of these fibers (McArdle, Katch & Katch, 1986). Hakkinen (1985) reported that concentric force at fast contraction speeds is dependent on FT fibers. ST fibers are not recruited for this type of contraction. Thus, the subjects in Hickson's (1980) and Dudley and Djamil's (1985) studies may have shown a decrease in strength because of the "selective hypertrophy" of the ST fibers. Nonetheless, this argument is not be valid since these researchers endurance trained their subjects with interval-type training, which recruits a high number of FT fibers (Hakkinen, 1985). However, research in the area of muscle fiber recruitment with this combination training is necessary in order to observe changes, if any, in the fast oxidative glycolytic fibers (FOG). The combination training may effect these muscle fiber types differently than if an individual trains for only one activity.

Further research is also required that measures muscle glycogen. It has been reported that, with intense endurance and resistive-type training, the exercised muscles may suffer from chronic glycogen depletion (Dudley & Fleck, 1987). The chronic muscle glycogen depletion results in a decreased performance (Houston, Marrin, Green & Thomson, 1981). Thus, this may be another possibility as to why Dudley and Djamil (1985) and Hickson (1980) observed a decrease in strength.

A decrease in performance may have been observed because of overtraining (Stone et al., 1984). The subjects in the combination groups exercised more frequently than those in the weight training only group. Thus, the subjects may have suffered from muscle fatigue and soreness, which occurs after intense bouts of interval and weight training (Evans et al., 1986). Therefore, further research on comparing the effects of different intensities and durations of the combination training is required.

Few studies have researched the effects of endurance training on strength gains achieved by weight training. This makes it difficult to give any conclusive statements about this type of training. Nonetheless, it poses the challenge for further research of the possible physiological adaptations that may occur with this combination training.

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APPENDIX A

METHODOLOGY

Pilot Study

Prior to this investigation, a pilot study was conducted on eight volunteers, by the researcher, to become more experienced with the testing procedures. Those that assisted the researcher in data collection were also involved in the pilot study in order to increase their consistency with the testing protocol.

Subject Selection

Prior to subject selection, permission was obtained from the Human Subjects Committee (Appendix B) in order to perform this study. The 25 subjects who participated in this study were among volunteers who registered for a physical fitness activity course entitled "Bodybuilding and Fitness". These subjects were randomly assigned to one of two groups: weight lifting (W) or running and weight lifting (RW). Subjects in the control (C) group were volunteers from leisure sports activity classes, i.e. bowling and golf. Criteria utilized for subject selection required the participants to be:

1. Females, aged 18-30.
2. Uninvolved in a weight training program for at least six months.
3. Uninvolved in a strenuous aerobic conditioning program for at least six months (i.e. less than 30 minutes per week).

4. Free of orthopedic problems.
5. Free of high blood pressure (i.e., > 140/90 mm Hg).
6. Nonsmokers (i.e. never smoked or refrained from any smoking for six months or more).

GENERAL METHOD

Instructional Procedures

All subjects were given an oral detailed explanation of the study, including its risks, benefits, and procedures, prior to any testing. Those subjects consenting to participate, completed a medical history questionnaire (Appendix C) to insure that none of them were at any major risks for problems caused by the exercise regimens (i.e. chest pain, breathing difficulties, myocardial infarction). Following a close review of the medical history questionnaire, subjects were asked to read and sign an informed consent which also explained the risks and benefits of the study (Appendix D). Subjects then received a written explanation of the pretesting procedures (Appendix E).

Procedures

The subjects were tested on two days at the beginning of the study. The first pretest day consisted of skinfold measures, girth measures, 1-RM measures on the Universal leg press and leg extension, and hydrostatic weighing. Three days following this, subjects were retested for leg strength, skinfolds, and thigh girth, for reliability purposes. The three day rest period was chosen because peak muscle soreness, which could have influenced muscle strength, has been reported in subjects at 24-48 hours post training (Evans et al., 1986). Subjects in the experimental groups were also pre- and posttested for the 12 min run. Although this was not a dependent measure of the study, it was necessary to demonstrate that the RW group's running program was sufficient to elicit cardiovascular improvements.

Prior to any 1-RM testing, subjects were instructed on proper weight training techniques. Subjects were then given a warm-up of five repetitions at a submaximal load of 90 lbs. The subject performed one repetition each time the researcher increased the weightload. Three to five trials were performed in order to determine 1-RM for each subject. One-RM was determined if the subject could not lift the weight properly or at all. Subjects were given a one minute recovery period between each trial. The retesting procedures utilized to estimate stability reliability were the same as the initial testing procedures. W and RW were remeasured for 1-RM every two weeks throughout the nine week study for the purpose of a new weight lifting intensity prescription. However, the posttest measurement was conducted one week following the final two week retest of 1-RM.

Hydrostatic weighing was performed as described by Katch and McArdle (1983). Subjects were weighed in a stainless steel rectangular tank. They were measured while supine on a mesh basket supported by four load cells. The tank was recalibrated every third subject. Subjects' weights were observed and recorded from both a digital display and a multiple channel recorder. Each subject performed eight trials. The three highest trials were averaged and used to compute body density.

Subjects' residual volume was measured by the oxygen dilution technique. This was performed as described by Wilmore, Vodak, Parr, Girandola and Billing (1980). First, the subjects' vital capacity was measured. Following this, a five liter anesthesia bag was filled with 100% oxygen. The amount of oxygen placed in the bag was determined by calculating 85% of the subjects' maximal vital capacity. The subjects breathed with a metronome for seven to eight breathing cycles, and were instructed to expire as much air as possible, after which the valve was switched to the anesthesia bag filled with 100% oxygen. The subjects breathed seven to eight cycles once again, and maximally expired as much air as possible. This procedure was performed twice. The anesthesia bag was connected to an Applied Electrochemistry S-3A analyzer for the oxygen analysis, and an Applied Electrochemistry CD-3A analyzer for the carbon dioxide analysis. If the two residual volume values were greater than a 5% difference, a third measure was taken.

Percent body fat via skinfold measures was taken at three sites on the right side of the body: triceps, suprailiac, and quadriceps. Five skinfold measurements were recorded at each site. These measures were averaged and used to calculate percent body fat as described by Jackson, Pollock and Ward (1980). Thigh girth was also measured as described by Jackson et al. (1980), with an added girth measure located 1.18 cm above the patella (AP).

The C group was measured for leg strength, thigh girth and percent body fat via skinfolds and hydrostatic weighing in the same manner as the experimental groups. However, they were only tested prior to and following the study.

The maximum heart rates were calculated for those in the RW group using the formula 220-age. From this predicted maximum heart rate, the Karvonnen method was used to determine each subjects' target heart rate (THR) at 75% heart rate reserve.

Subjects' body weight was measured weekly on a calibrated scale. Body weight was measured to the nearest .25 kg.

The experimental groups performed their assigned workouts at the same time three days per week. Each group performed the first two phases of the periodization model as described by Stone and O'Bryant (1984). The periodization model was chosen since research has shown that periodization programs produce "superior strength and power development with relatively novice subjects" (Charniga, et al., 1986). Although Stone and O'Bryant's model consists of four phases, only the first two were chosen because the investigator did not want the constant change in intensity and volume to be a confounding variable. The two phases are: (1) hypertrophy phase and (2) basic-strength phase. The hypertrophy or "adaptation phase" is a program of high volume and low intensity (i.e., high repetitions and low weights). It allows the subjects to adapt to weight training. The "basic-strength" phase is a program of moderate volume and high intensity (i.e., low number of repetitions with a greater workload). A more detailed explanation follows.

For the first two weeks, W group's training consisted of eight to twelve repetitions at 60% of each subjects' 1-RM. Microcycles were also incorporated, i.e., on Mondays and Fridays subjects performed three sets of eight to twelve repetitions on the leg apparatus: leg press, leg extension, leg curls and calf raises (Universal apparatus); and two sets of eight to twelve repetitions on the arm apparatus: bench press, arm curls, tricep press, shoulder shrugs, latissimus dorsi pull down, military press (Universal apparatus); chest flies, chest press, shoulder flies, military press, and abdominals (Nautilus apparatus). On Wednesdays, the subjects performed three sets on the arm apparatus and two sets on the leg apparatus. Following the first two weeks of low weights, high repetitions or the "adaptation phase", subjects increased their percentage of weight lifted to 75% of 1-RM. The repetitions were decreased to four to six, and subjects performed four sets on the leg apparatus on Mondays and Fridays, and three sets on the arm apparatus. On Wednesdays, the subjects performed three sets on the leg apparatus and four sets on the arm equipment.

