ABSTRACT

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This study was conducted to determine the effects of a circuit weight training program on cardiac patients. Certain variables were chosen to be examined so that safe and effective guidelines for a circuit weight training program for cardiac patients could be established.

Thirteen males and one female from the Phase III and IV Cardiac Rehabilitation Unit of the La Crosse Exercise Program volunteered to participate in an eight week circuit weight training program. Each subject exercised three times a week, performing two sets of 12 to 15 repetitions on each of the seven exercises in the circuit. During the pretest and posttest each subject was tested on two of the seven exercises in the circuit - leg squat and bench press.

After the experimental period there was a 30% increase in strength in the two exercises measured. There was no significant change in resting or exercising heart rate at the end of eight weeks of training. No significant electrocardiographic abnormalities, unique to the weight training exercises, were observed. Two blood pressure measurements, diastolic during recovery from the leg squat exercise and systolic during recovery from the bench press exercise were significantly higher after eight weeks of circuit weight training. These two measurements were significantly lower than measurements taken after a two minute recovery from a maximum graded exercise test.

THE EFFECTS OF A CIRCUIT WEIGHT TRAINING PROGRAM ON HEART RATE, BLOOD PRESSURE AND ELECTROCARDIOGRAPHIC ACTIVITY IN CARDIAC PATIENTS

A Thesis Presented

to

The Graduate Faculty

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In Partial Fulfillment

of the Requirements for the

Master of Science Degree

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by

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CHAPTER I

INTRODUCTION

Training for muscular strength has been a part of the fitness and sports movement for many years. There is substantial research supporting the pros and cons of this type of training for the general asymptomatic adult population. Only recently has there been any interest in the effects of strength training for select populations, such as cardiac patients. At present, the majority of cardiac rehabilitation programs do not include any type of strength training but instead are centered around aerobic exercise and recreational activities. Research has shown, however, that fitness is more than just aerobic conditioning ((Golding, 1980). In order to achieve a well-rounded, overall fitness regimen, upper body conditioning, such as that provided by strength training, should be a part of all exercise programs, including those for cardiac patients.

In order to provide a safe strength training program for cardiac patients, certain restrictions and guidelines need to be established. To date, there have been only a handful of investigations on this topic but few have reported the specific components of establishing an entire program. Each researcher utilized components unique to his/her particular program or population that are not easily transferrable to other situations. A need exists for combining some basic guidelines and parameters from each study to provide an overall interpretation and discussion on the design and implementation of a safe and effective strength/endurance training program for the cardiac population. In combining the findings reported by these other researchers, certain specific parameters need to be investigated and reported. These include but are not limited to: strength, heart rate, blood pressure, and electrocardiographic activity. The changes in these measurements, if any, will help to evaluate the safety and efficacy of a strength training program for cardiac patients.

Purpose of the Study

This study was conducted to provide information which would assist in the design and implementation of a modified strength training exercise program for Phase III and IV cardiac rehabilitation participants. This study investigated four specific components regarding the effects of participating in a strength training program: strength development, heart rate response, blood pressure response, and electrocardiographic changes.

Need for the Study

In developing the parameters for a safe and effective strength training program for cardiac patients, certain background knowledge was necessary to determine what exercises should be included and excluded, what method of testing to utilize, the amount of weight to lift, what type training to implement, etc. Few studies have been done which would give appropriate guidelines to initiate and administer such a program. In combining the current available research on this topic and the results of this study, a more comprehensive guide for implementing strength training programs for cardiac patients can be established.

Hypotheses

In the execution of this research project, the following null hypotheses were tested:

1. At the end of twelve weeks of participation in a muscular strength/endurance training program, there would be no significant difference in the pre and posttest measurements of: a) weight lifted on the leg squat exercise, b) weight lifted on the bench press exercise.

2. At the end of the experimental period, there would be no significant difference in the pre and posttest blood pressure measurements of either the leg squat or bench press exercises at: a) rest, b) immediate post-exercise, c) one minute recovery.

3. At the end of the experimental period, there would be no significant difference in the pre and posttest heart rate measurements of either the leg squat or bench press exercises at: a) rest, b) exercise, c) one-minute recovery.

Assumptions

The following assumptions made for this research project were:

1. Subjects exercised to the best of their ability when performing the required tests and training.

2. Subjects did not alter their daily aerobic exercise or medication schedule.

3. All testing equipment was calibrated and functioning properly.

Delimitations

The following delimitations set by the researcher included:

1. Subjects were members of the Phase III and IV Cardiac Rehabilitation Unit of the La Crosse Exercise Program.

2. Subjects were required to have their physician's written permission to participate in the program.

3. Subjects performed two sets of fifteen repetitions on each of the seven exercises during each exercise session. These exercises were: leg squat, bench press, leg extension, lat pulldowns, leg curl, bicep curl, and pullover.

4. Subjects trained consistently, attending 70% of the exercise sessions during the eight weeks of training.

5. All subjects were tested with submaximal lifts instead of a one-repetition maximum lift.

6. Subjects were tested on only two exercise stations; one upper body evaluation - the bench press, and one lower body evaluation - the leg squat.

Limitations

The following limitations which were beyond the control of the researcher but in some way may have affected the outcome of the study included:

1. The previous conditioning of the subjects relative to weight training.

2. The temperature and humidity of the testing environment and its influence on heart rate and blood pressure.

Definition of Terms

Blood Pressure - the pressure exerted by the blood upon the walls of the blood vessels, especially the arteries (Woolf, 1981).

Cardiac Patients (Phase III & IV) - asymptomatic patients with known coronary heart disease and physically active persons with stable status (healed myocardial infarction, angina pectoris, pulmonary disease or claudication) (ACSM, 1982).

Heart Rate - the number of complete ventricular contractions per minute as counted from records of electrocardiograms or telemetry (Woolf, 1981).

Isokinetic Exercise - exercise or a series of exercises in which a muscle varies its length in a concentric and eccentric movement against a varied resistance at a preselected speed of movement (Klafs & Arnheim, 1977).

Isometric Exercise - exercise or a system of exercises in which opposing muscles are contracted against one another but no movement occurs in the joint involved (Klafs & Arnheim, 1977).

Isotonic Exercise - exercise or a system of exercises in which the muscle varies in length when activated against a set resistance (Klafs & Arnheim, 1977).

Muscular Endurance - a measure of a muscle's or muscle group's ability to continue exercising with a given submaximal workload (Wescott, 1982).

Repetitions - the number of times an exercise bout is performed in succession (Wescott, 1982).

Set - the number of individual exercise bouts performed (Wescott, 1982).

Strength - the force that a muscle or muscle group can exert against a resistance in one maximal effort (Fox & Mathews, 1981).

Universal Gym - a manufacturer of an isotonic exercise machine that provides a variety of exercise stations at which smooth running weight stacks are lifted by lever and pulley attachments (Wescott, 1982).

Valsalva Maneuver - a straining against a closed glottis which may cause sufficient positive pressure to impede blood flow to the heart (Woolf, 1981).

CHAPTER II

REVIEW OF LITERATURE

This chapter reviews current literature pertaining to cardiac rehabilitation, exercise and weight lifting. The parameters of the strength endurance training program utilized in the present investigation are drawn from the related research presented here.

This chapter is divided into the following sections: 1) a description of cardiac rehabilitation; 2) discussion of weight training programs for cardiac patients; 3) interpretation of hemodynamic responses to weight training; 4) examination of types of weight training programs; 5) investigation of strength testing procedures; and 6) explanation of designing a strength training program.

Cardiac Rehabilitation

In the last ten to 15 years, society has seen the emergence of an entirely new type of medical therapy - rehabilitation outside of the hospital environment. Phase III and IV cardiac rehabilitation programs are typical of this type of rehabilitation. There are several different purposes of such a program including: educating the patient about his/her particular medical situation; designing and implementing a personalized exercise prescription; and motivating the patient towards maintaining newly acquired "good" habits of diet, exercise and lifestyle. Skepticism remains in the medical community concerning the benefits of exercise for cardiac patients whether in a hospital or a private setting, though research has shown some definite obtainable benefits. These benefits include: weight loss (Barnard, Guzy, Rosenberg, & O'Brien, 1983; Beissel & Woffard, 1982; Hartung & Rangel, 1981), decreased resting blood pressure (Blumenthal, Calliff, Williams, & Hindman, 1983; Wilhelmson et al., 1975) and heart rate (Atwood et al., 1980; Cunningham, Ingram, & Rechnitzer, 1979; DeMaria, Neuman, Lee, Fowler, & Mason, 1978), increased ejection fraction (Jensen et al., 1980), decreased pulmonary ventilation (Wilhelmson, et al., 1975), increased stroke volume (Patterson, Shepard, Cunningham, Jones, & Andres, 1979; Waites, Watt, & Fletcher, 1983), increased maximal oxygen consumption (VO_2 max) (Atwood et al., 1980; Hartung & Rangel, 1981; Oldridge, Nagle, Balke, Corliss, & Kahn, 1978; Patterson et al., 1979), increased MET levels (Laslett, Baier, Paumer, & Amsterdam, 1983; Miller et al., 1978), and increased exercise tolerance capacity (Costill, Branam, Moore, Sparks, & Turner, 1974; DeMaria et al., 1978; Froelicher, 1980; Jensen et al., 1980; Robinson, Froelicher, & Utley, 1984).