The RW group ran for 25 minutes during the first half of their workout at 75% of their predicted maximum heart rate (Karvonnen method). Since the subjects were untrained, they initially ran/walked for 20 minutes the first two weeks. One-half of the subjects walked and ran about 40%-50% of the 20 minutes during the first two weeks. Following this adaptation to exercise, approximately 10% of the subjects were able to continually run for 20 minutes during the third week. They progressed to running for 25 minutes by the fourth week, and maintained this amount of running time for the remainder of the study. Approximately two to three subjects walked during the fourth week. However, the walking time for these subjects was minimal, and they eventually were able to run the entire time of 25 minutes by the fifth week. Pre-exercise heart rates, three exercise heart rates recorded at six minute intervals, and cool-down heart rates were recorded each workout by the subjects. To insure that the subjects were remaining in their THR, the researcher periodically checked the subjects' HR's via a stethescope. The second half of the experimental training program, the subjects performed the leg strengthening exercises, i.e. Universal leg press, leg extension, leg curls and Nautilus calf raises. Upon completion of the leg strengthening exercises, RW weight lifted four pieces of the arm apparatus of their choice for 30 minutes. These included Universal arm curls, triceps press, latissimus dorsi pull down, shoulder shrugs, and Nautilus chest curls, chest press, military press, and shoulder flies. The same macrocycle and microcycle applied as in the W group. All exercise sessions were monitored by the researcher and each subject kept a record of her exact workout for each session.

The experimenter chose to design the workouts to be of similar duration for the two groups. This meant that caloric expenditure was not identical for the treatments. The estimated kilocalorie (kcal) expenditure of weight lifting for females as calculated by Hempel and Wells (1985) and Hickson, Wilmore, Buono and Constable (1984) was estimated to be 6.5 kcals/min. Thus, one hour of weight training would utilize approximately 390 kcal. The caloric cost of running for 25 minutes is estimated to be 250 kcal (Sharkey,1984). Thus, RW was estimated to spend 445 kcal/h as compared to approximately 400 kcal/h for W. Since these are estimated values, some subjects may have utilized more or less kcals compared to others.

Research Design

A randomized control group pretest-posttest design was used in this study. The subjects were randomly assigned to one of the the two experimental groups and were randomly assigned to the experimental conditions. The experimetal groups either weight trained for one hour or ran for 25 minutes at 75% of their predicted heart rate and weight trained for 30 minutes following their run. The control group was chosen from a leisure sports activity class and was not exposed to a treatment.

STATISTICAL ANALYSES

Reliability Estimate

To estimate the consistency of the measurement techniques designed to assess the subjects' initial pretest values, test-retest reliability estimates were calculated on the following data: 1-RM leg strength, skinfold measurements, and thigh girth measurements. Intraclass correlations were computed for the hydrostatic weighing data, using the three highest trials from each subjects' weighing. Reliability estimates for experimental test items ranged from r=.95 to r=.99. The results may be found in Appendix F.

VALIDITY ESTIMATES

External Validity

The subjects of this study were female volunteers and were randomly assigned to one of the two experimental groups. The sampling procedure utilized allows the researcher to generalize to a college-aged population.

Internal Validity

Variance was minimized in this study by: (a) orienting subjects to the testing procedures before actual testing occurred; (b) having a control group; (c) training those assisting in data collection; (d) calibrating the equipment prior to all testing; and (e) having the posttesting identical to the pretesting procedures.

Data Analyses

Statistical analyses included a repeated measures analysis of variance (ANOVA) for several of the dependent measures: body weight, leg press and leg extension. One repeated measures ANOVA was calculated on the weekly body weight and biweekly leg strength variables (W and RW only), while the second was done using only the pre- and posttest values (W, RW and C). In addition, a pre-posttest repeated measures ANOVA was performed on midpoint girth, 1.18 cm above the patella girth (AP), and percent body fat (skinfolds and hydrostatic weighing), for the W, RW, and C groups. Tukey post hoc tests were computed if significant interactions were found. Correlational analyses using Pearson Product Moment correlations were calculated on the pretest variables and changes in all the dependent variables. The level of significance study was set apriori at .05. All data was analyzed using the Statistical Analysis System (SAS).

Summary ANOVA tables for all the pre- and posttesting measures and weekly and biweekly measures may be found in Appendix F. Summaries of the Tukey tests may also be found in Appendix F.

Pretesting analyses showed no significant differences between the subjects, and thus, agreed with the assumption of homogeneity of variance. Subject characteristics may be found in Appendix F.

Biweekly leg strength analyses revealed a significant improvement in leg strength by the experimental groups, above baseline. The experimental groups also showed a significantly greater posttest leg strength than the control group. The results of both the biweekly leg strength and pre- and posttest analyses may be found in Appendix F.

The subjects were also pre- and posttested for percent body fat and thigh girth. Body weight was measured on a weekly basis for W and RW, with pre- and post-measures on all groups. There was a significant interaction for the AP measures. However, there were no significant differences between the subjects in midpoint thigh girth, percent body fat, or body weight. The results may be found in Appendix F. The results of the repeated measures ANOVA calculated for the pre- and posttest 12 min run may be found in Appendix F. The results of the correlational analyses for all the pretest dependent variables and changes in all the dependent measures may be found in Appendix F.

Conclusions

Based upon the results of this study, the researcher retains the the following null hypotheses:

Ho: There is no significant difference between individuals who weight train for a total of one hour three times per week and those who combine weight training and an aerobic endurance activity for a total of one hour three times per week in:

1. body weight

2. percent body fat
3. isotonic leg strength (leg press and leg extension)
4. thigh girth (midpoint and 1.18 cm above the patella)

APPENDIX B

REQUEST TO HUMAN SUBJECTS' COMMITTEE

CERTIFICATE
OF
APPROVAL FOR RESEARCH
INVOLVING HUMAN SUBJECTS

Division of HPER

The Human Subjects Committee of the Division of Health, Physical Education and Recreation has reviewed the research of

Janet L. Walberg, Ph.D. and Stella L. Volpe

entitled Effect of endurance running on strength gains and muscle cell damage in women participating in a weight lifting program.

The members have judged the subjects participating in the related experiment (not to be at risk) as a result of their participation.

(If a risk proposal) Procedures have been adopted to control the risks at acceptably low levels. The potential scientific benefits justify the level of risk to be imposed.

Members of Divisional
Human Subjects Committee

______________________ Chairman	______________________ Date
______________________	______________________ Date
______________________	______________________ Date
______________________	______________________ Date

REQUEST FOR APPROVAL OF RESEARCH PROPOSAL
IN THE DIVISION OF HPER

Submitted to

Charles Baffi
Chairman, Division Human Subjects Committee and/or
Chairman, Institutional Review Board

by

Janet L. Walberg, Ph.D. and Stella L. Volpe
Principal Investigator

TITLE: Effect of endurance running on strength gains and muscle cell damage in women participating in a weight lifting program.

BACKGROUND/SCIENTIFIC JUSTIFICATION: Weight lifters avoid exercise due to testimonials that it decreases gains in strength and bulk. Theoretically, endurance exercise may increase breakdown of body protein for fuel and/or cause damage to muscle cells (as evidenced by an increase in serum creatine kinase, CK). However, aerobic exercise is beneficial for overall health plus dramatically enhances fat utilization. The latter would aid development of the lean, cut look desired by weight lifters and bodybuilders. There have been few scientific investigations to determine the positive or negative effects of aerobic exercise on the adaptations caused by resistance weight lifting.

PURPOSE(S): This study will assess the differences in strength gains, muscle hypertrophy, body fat and muscle cell damage in females during weight training alone or weight training plus endurance running.

EXPERIMENTAL METHODS & PROCEDURES: Subjects will be assigned to either a control (C), weight training only (WT), or weight training plus running (WT+RN) group. Initial measurements will be made of body weight, body composition (hydrostatic and skinfold), and exercise-induced muscle cell damage (5 ml blood sample assayed for CK immediately before and 24 hours after respective work out). WT subjects will participate in a supervised 3 d/wk, 1 hr/d weight training program (legs and upper body). WT+RN will participate in a weight training for legs only plus 1/2 hr of continuous running at 75% predicted maximal heart rate. All dependent measures will be reassessed at the end of the ten wk period.

STATEMENT DESCRIBING LEVEL OF RISK TO SUBJECTS: Subjects may experience muscle soreness due to exercise programs and temporary discomfort during blood sampling.

PROCEDURES TO MINIMIZE SUBJECT RISK (IF APPLICABLE): All exercise training will be supervised by at least two individuals. Subjects will be instructed on proper technique and injury prevention.

RISK/BENEFIT RATIO (IF RISK PROJECT): Subjects will be expected to benefit physically with an increase in strength and/or endurance exercise, depending on treatment group. Their knowledge of their body composition and of exercise principles will also be expected to increase. The risks of participation are minimal due to supervision of the training programs and utilization of a trained phlebotomist for the infrequent, small quantity blood sampling.

APPENDIX C
MEDICAL HISTORY QUESTIONNAIRE

LAST NAME	FIRST NAME	MIDDLE INITIAL
DATE of BIRTH	SEX	HOME PHONE
ADDRESS	CITY, STATE	ZIP
SS NUMBER	WORK PHONE	FAMILY PHYSICIAN

SECTION A

1. When was the last time you had a physical examination?

2. If you are allergic to any medications, foods, or other substances, please name them.

3. If you have been told that you have any chronic or serious illnesses, please list them.

4. Give the following information pertaining to the last three times you have been hospitalized. (Women: do not list normal pregnancies.)

	HOSPITALIZATION NUMBER 1	HOSPITALIZATION NUMBER 2	HOSPITALIZATION NUMBER 3
TYPE OF OPERATION			
MONTH AND YEAR HOSPITALIZED			
NAME OF HOSPITAL			
CITY AND STATE			

SECTION B

DURING THE PAST TWELVE MONTHS...

(PLEASE ANSWER YES OR NO)

1. Has a physician prescribed any form of medication for you?
2. Has your weight fluctuated more than a few pounds?
3. Did you attempt to bring about this weight change through diet and/or exercise?
4. Have you experienced any faintness, lightheadedness, blackouts?
5. Have you occasionally had trouble sleeping?
6. Have you experienced any blurred vision?
7. Have you had any severe headaches?
8. Have you ever experienced chronic morning cough?
9. Have you ever experienced any temporary change in your speech pattern such as slurring or loss of speech?
10. Have you ever felt unusually nervous or anxious for no apparent reason?
11. Have you ever experienced unusual heartbeats such as skipped beats or palpitations?
12. Have you ever experienced periods in which your heart felt as though it were racing for no apparent reason?

AT PRESENT...

(PLEASE ANSWER YES OR NO)

1. Do you experience shortness of breath or loss of breath while walking with others your own age?
2. Do you experience sudden tingling, numbness, or loss of feeling in your arms, hands, legs, feet, or face?
3. Have you ever noticed that your hands and feet sometimes feel cooler than other parts of your body?
4. Do you experience swelling of your feet and ankles?
5. Do you get pains or cramps in your legs?
6. Do you experience any pain or discomfort in your chest?
7. Do you experience any pressure or heaviness in your chest?
8. Have you ever been told that your blood pressure is abnormal?
9. Have you ever been told that your serum cholesterol or

triglyceride level was high?

10. Do you have diabetes?
    If yes, how is it controlled?
    __Dietary means __Insulin injection
    __Oral medication __Uncontrolled
11. How often would you characterize your stress level as being high?
    __Occasionally __Frequently __Constantly
12. Have you ever been told that you have any of the following illnesses?
    _Myocardial infarction _Arteriosclerosis _Heart disease
    _Coronary thrombosis _Rheumatic heart _Heart attack
    _Coronary occlusion _Heart failure _Heart murmur
    _Heart block _Aneurysm _Angina

SECTION C

Has any member of your immediate family been treated for or suspected to have any of these conditions? Please specify relationship to you (father, mother, sister, brother, etc.)

A. Diabetes
B. Heart Disease
C. Stroke
D. High Blood Pressure

SMOKING HABITS

(PLEASE ANSWER YES OR NO)

1. Have you ever smoked cigarettes, cigars, or a pipe?
2. Do you smoke presently?
   Cigarettes_____per day
   Cigars _____per day
   Pipefuls _____per day

3. At what age did you start smoking?_____years
4. If you have quit smoking, when did you quit?___________

DRINKING HABITS

1. During the past month, how many days did you drink

alcoholic beverages?
_____days

2. During the past month, how many times did you have five or more drinks per occasion?
_____times
3. On the average, how many glasses of beer, wine, or highballs do you consume per week?
Beer________glasses or cans
Wine________glasses
Highballs________glasses
Other________glasses

EXERCISE HABITS

(PLEASE ANSWER YES OR NO)

1. Do you exercise vigorously on a regular basis?

2. What activities do you engage in on a regular basis

3. If you walk, run, or jog, what is the average number of miles you cover per week?
_____miles

4. How many minutes on the average is each of your workouts?
_____minutes

5. How many workouts per week do you participate in on the average?
_____workouts

6. Is your occupation:
_____Inactive (e.g., desk job)
_____Light work (e.g., housework, light carpentry)
_____Heavy work (e.g., heavy carpentry, lifting)

7. Check those activities that you would prefer on a regular exercise program for yourself:
__Walking/running/jogging
__Stationary running
__Jumping rope
__Bicycling
__Stationary cycling
__Handball/racquetball/squash
__Basketball
__Swimming
__Tennis
__Aerobic dance
__Others (secify)

DIETARY HABITS

1. What is your current weight?_____lb. height?_____in.
2. What would you like to weigh?_____lb.
3. What is the most you ever weighed as an adult?_____lb.
4. What is the least you ever weighed as an adult?_____lb.

APPENDIX D
INFORMED CONSENT

HUMAN PERFORMANCE LABORATORY

Division of Health, Physical Education and Recreation
Virginia Polytechnic Institute and State University

INFORMED CONSENT

I, _________________________, do hereby voluntarily agree and consent to participate in a testing program conducted by the personnel of the Human Performance Laboratory of the Division of Health, Physical Education and Recreation of Virginia Polytechnic Institute and State University.

Title of Study: Effect of endurance running on strength gains and muscle cell damage in women participating in a weight lifting program.

The purposes of this experiment include: This study will assess the differences in strength gains, muscle growth, body and muscle cell damage in females during weight training alone or weight training plus running.

I voluntarily agree to participate in this testing program. It is my understanding that my participation will include: A weight training program or a weight training plus running program. Pretesting will include measurement of body fat (under water weighing), thigh girth (tape measure), and leg strength (Universal equipment), and muscle cell damage (blood sample taken immediately before and 24 hours after one exercise session). Training will take place three times per week for approximately one hour per session. Leg strength gains will be measured biweekly. Body fat, girth, and muscle cell damage measurements will be repeated at the end of the ten week training period.

I understand that participation in this experiment may produce certain discomforts and risks. These discomforts and risks include: Temporary muscle soreness may be a consequence to strength testing and training. Slight discomfort may be experienced during blood sampling.

Certain personal benefits may be expected from participation in this experiment. These include: Subjects may expect to increase their fitness plus

Appropriate alternative procedures that might be advantageous to you include:

I understand that any data of personal nature will be held confidential and will be used for research purposes only. I also understand that these data may only be used when not identifiable with me.

I understand that I may abstain from participation in any part of the experiment or withdraw from the experiment should I feel the activities might be injurious to my health. The experimenter may also terminate my participation should he feel the activities might be injurious to my health.

I understand that it is my personal responsibility to advise the researchers of any preexisting medical problem that may affect my participation or of any medical problems that might arise in the course of this experiment and that no medical treatment or compensation is available if injury is suffered as a result of this research. A telephone is available which would be used to call the local hospital for emergency service.

I have read the above statements and have had the opportunity to ask questions. I understand that the researchers will, at any time, answer my inquiries concerning the procedures used in this experiment.

Scientific inquiry is indispensable to the advancement of knowledge. Your participation in this experiment provides the investigator the opportunity to conduct meaningful scientific observations designed to make significant educational contribution.

If you would like to receive the results of this investigation, please indicate this choice by marking in the appropriate space provided below. A copy will then be distributed to you as soon as the results are made available by the investigator. Thank you for making this important contribution.

_____ I request a copy of the results of this study.

Date ____________________ Time _________a.m./p.m.

Participant Signature___________________________________

Witness____
HPL Personnel

Project Director__________________ Telephone____________

HPER Human Subjects Chairman Dr. Charles Baffi
Telephone ____________________

Dr. Charles Waring, Chairman, International Review Board for Research Involving Human Subjects. Phone 961-5283.