Ehsani, Martin, Heath and Coyle (1982) investigated the effects of prolonged exercise training in eight men with coronary artery disease. The mean age of the subjects utilized was 52 $\pm$ years. Training consisted of aerobic exercise performed three times a week for 30 minutes, progressively increasing from 50% to 80% VO_2 max. After a 12 month training period, Ehsani et al. (1982) found a decrease in resting and submaximal heart rate and systolic blood pressure at a given workload. A 42% increase in VO_2 max was also observed from program participation.

Bruckerhoff and LaFontaine (1984) studied some additional exercise benefits for coronary artery disease patients after coronary artery bypass surgery. The training consisted of 24 minutes of aerobic exercise utilizing a treadmill, steps, rowing machine and combined arm and leg ergometry. The subjects trained at 85% of symptom-limited maximal heart rate reserve. These researchers examined the changes in maximal MET levels and rate pressure products, as well as percent body fat alterations. All patients showed a significant increase in peak METS from 7.5 ($\pm$ 2.6) to 12.2 ($\pm$2.8). Rate pressure product at 7.2 METS decreased from 193 ($\pm$ 32) to 130 ($\pm$ 32). Maximal oxygen uptake increased in all subjects after the experimental period. In summary, the researchers stated that aerobic circuit training resulted in significant improvements in the cardiovascular fitness of coronary artery disease patients who had undergone coronary artery bypass graft surgery.

The majority of research studies indicate that cardiac rehabilitation programs provide excellent aerobic benefits for the patient. There is little research, however, which indicates the benefits or risks of any other type of exercise for the cardiac patient. Weight training, in adult fitness populations, has been shown to provide excellent muscular strength and endurance benefits while also possibly contributing to a higher sense of self-esteem and self-confidence. Thus, weight training programs designed for cardiac patients may also supplement the benefits obtained in their aerobic based exercise regimen.

Weight Training Programs for Cardiac Patients

The few existing studies investigating weight training programs for cardiac patients have provided valuable insight into the design and implementation of this type of program in the cardiac rehabilitation setting. Saldivar, Frye, Pratt and Herd (1983) studied the safety of a low-weight, low-repetition strength training program in patients with heart disease. These researchers observed the heart rate, blood pressure and electrocardiographic (ECG) responses of cardiac patients participating in a strength training program. The prescription for the program was based on the patient's prior history of strength work and any orthopedic limitations. The researchers compared the heart rate, blood pressure and electrocardiographic responses of strength training to those of dynamic exercise at the same heart rate level. The results were as follows: 1) all subjects participated in the strength training program with no symptoms; 2) no arrhthmias or ST-segment changes were observed during strength training that were not noted during dynamic exercise; 3) heart rate and systolic blood pressure responses were lower during strength training than during dynamic exercise; and 4) there was no change in the resting diastolic blood pressure as a result of the strength training program. Saldivar et al. (1983) concluded that a low-weight, low-repetition strength training program can be safe for individuals with heart disease.

Keleman et al. (1984) conducted a similar study with cardiac patients engaged in a circuit weight training program. The researchers compared a combined circuit weight training and jogging program to a jogging and volleyball control group. The weight training group performed two sets of 12 to 15 repetitions on ten exercise stations. The results of the study found that the weight lifting group had a 12% increase in treadmill time over the control group. The control group showed a strength increase at only one of the ten exercise stations while the weight training group had a 24% increase at seven out of eight stations. Exercise monitoring revealed only isolated premature ventricular contractions (PVC's), with the heart rate not exceeding the exercise prescription rate. The researchers concluded that:

> Circuit weight training appears to be safe and resulted in greater increases in endurance and strength as compared to traditional programs. Furthermore, circuit weight training was enjoyed by the patients and its variety and efficacy adds a new dimension to cardiac rehabilitation programs (p. 128).

Another study concerning weight training for cardiac patients examined the psychological impact of such a program. Ewart et al. (1984) evaluated the self-confidence enhancing effects of a circuit weight training versus walking/jogging program in 40 patients with documented coronary artery disease. The subjects completed self-efficacy scales which measured perceived ability to perform various day to day activities using the arms or legs. At the end of ten weeks of circuit training, the experimental group showed larger increases in upper body self-efficacy as compared to the non-weight lifting controls, which was consistent with the significant increases in strength found in the lifting group. Ewart et al. (1984) made the following conclusions concerning circuit weight training programs for cardiac patients: 1) it is a safe, simple way to increase self-confidence in the cardiac patient; 2) circuit weight training further increases the patient's self-perceived ability to perform activities of daily living; and 3) for those patients already participating in some type of walking or jogging program, the obtained benefits are more specific to upper body exercises because these muscles are less emphasized during walking/jogging.

Harris and Holly (1985) conducted a study which investigated the physiological responses of borderline hypertensive subjects to a circuit strength training program. The subjects performed a circuit consisting of ten exercise stations, completing 20 to 25 repetitions at each station. Heart rate and blood pressure measurements were taken at various times throughout the exercise session. At the conclusion of the training program, upper and lower strength were increased, as assessed by 12% and 53% gains found in the bench press and leg press, respectively, and by a 62% increase in total weight lifted per circuit. Muscular and cardiovascular endurance, determined by an arm VO_2 max test, improved by 28% and lean body mass was increased by 2%. Blood pressures and heart rates, at rest and during exercise, did not change after completing the training. The researchers concluded that circuit weight training is a safe and effective addition to an exercise program for borderline hypertensives. Also of significance was that this type of training did not appear to help in reducing blood pressure.

Vander, Franklin, Wrisley and Rubenfire (1985) performed a study comparing the electrocardiographic and hemodynamic responses between Nautilus training and maximal graded exercise testing (GXT) in cardiac patients. The Nautilus training consisted of 13 exercise stations, with the patients performing 12 repetitions at each station. The researchers compared heart rate, blood pressure, double product and ECG responses during strength training to those same parameters during maximal graded exercise testing. Numerous results were obtained following data collection and analysis. Nautilus peak heart rates were found to be only 60 to 64% of the treadmill maximal heart rates. The highest double product achieved during weight lifting was only 44 to 62% of that occurring during maximal treadmill testing. Diastolic blood pressure values during peak Nautilus training were 100 to 135% of the values obtained during exercise testing. Resting diastolic pressures increased from approximately 74 to 102 mmHg. There were no significant arrhythmias, ST-segment depression or symptoms observed during Nautilus training but the following were reported during GXT on the same subjects: eight individuals with positive ECG responses, eight with arrhythmias, three with anginal responses and four with abnormal hemodynamic responses. After completing this study, the researchers concluded that Nautilus training is relatively safe for cardiac patients and serves as a valuable addition to their aerobic conditioning program.

When working with cardiac patients, medications play an important role in the patient's exercise prescription. Stewart et al. (1983) examined the effect of beta blockade on circuit weight training in individuals with cardiovascular disease. The researchers, realizing that the training capabilities of patients on beta blockade may possibly be blunted, compared eight patients who were beta blocked to eight patients who were not to determine what degree of impairment might exist. All the patients participated in a ten station circuit weight training program performing two sets of 15 repetitions at each station. They lifted three times a week for a total of ten weeks. After completing the study, the subjects were found to have increased their mean treadmill time from 10.3 to 11.6 minutes and their strength capabilities by 20%. The researchers made the following conclusions from evaluating the data: 1) circuit weight training produces a significant aerobic and strength conditioning effect; and 2) those patients who are beta blocked will have slightly diminished, but still valuable, effects from participating in a circuit weight training program as compared to patients not on beta blockade.

Hemodynamic and Electrocardiographic Responses to Weight Training

A major concern in utilizing strength/endurance training with cardiac patients is safety. Medical doctors and program directors have questioned the appropriateness of the electrocardiographic and hemodynamic responses occurring during weight lifting. Isometric exercise can elicit Valsalva Maneuvers, contraindicated for individuals with various cardiovascular disorders. The Valsalva maneuver has long been recognized to have a detrimental effect on blood pressure and venous return, especially in the cardiac population. Several studies have evaluated the blood pressure and ECG changes occurring in cardiac populations during types of weight training.

Porth, Bamaah, Tristani and Smith (1984) investigated the mechanisms and clinical implications of the Valsalva maneuver. She suggested that there are apparently four phases of the maneuver and that each phase has its own individual blood pressure and heart rate responses. Phase I is the first three beats at the beginning of the strain and shows a definite increase in both the systolic and diastolic pressures. Heart rate changes are often variable during this stage. Phase II is an average of the last three beats of the strain and reveals a reversal of the increased blood pressures found in Phase I. Within the first six to seven seconds of strain, the heart rate shows a significant increase. Phase III is an average of the first three beats after strain release. The arterial blood pressure falls drastically and there is a small increase in heart rate. The final Phase, IV, is an average of the three slowest consecutive beats after strain and results in an increase in total peripheral resistance and therefore an increase in arterial pressure. At this time, three to eight seconds post-strain, the heart rate slows down again. These findings support the concern of detrimental changes occurring in heart rate and blood pressure from the performance of a Valsalva maneuver by cardiac patients.