APPENDIX E
PRETESTING INSTRUCTIONS

INSTRUCTIONS FOR HYDROSTATIC WEIGHING

Arrive at the Human Performance Lab, Gym 230, at the assigned time and check in with the technician. Be sure that you have fasted for at least 2 hours prior to the weighing. You will be weighed in your bathing suit, so bring one to change into or wear one under your street clothes.

The following list is what you will be asked to do:

1. First, your Residual Volume will be measured. This is used in the calculation of your percent fat. It measures the amount of air that is remaining in your lungs after a maximum expiration. You will be asked to blow out as much air as you can into a blue tank (spirometer). This measures your vital capacity, which is the maximum amount of air you can blow out of your lungs after a maximal inspiration. In a prone position on the cot, a noseclip will be fitted and an anesthesia bag with a mouthpiece attached will be placed in the mouth. Always keep a tight seal around the mouthpiece! After about one minute of breathing room air, you will be asked to exhale as much air from your lungs as possible. Signal the technician when you have done this, and the valve will be switched to the bag filled with 100% oxygen. Again, you will breathe normally for about

a minute. Once again, you will be asked to breathe out as much air as possible into the bag. Your oxygen and carbon dioxide will be analyzed, and then you will be set to get into the water tank!

2. First, you will be weighed. Next, you will be asked to gently get into the tank. Remove all air bubbles from your suit and hair. Next, you will place small weights around your ankles and on your chest. The test administrator will ask you to slowly lay back and breathe out as you go down. Remain as still as possible for a few seconds. An administrator will tap on the side of the tank to signal you to come up. Be sure you come up sooner if you have to do so! This exercise will be performed 7-8 times. (If you would feel more comfortable with a noseclip or holding your nose, tell the technician.)

3. After you are dried, change into dry clothes, shorts and a short- sleeved shirt, a test administrator will measure your percent fat with the skin calipers. All measurements will be taken on the right side of your body at the back of the arm, above the hip, and the thigh.

INSTRUCTIONS FOR MEASUREMENT OF 1-RM

When being mesaured for 1-repetition maximum (1-RM), which is the maximum amount of weight you can lift once on each weight training apparatus, be sure that you arrive at the weight training room in War Memorial Gym at the assigned time. Report to the technician. Wear clothing that you can move easily in, i.e. shorts, sweatpants, t-shirt. You will be asked to warm up on the specified piece of equipment at very low weights. Following this, you will perform three trials of lifting weights. The third trial will be your 1-RM. A fourth trial will be performed only if 1-RM was not achieved by the third trial.

GIRTH AND WEIGHT MEASUREMENTS

Girth will be measured at the center of the quadricep (thigh) and three inches above the kneecap. Thus, you will need to wear shorts. This will be measured twice: at the beginning and after the final week of training.

BODY WEIGHT

Body weight will be measured on a weekly basis. It is preferable that you do not eat at least two hours prior to being weighed. Of great importance, is the fact that we do not want you to change your diet in this study!

WORK-OUT SCHEDULE

WEEK 1 AND WEEK 2

Mondays and Fridays do 3 sets of 8 - 12 repetitions on all the leg equipment and 2 sets of 8 - 12 repetitions on all the arm equipment. On Wednesdays, do 2 sets of 8 - 12 repetitions on all the leg equipment and 3 sets of 8 - 12 repitetions on the arm equipment.

WEEKS 3 THROUGH 10

On Mondays and Fridays do 4 sets of 4 - 6 repetitions on all the leg equipment and 3 sets of 4 - 6 repetitions on all the arm equipment. On Wednesdays, do 3 sets of 4 - 6 repetitions on all the leg equipment and 4 sets of 4 - 6 repetitions on all the arm equipment.

NOTE

Both groups in the study will be retested for leg strength every other Saturday. You must be retested. If you are going out of town let me know so I can make a special arrangement with you. Your cooperation is appreciated!

APPENDIX F

STATISTICAL ANALYSES

Table of Reliability Estimates (Pearson Product Moment Correlations)

Leg Press	r=.95**
Leg Extension	r=.97**
Hydrostatic Weighing	R=.99***
Skinfold Measures	r=.98**
Midpoint Patella	r=.99**
1.18 cm Above Patella	r=.99**

** (Measures were taken approximately 72 h following the first measure.)

*** Intraclass correlation was used for the three highest values of the eight trials that were performed for each subject.

Summary ANOVA Table for Leg Press Measures (Pretest)

Source	SS	df	MS	F	p
Group	400.07	2	200.04	0.15	.8649
Error I	30131.43	22	1369.61	-	-

Summary ANOVA Table for Leg Extension Measures (Pretest)

Source	SS	df	MS	F	p
Group	721.48	2	360.74	1.37	.2758
Error I	5807.52	22	263.98	-	-

Summary ANOVA Table for Skinfold Measures (Pretest)

Source	SS	df	MS	F	p
Group	9.07	2	4.53	0.20	.8182
Error I	492.57	22	22.39	-	-

Summary ANOVA Table for Hydrostatic Weighing Measures (Pretest)

Source	SS	df	MS	F	p
Group	34.05	2	17.02	0.27	.7642
Error I	1363.72	22	61.99	-	-

Summary ANOVA Table for Midpoint Girth Measures (Pretest)

Source	SS	df	MS	F	p
Group	8.17	2	4.09	0.12	.8849
Error I	731.32	22	33.24	-	-

Summary ANOVA Table for Girth Measures 1.18 cm Above the Patella (Pretest)

Source	SS	df	MS	F	p
Group	3.05	2	1.52	0.08	.9195
Error I	397.55	22	18.07	-	-

Summary ANOVA Table for Body Weight Measures (Pretest)

Source	SS	df	MS	F	p
Group	65.60	2	32.89	0.32	.7301
Error I	2261.63	22	102.80	-	-

Summary ANOVA Table for the 12 Min Run (Pretest)

Source	SS	df	MS	F	p
Group	3.65	1	3.65	1.79	.1994
Error I	32.59	16	2.04	-	-

Summary ANOVA Table for Leg Press Measures
(Pre- to Posttest)

Source	SS	df	MS	F	p
Group	36504.22	2	18252.11	5.83	.0093*
Error I	68894.03	22	3131.55	-	-
Time	99238.16	1	99238.16	46.88	.0001*
Time*Group	48006.02	2	24003.01	11.34	.0004*
Error II	46570.73	22	2116.85	-	-

* $(p < .05)$

Summary ANOVA Table for Leg Extension Measures
(Pre- to Posttest)

Source	SS	df	MS	F	p
Group	9415.88	2	4707.94	9.46	.0011*
Error I	10943.88	22	497.44	-	-
Time	14082.00	1	14082.00	122.20	.0001*
Time*Group	3646.29	2	1823.14	15.83	.0001*
Error II	2535.71	22	115.26	-	-

* ($p < .05$)

Summary ANOVA Table for Skinfold Measures (Pre- to Posttest)

Source	SS	df	MS	F	p
Group	17.00	2	8.50	0.19	.8273
Error I	978.06	22	44.46	-	-
Time	0.3153	1	0.3153	0.28	.5997
Time*Group	1.73	2	0.8612	0.77	.4730
Error II	24.46	22	1.11	-	-

Summary ANOVA Table for Hydrostatic Weighing Measures (Pre- to Posttest)

Source	SS	df	MS	F	p
Group	84.58	2	42.29	0.37	.6932
Error I	2497.22	22	113.51	-	-
Time	0.1417	1	0.1417	0.04	.8363
Time*Group	0.9524	2	0.4762	0.15	.8643
Error II	71.34	22	3.24	-	-

Summary ANOVA Table for Midpoint Girth Measures
(Pre- to Posttest)

Source	SS	df	MS	F	p
Group	15.27	2	7.65	0.13	.8792
Error I	1296.61	22	58.94	-	-
Time	0.4099	1	0.4099	0.39	.5386
Time*Group	0.7021	2	0.3511	0.33	.7195
Error II	23.11	22	1.05	-	-

Summary ANOVA Table for Girth Measures 1.18 cm Above the Patella (Pre- to Posttest)

Source	SS	df	MS	F	p
Group	16.94	2	8.47	0.24	.7860
Error I	765.10	22	34.78	-	-
Time	0.8834	1	0.8834	2.25	.1480
Time*Group	2.82	2	1.41	3.59	.0448*
Error II	8.65	22	0.3930	-	-