Ewing, Kerr, Legget and Murray (1976) investigated the cardiovascular responses to a sustained handgrip and a Valsalva maneuver in five men with untreated mild hypertension. These researchers found that at the end of the handgrip period in which the Valsalva maneuver was performed, the blood pressure was higher and the heart rate lower than when the subjects performed the sustained handgrip without the Valsalva maneuver. In conclusion, the researchers stated that in view of its effect on the blood pressure and heart rate, the performance of a Valsalva maneuver during sustained handgrip or any other type of straining exercise should be avoided.

Kivowitz et al. (1971) also studied the effects of isometric exercise in 22 patients with coronary artery disease. In this investigation, the patients were monitored via an intra-arterial catheter while performing an isometric handgrip exercise. The researchers noted increases in arterial pressure (avg. 87 to 104 mmHg), coronary sinus blood flow, myocardial oxygen consumption (+45%) and systemic valvular resistance. It was observed that those patients with good left ventricular function had fewer problems in performing this type of exercise than did patients with poor left ventricular function.

Hemodynamic responses to isotonic weight training have proven to be much safer than those responses found with isometric training. Greer, Dimick and Burns (1984) investigated the heart rate, blood pressure and rate pressure product responses to several different methods of strength training in a normal population. These variables were determined for five subjects performing five different strength training exercises at 75% and 100% of their maximum voluntary contraction (MVC). The exercises included both isometric and isotonic exercises with free weights. During all of the exercises, blood pressure and rate pressure product increased, while heart rate increased in most of the exercises. Rate pressure product was highest for those exercises performed at 100% MVC. The exercise which produced the smallest increases in heart rate, blood pressure and rate pressure product was an interrupted isotonic weight training regimen, similar to what is found in circuit weight training programs.

Blomqvist, Lewis, Taylor and Graham (1981) studied the similarity of hemodynamic responses to static and dynamic exercise of small muscle groups. The subjects, healthy "normals", performed upright submaximal and maximal dynamic exercises of four different types: 1) one-arm curl, 2) one-leg bicycle exercise, 3) one-arm bicycle exercise, and 4) two-leg bicycle exercise. The results showed that the "magnitude of the active muscle mass is a more important determinant of the cardiovascular response than the mode of contraction, i.e., static versus dynamic" (Blomqvist et al., 1981, p. 90). Thus, the researchers suggested that the differences between static and dynamic exercise become fewer as the size of the muscle being exercised is reduced.

A study by Freedson et al. (1984) investigated intra-arterial blood pressure during free weight and hydraulic resistive exercise. Blood pressure was monitored continuously with a pressure transducer/femoral artery catheter. Ten repetitions of bench press free weight exercise at 25% and 50% of a maximum voluntary isometric contraction were performed. Their results indicated that under certain conditions this type of exercise can produce blood pressure responses close to hypertensive levels. It is important, therefore, to closely monitor the blood pressure response during any type of exercise involving weight training.

Atkins, Matthews, Blomqvist and Mullins (1976) investigated the incidence of arrhythmias during isometric versus dynamic exercise. The number of arrhythmias occurring during isometric handgrip was compared to bicycling in a group of 45 patients with various forms of heart disease. None of the subjects were on any type of anti-arrhythmic drug. The researchers found that atrial arrhythmias were equally common during the handgrip and bicycle exercise but ventricular arrhythmias were more frequent during handgrip exercise. Patients with coronary artery disease and/or depressed left ventricular function developed twice the incidence of ventricular arrhythmias with isometric exercise as compared with dynamic exercise. Also noted was that all patients who developed arrhythmias did so at 50% or more of their maximal voluntary contraction.

Gettman, Ayres, Pollock, Durstine and Grantham (1976) studied the physiological effects of circuit strength training on adult males. The program consisted of performing two sets of 11 isokinetic exercises three times a week for ten weeks. Their data found that circuit weight training showed significant increases in treadmill time, VO_2 max, and maximal ventilation (VE max). There were also significant decreases in maximal and resting heart rate. The researchers noted significant reductions in percent body fat, fat weight and the sum of six different skinfolds. The strength program, as expected, showed significant increases in strength while the control jogging group experienced decreases in strength.

Types of Weight Training Programs

In structuring a modified muscular strength/endurance exercise program, a review of the wide variety of options for this type of training is necessary to determine the most appropriate method to use. There are basically three major methods of training any muscle group: isometrics, isotonics or isokinetics.