* ($p < .05$)

Summary ANOVA Table for Body Weight Measures
(Pre- to Posttest)

Source	SS	df	MS	F	p
Group	143.94	2	71.97	0.36	.7024
Error I	22.31	22	1.01	-	-
Time	2.58	1	2.58	2.55	.1247
Time*Group	3.19	2	1.60	1.58	.2294
Error II	22.31	22	1.01	-	-

Summary ANOVA Table for the 12 min Run (Pre- to Posttest)

Source	SS	df	MS	F	p
Group	76.70	1	76.70	16.71	.0009*
Error I	73.45	16	4.59	-	-
Time	30.22	1	30.22	76.59	.0001*
Time*Group	36.66	1	36.66	92.96	.0001*
Error II	6.31	16	0.39	-	-

* ($P < .05$)

Summary ANOVA Table for Leg Press Measures (Biweekly)

Source	SS	df	MS	F	p
Group	8600.04	1	8600.04	1.00	.3330
Error I	138046.77	16	8627.92	-	-
Time	232511.03	5	46502.21	36.54	.0001*
Time*Group	2930.47	5	586.09	0.46	.8045
Error II	101815.42	80	1272.69	-	-

* (p < .05)

Summary ANOVA Table for Leg Extension Measures (Biweekly)

Source	SS	df	MS	F	p
Group	69.52	1	69.52	0.05	.8319
Error I	23880.08	16	69.52	-	-
Time	28854.26	5	5770.85	60.52	.0001*
Time*Group	138.52	5	27.70	0.29	.9169
Error II	7628.20	80	95.35	-	-

* (p < .05)

Summary ANOVA Table for Body Weight Measures (Weekly)

Source	SS	df	MS	F	p
Group	444.44	1	444.44	0.54	.4740
Error I	16143.95	16	1008.99	-	-
Time	3.52	8	0.4395	0.64	.7434
Time*Group	3.29	8	0.4118	0.60	.7774
Error II	88.01	128	0.6876	-	-

* ($p < .05$)

Summary Tukey Tests for Leg Press
(Pre- to Posttest and Posttest)

Source	
Pre- to Posttest	Q
Weight Training (W)	5.47*
Running + Weight Training (RW)	7.06*
Control (C)	.05
Posttest	
W compared to C	4.91*
RW compared to C	6.03*
W compared to RW	.91

* ($p < .05$ Qcv(.05) = 3.50 for 22 df

Summary Tukey Tests for Leg Press (Biweekly for W and RW)

Source	Q
Pretest and Week 2	.82
Pretest and Week 4	3.25
Pretest and Week 6	5.02*
Pretest and Week 8	5.73*
Pretest and Posttest	7.98*
Week 2 and Week 4	2.42
Week 2 and Week 6	4.20*
Week 2 and Week 8	4.90*
Week 2 and Posttest	7.15*
Week 4 and Week 6	1.77
Week 4 and Week 8	2.48
Week 4 and Posttest	4.73*
Week 6 and Week 8	.71
Week 6 and Posttest	2.95
Week 8 and Posttest	2.25

* (p < .05 Qcv(.05) = 4.13 for 80 df

Summary Tukey Tests for Leg Extension
(Pre- to Posttest and Posttest)

Source	Q
Pre to Posttest	
Weight Training (W)	7.92*
Running + Weight Training (RW)	10.40*
Control (C)	1.65
Posttest	
W compared to C	8.26*
RW compared to C	9.74*
W compared to RW	1.09

(p < .05 Qcv(.05) = 3.50 for 22 df

Summary Tukey Tests for Leg Extension
(Biweekly for W and RW)

Source	Q
Pretest and Week 2	1.51
Pretest and Week 4	5.61*
Pretest and Week 6	6.91*
Pretest and Week 8	8.20*
Pretest and Posttest	10.20*
Week 2 and Week 4	4.10
Week 2 and Week 6	5.40*
Week 2 and Week 8	6.70*
Week 2 and Posttest	8.64*
Week 4 and Week 6	1.30
Week 4 and Week 8	2.60
Week 4 and Posttest	4.53*
Week 6 and Week 8	1.30
Week 6 and Posttest	3.23
Week 8 and Posttest	1.94

* ($p < .05$ $Q_{cv}(.05) = 4.13$ for 80 df

Summary Tukey Tests for Girth 1.18 cm Above the Patella (Pre- to Postest and Posttest)

Source	
Pre- to Posttest	Q
Weight Training (W)	2.11
Running + Weight Training (RW)	2.08
Control (C)	1.30
Posttest	
W compared to C	5.48*
RW compared to C	5.99*
W compared to RW	.25

* (p < .05 Qcv(.05) = 3.50 for 22 df

Table of Subject Characteristics**

GROUP	WEIGHT (kg)	HEIGHT (cm)	AGE (yrs)
W (N = 8)	58.7±3.7	164.7±2.5	21.0±0.5
RW (N = 10)	62.0±2.9	165.5±2.2	20.1±0.3
C (N = 7)	58.7±4.2	162.0±2.2	24.3±1.5

** Values represent means ± SEM

Table of Biweekly Leg Press Values (kg)**

	GROUP	
	W	RW
N	8	10
WEEK		
Pretest	98.4±6.3	98.3±4.1
Two	100.1±6.1	108.6±5.2
Four	119.3±6.2	126.2±6.4
Six	128.1±6.4	144.4±8.9
Eight	137.1±6.3	146.4±8.9
Posttest	155.2±13.2	163.2±8.5

** Values represent means ± SEM

Table of Biweekly Leg Extension Values (kg)**

	GROUP	
	W	RW
N	8	10
WEEK		
Pretest	35.0±3.6	34.2±1.4
Two	37.1±3.1	38.0±2.4
Four	45.9±2.7	46.3±2.3
Six	48.9±2.7	49.2±1.7
Eight	51.0±2.9	52.3±3.5
Posttest	54.3±3.0	56.8±3.1

** Values represent means ± SEM

Table of Leg Strength Values (kg)**

	GROUP		
	W	RW	C
N	8	10	7
LEG PRESS			
Pretest	98.4±6.3	98.3±4.1	102.4±7.0
Posttest	155.2±13.2*	163.2±8.5*	102.2±8.9
LEG EXTENSION			
Pretest	35.0±3.6	34.2±1.4	29.2±2.7
Posttest	54.3±3.0*	56.8±3.1*	33.4±2.0

** Values represent means ± SEM
* (p < .05 for W and RW compared to C)

Table of Percent Body Fat (%) and LBM (kg) Values **

	GROUP		
	W	RW	C
N	8	10	7
HYDROSTATIC WEIGHING DATA			
Pretest	25.4±3.5	24.5±1.9	22.5±2.9
Posttest	25.6±3.5	24.8±1.5	22.1±2.7
SKINFOLD DATA			
Pretest	22.2±1.9	23.3±1.2	21.9±1.9
Posttest	22.9±1.8	23.2±1.3	21.7±2.0
LEAN BODY MASS DATA			
Pretest	43.1±1.3	46.6±1.6	45.1±2.6
Posttest	44.7±1.3	47.1±1.5	45.0±2.6

** Values represent means ± SEM

Table of Thigh Girth Measurements (cm)**

	GROUP		
	W	RW	C
N	8	10	7
MIDPOINT GIRTH			
Pretest	55.9±2.8	57.2±1.2	56.1±2.0
Posttest	56.1±2.5	56.9±1.2	55.6±1.7
1.18 cm ABOVE THE PATELLA			
Pretest	42.9±2.2	43.1±0.7	41.9±1.5
Posttest	43.7±2.2*	43.7±0.6*	41.9±1.3

** Values represent means ± SEM
* ($p < .05$ for W and RW compared to C)

Table of Weekly Body Weight Measures (kg)**

	GROUP	
	W	RW
N	8	10
WEEK		
Pretest	58.7±3.7+	62.0±2.9+
One	60.3±3.9	64.0±3.5
Two	60.3±3.7	63.5±2.9
Three	60.0±3.5	63.4±2.8
Four	60.1±3.7	63.8±3.0
Five	60.4±3.7	63.9±3.2
Six	60.5±3.5	63.7±2.6
Seven	60.5±3.1	63.3±2.7
Eight	60.5±3.1	63.6±2.7
Nine	60.5±3.2	63.9±2.9
Posttest	59.7±3.4+	62.7±2.9+

** Values represent means ± SEM
+ Subjects were weighed in their bathing suits

Table of Pre- and Posttest Body Weight Measures (kg)**

	GROUP		
	W	RW	C
N	8	10	7
Pretest	58.7±3.7	62.0±2.9	58.7±4.2
Posttest	62.7±3.4	59.7±2.9	58.4±4.2

** Values represent means ± SEM

Table of Correlational Analyses on Pretest Variables**

	LEG PRESS	LEG EXT.	BODY WEIGHT	% FAT	MG	AP	LBM
LEG PRESS	1.00 0.00	0.54 0.02	0.64 0.00	0.42 0.08	0.60 0.00	0.65 0.00	0.42 0.09
LEG EXT.	0.54 0.02	1.00 0.00	0.22 0.37	0.19 0.44	0.24 0.33	0.26 0.29	0.18 0.48
BODY WEIGHT	0.64 0.00	0.22 0.37	1.00 0.00	0.89 0.00	0.85 0.00	0.76 0.00	0.71 0.00
% FAT	0.42 0.08	0.19 0.44	0.89 0.00	1.00 0.00	0.86 0.00	0.71 0.01	0.54 0.02
MG	0.60 0.00	0.24 0.33	0.85 0.00	0.86 0.00	1.00 0.00	0.93 0.00	0.37 0.13
AP	0.65 0.00	0.26 0.29	0.76 0.00	0.71 0.00	0.93 0.00	1.00 0.00	0.36 0.15
LBM	0.42 0.09	0.18 0.48	0.71 0.00	0.54 0.02	0.37 0.13	0.36 0.15	1.00 0.00

** Numbers represent Pearson Product Moment Correlations with level of significance
LEG EXT.: Leg Extension; % FAT: Percent Fat; MG: Midpoint Thigh Girth; AP: Girth 1.18 cm Above the Patella; LBM: Lean Body Mass

The Following is a Legend for the Next Two Pages of Tables

LP: Leg Press
LE: Leg Extension
BW: Body Weight
PF: Percent Fat
MG: Midpoint Thigh Girth
AP: Girth, 1.18 cm Above the Patella
LBM: Lean Body Mass
LPC: Change in Leg Press
LEC: Change in Leg Extension
BWC: Change in Body Weight
PFC: Change in Percent Fat
MGC: Change in Midpoint Thigh Girth
APC: Change in Girth 1.18 cm Above the Patella

Table of Correlational Analyses for All Pretest Measures and Pre- to Posttest Changes in All Measures**

	LP	LE	BW	PF	MG	AP	LBM
LP	1.00 0.00	0.55 0.02	0.70 0.00	0.50 0.036	0.70 0.00	0.77 0.00	0.46 0.05
LE	0.55 0.02	1.00 0.00	0.29 0.24	0.15 0.55	0.32 0.20	0.37 0.14	0.25 0.32
BW	0.70 0.00	0.29 0.24	1.00 0.00	0.76 0.00	0.85 0.00	0.76 0.00	0.71 0.00
PF	0.49 0.04	0.15 0.55	0.76 0.00	1.00 0.00	0.81 0.00	0.68 0.00	0.09 0.73
MG	0.68 0.00	0.32 0.20	0.85 0.00	0.81 0.00	1.00 0.00	0.92 0.00	0.37 0.13
AP	0.77 0.00	0.37 0.14	0.76 0.00	0.68 0.00	0.92 0.00	1.00 0.00	0.37 0.13
LBM	0.46 0.05	0.25 0.32	0.71 0.00	0.09 0.73	0.37 0.13	0.37 0.13	1.00 0.00
LPC	-0.38 0.12	-0.42 0.08	-0.49 0.04	-0.28 0.25	-0.28 0.26	-0.24 0.34	-0.42 0.08
LEC	0.44 0.07	-0.24 0.33	0.58 0.01	0.34 0.16	0.39 0.11	0.36 0.15	0.51 0.03
BWC	-0.24 0.33	-0.19 0.45	-0.30 0.22	-0.38 0.11	-0.36 0.15	-0.23 0.36	-0.02 0.93
PFC	0.03 0.89	-0.22 0.38	0.05 0.84	-0.25 0.32	0.15 0.54	0.19 0.43	0.29 0.23
LBMC	-0.28 0.26	-0.37 0.13	-0.38 0.12	-0.14 0.58	-0.45 0.06	-0.43 0.07	-0.44 0.07
MGC	-0.13 0.59	-0.07 0.78	-0.22 0.38	-0.07 0.78	-0.34 0.17	-0.25 0.31	-0.19 0.43
APC	-0.084 0.74	-0.21 0.39	0.048 0.85	0.22 0.37	0.13 0.59	0.01 0.98	-0.12 0.64

** Numbers represent Pearson Product Moment Correlations with level of significance

Table of Correlational Analyses of All Pretest Measures and All Pre- to Posttest Measures (Continued)

	LPC	LEC	BWC	PFC	LBMC	MGC	APC
LP	-0.38 0.12	0.44 0.07	-0.24 0.33	0.03 0.89	-0.28 0.26	-0.13 0.59	-0.08 0.74
LE	-0.42 0.08	-0.24 0.33	-0.19 0.45	-0.22 0.38	-0.37 0.13	-0.07 0.78	-0.21 0.39
BW	-0.49 0.04	0.58 0.01	-0.30 0.22	0.05 0.84	-0.38 0.12	-0.22 0.38	0.05 0.85
PF	-0.28 0.25	0.34 0.16	-0.38 0.12	-0.25 0.32	-0.14 0.58	-0.07 0.78	0.22 0.38
MG	-0.28 0.26	0.39 0.11	-0.36 0.15	0.15 0.54	-0.45 0.06	-0.34 0.17	0.13 0.59
AP	-0.24 0.34	0.36 0.15	-0.23 0.36	0.19 0.43	-0.43 0.07	-0.25 0.31	0.01 0.98
LBM	-0.42 0.08	0.51 0.03	-0.02 0.93	0.29 0.23	-0.44 0.07	-0.19 0.44	-0.12 0.63
LPC	1.00 0.00	0.01 0.97	0.32 0.19	-0.04 0.87	0.29 0.25	0.21 0.41	0.28 0.26
LEC	0.00 0.97	1.00 0.00	-0.09 0.74	0.02 0.95	-0.06 0.81	-0.34 0.17	-0.02 0.93
BWC	0.32 0.19	-0.09 0.74	1.00 0.00	0.23 0.37	0.40 0.09	0.49 0.04	0.31 0.22
PFC	-0.04 0.87	0.02 0.95	0.23 0.37	1.00 0.00	-0.43 0.08	-0.08 0.75	0.19 0.45
LBMC	0.29 0.25	-0.06 0.81	0.40 0.09	-0.43 0.08	1.00 0.00	0.30 0.22	0.04 0.86
MGC	0.21 0.41	-0.34 0.17	0.49 0.04	-0.08 0.75	0.30 0.22	1.00 0.00	0.38 0.12
APC	0.28 0.26	-0.02 0.93	0.31 0.22	0.19 0.45	0.04 0.86	0.38 0.12	1.00 0.00

** Numbers represent Pearson Product Moment Correlations with level of significance

APPENDIX G
RAW DATA TABLES

Table of Biweekly Leg Press Measures (kg)

			WEEK				
SUBJECT#	GROUP	PRE	2	4	6	8	POST
1	W	97.5	89.6	140.6	134.9	151.9	231.3
2	W	78.2	86.2	112.3	123.6	123.6	166.7
3	W	134.9	134.9	140.6	140.6	151.9	151.9
4	W	100.9	108.9	111.1	120.2	131.5	166.7
5	W	89.6	89.6	89.6	108.9	121.3	116.8
6	W	86.2	89.6	120.2	140.6	151.9	144.0
7	W	110.0	112.3	131.5	155.3	155.3	155.3
8	W	89.6	89.6	108.9	100.9	108.9	108.9
9	RW	122.5	134.9	142.9	140.6	164.4	164.4
10	RW	74.8	78.2	97.5	112.3	134.9	155.3
11	RW	97.5	108.9	112.3	132.7	140.6	141.7
12	RW	112.0	112.3	123.6	134.9	140.6	144.0
13	RW	98.7	108.9	112.3	133.8	108.9	125.9
14	RW	100.9	120.2	134.9	208.6	212.0	225.7
15	RW	89.6	110.0	110.0	110.0	123.6	164.4
16	RW	99.8	123.6	166.7	163.3	163.3	168.9
17	RW	97.5	108.9	121.3	151.9	144.0	163.3
18	RW	89.6	100.9	140.6	155.3	131.5	178.0