Isometric Exercise

> Isometric exercise - is one that generates heat and energy by forcefully contracting the muscle in a static position, that is with no change in the length of the muscle or in the angle of the joint at which the contraction occurs. This type of exercise has been shown to be most effective when the person holds a maximal contraction for five seconds and repeats the procedure 5-10 times daily (Klafs & Arnheim, 1977, p. 71).

The advantage of this method of developing muscular strength and endurance is that no equipment is necessary and the exercises can be performed anywhere at any time. The major limitation of isometric exercise is that it strengthens the muscle at only one angle in its entire range of movement. A large variety of exercises have to be performed in order to strengthen the muscle throughout its movement range. Another important disadvantage of this method is that studies have shown isometric exercises to cause the highest increases in blood pressure of the three strength methods (Greer et al., 1984).

Isotonic Exercise

> Isotonic exercise - involves either shortening or lengthening the muscle throughout its complete range of motion. It entails the moving of a resistive force, either a part of the body or some extraneous object. These exercises are known as progressive resistance exercises (PRE) and were first introduced by DeLorme and Watkins in the late 1940's (Klafs & Arnheim, 1977, p. 71).

An advantage of this type of training is its superiority to the isometric form of training for the development of strength and endurance. Isotonic exercise results in a more rapid rate of recovery than does isometric exercise. It also has the lowest risk of injury of any of the strength training methods.

Isokinetic Exercise

> Isokinetic exercise - employs total involvement of the muscle fibers inasmuch as the resistance varies according to the angle of the pull and the degree of fatigue developed throughout the exercise. These adjustments are made automatically by means of a special device which monitors the contractions and varies the resistance so that it is constant and consistent (Klafs & Arnheim, 1977, p. 71).

This type of progressive resistance exercise is undoubtedly the best because it trains the muscle near maximally throughout its entire range of movement and varies the workload based on the strength of the muscle. The disadvantage of this training method is that it is the least feasible for the general population. The equipment necessary to perform this exercise, such as Cybex, is very expensive to purchase and maintain for general usage, and thus not readily accessible.

Summary

Figure 1 represents a comparison of the strength and endurance gains which can be obtained from isometric, isotonic and isokinetic programs (Fox & Mathews, 1981). Additionally, Table 1 provides a summary of the advantages and disadvantages of each method (Lamb, 1984).

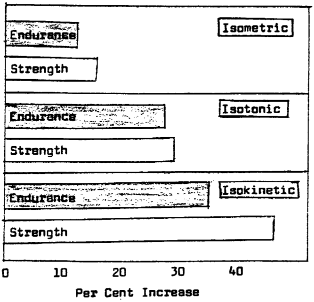

Figure 1. A comparison of muscular strength and endurance gains achieved by isometric, isotonic, and isokinetic weight programs.

Table 1

Summary of Advantages of Isokinetic, Isotonic, and Isometric Training Methods

Criterion	Type of Training		
	Isokinetic	Isotonic	Isometric
Rate of Strength Gain	1	1	2
Strength Gain Throughout Range of Motion	Excellent	Good	Poor
Time per Training Session	2	3	1
Expense	3	2	1
Ease of Performance	2	3	1
Ease of Progress Assessment	Expensive Equipment Required	Excellent	Dynamometer Required
Adaptability to Specific Movement	1	2	3
Probability of Soreness	Little Soreness	Much Soreness	Little Soreness
Probability of Musculo-skeletal Injury	Slight	Moderate	Slight
Cardiac Risk	Some	Slight	Moderate
Skill Improvement	Some	Some	None

Note: A rating of 1 is superior, 2 is intermediate, and 3 is inferior.

(Taken from Lamb, 1984, p. 280)

Strength Testing

Standardized strength/endurance testing protocols are not presently available for the cardiac population. Researchers, reporting primarily in abstract form, have not elucidated the specific means by which they performed their testing or prescribed their strength/endurance exercises. As well, little rationale of methodology exists.

In establishing the initial testing resistance for a particular weight training program, the amount of weight utilized is often arbitrarily decided. The most common method of determining a testing or initial lifting weight for a strength measurement is to use the one-repetition maximum technique (Klafs & Arnheim, 1977; O'Shea, 1976; Wescott, 1982). With this procedure, a weight load that a subject can lift for just one repetition is decided by trial and error. There is no established formula for determining this weight based on a person's body weight, age, gender, etc. Once the initial testing/lifting weight load has been decided through a one-repetition maximum, a daily exercise prescription is established.

O'Shea (1976) recommends that a subject should perform 12 to 15 repetitions for achieving muscular endurance. Thus, in measuring muscular strength/endurance or determining an initial weight load, this author suggests using a set percentage of the individual's body weight and having him/her perform a predetermined number of repetitions (15 to 20). The following percentages are proposed for use in testing but may be modified in special situations where the load may be too heavy (i.e., cardiac patients or other special populations): 1) leg squat exercise 90% of body weight for men and 60% of body weight for women; and 2) bench press exercise 60% of body weight for men and 40% of body weight for women. An exercise prescription is then established based on the results.

The testing methods used with cardiac patients are not clearly described in many studies. Those few with better clarification indicated utilization of a one repetition maximum lift but exact procedures were not available.

Designing the Strength Training Program

Once the general method to be utilized for training has been chosen and the initial testing completed, an exercise prescription and strength training program must be developed. Circuit weight training is the most widely recommended program for the beginner. This offers a complete, well-rounded exercise routine in a minimal amount of time.

The specific protocol for obtaining isotonic strength and endurance gains varies greatly from isometric and isokinetic protocols (see Table 2, Lamb, 1984, pp. 274-278). The exercise session is comprised of performing a certain number of sets and repetitions of each exercise, as well as allotting time for rest. The general consensus for achieving combined isotonic strength and endurance gains suggests a minimum of 15 repetitions (Vitale, 1973). Wescott (1982), however, recommends performing a ten-repetition maximum, which is approximately 75% of the individual's one repetition maximum. The ten repetition maximum, states Wescott (1982), is heavy enough to promote strength development and light enough to allow 45 seconds of actual lifting time, which is ideal. One to three sets of each exercise is recommended for the most beneficial gains (Knuttgen, 1976; O'Shea, 1976; Vitale, 1973; Wescott, 1982).

Table 2

Comparison of Isometric, Isotonic and Isokinetic Weight Training Protocols

	Isometric	Isotonic	Isokinetic
Days/week for strength/endurance gains	5-7	3-4	4-5
Sets	——	2-4	——
Repetitions	5-10	10-12	5-10
Recovery between Sets	2-3 mins.	5-10 mins.	5-10 mins.
Strength Maintenance	1 x week	2 x week	1-2 x week

(Taken from Lamb, 1984)

Choosing the rest interval between exercises and sets is somewhat more difficult as there is little current research on this topic. Resting of muscle groups can be achieved by several different means. According to Wescott (1982), when completing a circuit of exercises instead of several sets of one exercise, the rest period between each exercise can be quite short (30 seconds to one minute) because each exercise utilizes a different prime mover muscle group. Thus, when performing a circuit of exercises, the individual alternates the muscle group being utilized at each station thus allowing a "rest period" for that particular set of muscles. Three workouts per week with a day of rest in between is the usual for beginners.

The order of the circuit should be designed so that opposing muscle groups (i.e. bicep/tricep or quadricep/hamstring) can be exercised consecutively, allowing for an optimal training effect. The exercises to be included should encompass the major body parts, shoulders, back, arms, chest and legs and their respective muscle groups.

Summary

The literature reviewed within this chapter indicates the importance of several factors regarding the implementation of a strength training program for persons with cardiovascular disease. Ideally, this type of program should serve as an adjunct to the cardiac patient's aerobic exercise session. If properly designed and supervised, weight training programs appear to be as safe as aerobic exercise programs. In choosing the type of program to be employed, it appears that isotonic training is the most widely used and the most feasible for producing muscular strength and endurance gains in the cardiac population. Measurements which need to be taken throughout the training period include, but are not limited to, heart rate, blood pressure, and electrocardiographic responses. Careful consideration should be given to proper breathing and lifting techniques to avoid performing a Valsalva maneuver. Overall, it appears that with appropriate guidelines and restrictions a strength training program can be a safe and beneficial addition to most cardiac rehabilitation programs.

CHAPTER III

METHODS

This study was conducted to demonstrate that cardiac patients participating in an exercise program for muscular strength/endurance could achieve significant gains without experiencing any detrimental effects relative to blood pressure or heart rate. Previously, it had been believed that cardiac patients should not participate in any type of strength development program because of the possibility of high blood pressure responses or ectopic beats. The goal of this study, therefore, was to determine the effect of a strength/endurance training program on heart rate, blood pressure and electrocardiographic activity.

This chapter is divided into the following sections: 1) selection of subjects, 2) description of exercise stations, 3) subject orientation, 4) testing equipment, 5) testing procedures, 6) parameters measured during exercise testing, 7) exercise testing and training rationale, 8) exercise prescription, 9) daily training sessions, 10) posttest and 11) data analysis.