Table of Biweekly Leg Extension Measures (kg)

				WEEK			
SUBJECT#	GROUP	PRE	2	4	6	8	POST
1	W	31.8	39.7	49.9	49.9	51.0	57.8
2	W	17.0	26.1	34.0	36.3	37.4	37.4
3	W	39.7	29.5	46.5	54.4	58.9	63.5
4	W	36.3	35.2	49.9	54.4	57.8	58.9
5	W	31.8	31.8	40.8	41.9	45.4	49.9
6	W	32.9	40.8	40.8	51.0	49.9	53.3
7	W	53.3	54.4	58.9	58.9	61.2	63.5
8	W	37.4	39.7	46.5	44.2	46.5	49.9
9	RW	36.3	45.4	58.9	58.9	78.2	78.2
10	RW	31.8	32.9	45.4	45.4	46.5	47.6
11	RW	41.9	45.4	46.5	49.9	54.4	51.0
12	RW	36.3	45.4	54.4	57.8	58.9	61.2
13	RW	36.3	49.9	51.0	51.0	52.2	58.9
14	RW	36.3	36.3	45.4	46.5	115.0	52.2
15	RW	29.5	30.6	41.9	43.1	92.5	47.6
16	RW	29.5	30.6	40.8	45.4	117.5	61.2
17	RW	36.3	31.8	45.4	48.8	107.5	63.5
18	RW	27.2	31.8	32.9	45.4	80.0	46.5

Table of Pre- and Posttest Leg Press Measures (kg)

SUBJECT#	GROUP	PRETEST	POSTTEST
1	W	97.5	231.3
2	W	78.2	166.7
3	W	134.9	151.9
4	W	100.9	166.7
5	W	89.6	116.8
6	W	86.2	144.0
7	W	110.0	155.3
8	W	89.6	108.9
9	RW	122.5	164.4
10	RW	74.8	155.3
11	RW	97.5	141.7
12	RW	112.0	144.0
13	RW	98.7	125.9
14	RW	100.9	225.7
15	RW	89.6	164.4
16	RW	99.8	168.9
17	RW	97.5	163.3
18	RW	89.6	178.0
19	C	89.6	91.8
20	C	120.2	120.2
21	C	74.8	91.8
22	C	134.7	123.6
23	C	98.7	100.9
24	C	89.6	89.6
25	C	108.9	97.5

Table of Pre- and Posttest Leg Extension Measures (kg)

SUBJECT#	GROUP	PRETEST	POSTTEST
1	W	31.8	57.8
2	W	17.0	37.4
3	W	39.7	63.5
4	W	36.3	58.9
5	W	31.8	49.9
6	W	32.9	53.3
7	W	53.3	63.5
8	W	37.4	49.9
9	RW	36.3	78.2
10	RW	31.8	47.6
11	RW	41.9	51.0
12	RW	36.3	61.2
13	RW	36.3	58.9
14	RW	36.3	52.2
15	RW	29.5	47.6
16	RW	29.5	61.2
17	RW	36.3	63.5
18	RW	27.2	46.5
19	C	22.7	31.8
20	C	27.2	31.8
21	C	24.9	29.5
22	C	44.2	45.4
23	C	27.2	31.8
24	C	27.2	31.8
25	C	30.6	31.8

Table of Pre- and Posttest Skinfold Measures (%)

SUBJECT#	GROUP	PRETEST	POSTTEST
1	W	20.6	20.6
2	W	14.8	16.0
3	W	31.7	30.1
4	W	21.7	25.7
5	W	19.5	21.7
6	W	26.6	26.6
7	W	17.2	16.0
8	W	25.7	26.6
9	RW	25.7	23.7
10	RW	19.5	18.3
11	RW	21.2	22.7
12	RW	26.6	26.6
13	RW	27.2	28.4
14	RW	21.2	19.5
15	RW	20.6	19.5
16	RW	18.3	19.5
17	RW	29.3	30.1
18	RW	23.2	23.7
19	C	22.5	21.9
20	C	26.7	26.2
21	C	18.9	18.3
22	C	24.7	22.7
23	C	28.5	29.8
24	C	17.8	19.5
25	C	14.2	13.6

Table of Pre- and Posttest Hydrostatic Weighing Data (%)

SUBJECT#	GROUP	PRETEST	POSTTEST
1	W	27.6	27.0
2	W	16.6	18.2
3	W	44.6	44.8
4	W	25.9	24.3
5	W	22.7	21.2
6	W	27.1	29.8
7	W	10.2	11.1
8	W	28.6	29.6
9	RW	31.6	28.9
10	RW	22.7	17.9
11	RW	26.7	23.6
12	RW	25.2	25.1
13	RW	25.0	29.9
14	RW	25.1	25.1
15	RW	19.0	20.5
16	RW	17.0	20.4
17	RW	35.2	33.4
18	RW	17.2	22.8
19	C	26.6	26.5
20	C	26.2	26.2
21	C	16.5	13.8
22	C	25.4	24.9
23	C	33.7	32.4
24	C	11.7	14.3
25	C	16.9	16.9

Table of Pre- and Posttest Midpoint Girth Measures (cm)

SUBJECT#	GROUP	PRETEST	POSTTEST
1	W	55.225	55.750
2	W	47.700	48.367
3	W	72.635	70.900
4	W	53.915	55.900
5	W	49.230	50.600
6	W	59.950	59.367
7	W	51.640	51.460
8	W	57.100	56.166
9	RW	60.885	59.200
10	RW	51.750	49.570
11	RW	55.365	56.000
12	RW	57.270	56.600
13	RW	59.015	59.260
14	RW	59.310	60.116
15	RW	51.640	51.800
16	RW	56.265	57.367
17	RW	63.750	62.030
18	RW	56.292	57.367
19	C	56.385	55.930
20	C	62.340	60.980
21	C	50.240	49.467
22	C	63.450	59.800
23	C	56.240	56.730
24	C	53.780	56.400
25	C	50.060	49.930

Table of Pre- and Posttest Girth Measures 1.18 cm Above the Patella (cm)

SUBJECT#	GROUP	PRETEST	POSTTEST
1	W	42.300	43.567
2	W	36.100	37.150
3	W	56.535	56.660
4	W	43.850	46.117
5	W	38.320	38.060
6	W	44.982	45.300
7	W	41.525	41.480
8	W	40.335	40.900
9	RW	45.250	45.000
10	RW	38.750	40.000
11	RW	41.680	42.200
12	RW	42.950	42.860
13	RW	43.310	45.560
14	RW	44.520	45.550
15	RW	41.540	41.300
16	RW	44.625	44.400
17	RW	45.835	45.816
18	RW	42.975	44.580
19	C	41.542	40.950
20	C	46.425	44.830
21	C	38.850	38.433
22	C	46.660	45.380
23	C	45.600	45.760
24	C	39.800	41.000
25	C	37.310	36.770

Table of Weekly Body Weight Measures (kg)*

SUBJECT #	GROUP	PRE	WEEK 1	2	3	4	5	6	7	8	9	POST
1	W	54	53	55	55	55	55	55	55	55	55	55
2	W	47	49	49	49	49	49	50	51	51	51	49
3	W	79	81	81	80	80	81	80	79	78	79	78
4	W	62	63	64	64	64	63	64	64	65	65	66
5	W	55	56	56	56	55	55	56	57	57	58	57
6	W	67	70	68	68	69	69	69	67	68	67	66
7	W	50	52	51	51	51	53	52	53	53	52	51
8	W	56	58	58	57	58	58	58	58	57	57	56
9	RW	75	77	76	76	77	77	75	74	76	76	74
10	RW	49	50	50	50	50	49	50	49	50	49	48
11	RW	61	64	64	64	64	64	64	62	63	63	62
12	RW	69	70	68	67	68	67	67	67	67	67	67
13	RW	71	75	74	74	74	75	74	75	74	74	73
14	RW	57	59	59	59	59	61	59	60	59	60	59
15	RW	51	53	53	53	53	53	53	52	53	54	51
16	RW	61	62	62	63	64	64	64	64	64	65	64
17	RW	72	75	74	73	74	74	74	73	74	75	73
18	RW	54	55	55	55	56	56	57	57	56	56	56

* Subjects were pre- and posttested in their bathing suits

Table of Pre- and Posttest Body Weight Measures (kg)*

SUBJECT#	GROUP	PRETEST	POSTTEST
1	W	54	55
2	W	47	49
3	W	79	78
4	W	62	66
5	W	55	57
6	W	67	66
7	W	50	51
8	W	56	56
9	RW	75	74
10	RW	49	48
11	RW	61	62
12	RW	69	67
13	RW	71	73
14	RW	57	59
15	RW	51	51
16	RW	61	64
17	RW	72	73
18	RW	54	56
19	C	59	59
20	C	73	73
21	C	46	46
22	C	74	73
23	C	58	58
24	C	52	53
25	C	49	48

* Subjects were pre- and posttested in their bathing suits

Table of Subjects' Height and Age

SUBJECT#	GROUP	HEIGHT (cm)	AGE (yrs)
1	W	156.0	21
2	W	164.5	22
3	W	158.5	22
4	W	172.0	22
5	W	173.6	19
6	W	170.5	19
7	W	156.0	22
8	W	166.5	21
9	RW	176.0	19
10	RW	164.0	19
11	RW	168.5	20
12	RW	169.5	21
13	RW	157.5	20
14	RW	166.5	21
15	RW	170.5	20
16	RW	154.0	19
17	RW	158.0	20
18	RW	170.0	22
19	C	163.5	27
20	C	174.0	30
21	C	156.5	21
22	C	159.5	22
23	C	163.0	28
24	C	158.3	22
25	C	159.5	20

APPENDIX H
DATA SHEETS

SKINFOLD DATA--PRE-EXPERIMENTAL

SUBJECT:______________________________ DATE:___________

AGE:________

TEST ADMINISTRATOR:____

	TRICEP	SUPRAILIAC	THIGH
TRIAL 1	______	_______	______
TRIAL 2	______	_______	______
TRIAL 3	______	_______	______
TRIAL 4	______	_______	______
TRIAL 5	______	_______	______

SUM OF 3 SITES (avg. mm):_________ PERCENT FAT:_________

- -

SKINFOLD DATA--POST-EXPERIMENTAL

TEST ADMINISTRATOR:____________________ DATE:___________

	TRICEP	SUPRAILIAC	THIGH
TRIAL 1	______	______	______
TRIAL 2	______	______	______
TRIAL 3	______	______	______
TRIAL 4	______	______	______
TRIAL 5	______	______	______

SUM OF 3 SITES (avg. mm):____________ PERCENT FAT:_______

HYDROSTATIC WEIGHING DATA

CIRCLE ONE: PRE-EXPERIMENTAL POST-EXPERIMENTAL

SUBJECT:____________________________ DATE:__________

TEST ADMINISTRATORS:____

____

WEIGHT (Ma):______________kg

WATER TEMPERATURE (C):_________________

RESIDUAL VOLUME (RV):________________

Value of 10 lb. Weight in Tank (VWT):_____________

TRIALS (#g) [First line is equal to the # of boxes on the graph, the second line is equal to the digital display reading.]

1	________	________	5	________	________
2	________	________	6	________	________
3	________	________	7	________	________
4	________	________	8	________	________

[4.2 kg/VWT = x/#g] = Mh20 = ______________

Dh20 = (look in chart from Katch and McArdle) Dh2o = _______

Body Density (BD)=Ma / [{Ma - Mh2o}/Dh2o] - RV

BD =________/[{_________ - __________}/________] - _________

BD = __________

% FAT = 4.95/BD - 4.50

% FAT = __________%

DATA FOR 1-RM LIFTS

SUBJECT:______________________________ AGE:________

WEIGHT (lb):_____________ (kg):_________________

TEST ADMINISTRATORS:____

____

DATE:_____________________________________

CIRCLE ONE: Pre-Experimental

Week 2

Week 4

Week 6

Week 8

Post-Experimental (end of week 10)

	TRIAL 1	TRIAL 2	TRIAL 3
BENCH PRESS	________	________	________
MILITARY PRESS	________	________	________
ARM CURLS	________	________	________
TRICEP PRESS	________	________	________
LAT PULLS	________	________	________
LEG CURLS	________	________	________
LEG PRESS	________	________	________
LEG EXTENSION	________	________	________

GIRTH MEASUREMENTS

SUBJECT:______________________________ DATE:____________

TEST ADMINISTRATORS:____

CIRCLE ONE: PRE-EXPERIMENTAL--FIRST TEST

PRE-EXPERIMENTAL--SECOND TEST

**** To measure girth, place the tape measure at the top of the iliac crest, and at the top of the patella. Write down the total in inches and centimeters. Next, measure the girth at the midpoint of this measurement and 3 inches above the top of the patella. Always perform 3 trials. Always measure the right leg.****

TOTAL:_______________inches ___________________cm

MIDPOINT:

TRIAL 1 ____________inches ___________cm

TRIAL 2 ____________inches ___________cm

TRIAL 3 ____________inches ___________cm

AVERAGE: ____________inches ___________cm

3" ABOVE PATELLA:

TRIAL 1 ____________inches ___________cm

TRIAL 2 ____________inches ___________cm

TRIAL 3 ____________inches ___________cm

AVERAGE: ____________inches ___________cm

GIRTH MEASUREMENTS -- POST-EXPERIMENTAL

SUBJECT:____

TEST ADMINISTRATORS:____

DATE:______________________________

TOTAL:_______________inches   _________________cm

MIDPOINT:

TRIAL 1	_____________inches	_____________cm
TRIAL 2	_____________inches	_____________cm
TRIAL 3	_____________inches	_____________cm
AVERAGE:	_____________inches	_____________cm

3" ABOVE PATELLA:

TRIAL 1	_____________inches	_____________cm
TRIAL 2	_____________inches	_____________cm
TRIAL 3	_____________inches	_____________cm
AVERAGE:	_____________inches	_____________cm

CALCULATIONS FOR RESIDUAL VOLUME

SUBJECT'S NAME: ____________________________________

TECHNICIAN: ______________________________ DATE: ________

VITAL CAPACITY VALUES (VC) (LITERS):

TRIAL 1	TRIAL 2	TRIAL 3
________	________	________

****TAKE GREATEST VITAL CAPACITY****

AMOUNT OF OXYGEN TO PUT IN ANESTHESIA BAG:

85% x ______ (VC) = _______ Liters

REBREATHING VALUES:

OXYGEN: ____________________% CO_2: _________________________%

RESIDUAL VOLUME (RV) = VO_2 (L) x (b - a)/(c - d)

WHERE:

VO_2 = Volume of O_2 in bag

a = 0%

b = 100 - Total = % N_2 (Total = O_2 + CO_2)

c = 80%

d = .2% + value of b

RV = ________L x (_______ - ________)/(_________ - ___________)

RV = _________L

RESULTS OF THE STUDY

Thank you for participating in this study. We hope that the training and educational sessions were beneficial to you. The following are your personal results. Thanks again!

SUBJECT'S NAME:________________________________

PRE-EXPERIMENTAL RESULTS

PERCENT FAT

HYDROSTATIC WEIGHING:__________% CALIPERS____________%

GIRTH MEASUREMENTS

RIGHT THIGH (midpoint):_________inches _____________cm

RIGHT THIGH (3" above knee):_________inches _____________cm

LEG STRENGTH

LEG PRESS:__________lbs. LEG EXTENSION:____________lbs.

POST-EXPERIMENTAL RESULTS

PERCENT FAT

HYDROSTATIC WEIGHING:__________% CALIPERS_________%

GIRTH MEASUREMENTS

RIGHT THIGH (midpoint):__________inches ____________cm

RIGHT THIGH (3" above knee):_________inches ____________cm

LEG STRENGTH

LEG PRESS:____________lbs. LEG EXTENSION:__________lbs.

VITA

Stella L. Volpe was born on July 31, 1963 in Philadelphia, Pennsylvania. She was raised in a suburb north of Philadelphia called Flourtown. She received a Bachelor of Science degree in exercise science, with minors in physiology and biology, from the University of Pittsburgh, Pittsburgh, Pennsylvania. While at the University of Pittsburgh, she played varsity field hockey. She also met her best friend, Gary Snyder. She graduated from Pitt in April of 1985.

In August of 1985, Stella attended her first year as a Masters student at Virginia Tech. Upon completion of her Masters of Science degree in exercise physiology/cardiac rehabilitation at Virginia Tech, she plans to obtain employment in a hospital-based cardiac rehabilitation program. Following approximately one year of employment, Stella plans to return to school to obtain her doctorate in nutrition or exercise physiology.

Stella L. Volpe