Selection of Subjects

The subjects utilized in this study were volunteers from the Phase III and IV Cardiac Rehabilitation Unit of the La Crosse

Exercise Program, La Crosse, Wisconsin. There were 13 males and one female ranging in age from 40 to 72 years. All subjects were involved in the unit for a minimum of three months prior to the start of this study. Volunteers were recruited through memos and posters advertising the muscular strength_endurance training program. The subjects were required to complete an informed consent after being instructed on the details of the program (Appendix A). A letter was sent out to each subject's personal physician requesting permission to participate. This letter contained details of the program components as well as an explanation of the pretest and posttest procedures (Appendix B). Included with the cover letter was a permission slip which had to be completed, signed by the physician and returned to the researcher before the subject could participate in the program (Appendix C). The sample size was 16, with the subjects serving as their own controls.

Description of Exercise Stations

The program developed consisted of seven exercises for muscular strength/endurance training, utilizing Universal weight training equipment. These seven exercises were chosen for the following reasons:

1. Time - the subjects needed to perform these exercises in a 20 to 30 minute time frame.

2. Ease of Learning - when dealing with a population unfamiliar with this type of training, teaching a larger number

of exercises would have been time consuming, confusing to the subject and unnecessary.

3. Exercising the Major Muscle Groups - these particular seven exercises were chosen because they represented the most well-rounded, overall training regimen.

The following is a brief description of the exercise performed at each station on the circuit (Universal Weight Training Equipment Co., 1984):

Station #1

This station was a Universal Centurion Dynamic Variable Resistance (DVR) Leg Squat Machine (Model #9447). To perform this exercise, the subject started with the shoulders placed under the pads, the knees flexed to a 90 degree angle and feet flat on the platform, shoulder-width apart. The subject, then, concentrated on extending the legs as he/she moved to an erect position. The back was held straight and erect throughout the movement. The subject exhaled as he/she stood up. The exercise was completed as the subject fully extended the legs and then in a controlled manner released the weight back to its original position, (See Figures 2 and 3).

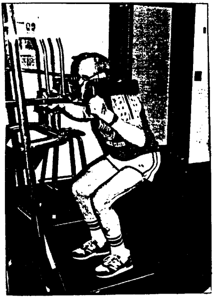

Figure 2. Start of Leg Squat Exercise.

Figure 3. Finish of Leg Squat Exercise

Station #2

This station was a Universal Centurion DVR Chest Press (Model #9024). The subject began this exercise lying supine on the bench with his/her head towards the stack of weights, the knees bent, and feet placed on the end of the bench. To start the exercise, the subject loosely gripped the handles and pressed the weight upward. The subject exhaled as the weight was being raised. The subject fininshed with the arms fully extended and then slowly released the weight back to its original position (see Figures 4 and 5).

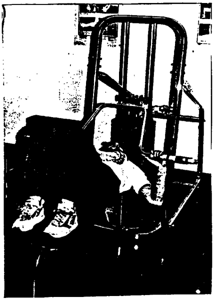

Figure 4. Start of Bench Press Exercise.

Figure 5. Finish of Bench Press Exercise.

Station #3

This station was a Universal Centurion DVR Leg Extension Machine (Model #9033). The subject sat facing forward on the chair with the back fully supported. The ankles were placed under the roller pads and the feet were dorsiflexed. To perform the exercise, the subject extended the legs from a 90 degree angle to 180 degrees and then slowly released the weight back to its original position. The subject exhaled as the legs were extended (see Figures 6 and 7).

Figure 6. Start of Leg Extension Exercise.

Figure 7. Finish of Leg Extension Exercise.

Station #4

This station utilized a Universal Standard Resistance (SR) Free Standing High Pulley (Model #9259). The exercise performed at this station was a latissimus pulldown. The subject was seated facing the stack of weights, knees bent to a 90 degree angle and feet flat on the platform. To perform this exercise, the subject loosely gripped the padded portion of the handlebars and then pulled the bar down towards the body. To complete the exercise, the subject lightly touched the middle of the bar to the nape of the neck and then slowly released the weight back to its original position. As the bar was pulled down, the subject leaned forward slightly and exhaled (see Figures 8 and 9).

Figure 8. Start of Latissimus Pulldown Exercise.

Figure 9. Finish of Latissimus Pulldown Exercise.

Station #5

This station was a Universal Centurion DVR Leg Curl (Hamstring) Machine (Model #9449). To perform this exercise, the subject laid face down on the bench with his/her head towards the stack of weights. The knees extended off the end of the bench and the heels were placed under the roller pads. The subject began by pulling his/her heels toward the bottocks.

The exercise was completed when the subject pulled the roller pads as close to the buttocks as possible and then slowly released the weight back to the starting position. Subject exhaled as the weight was lifted (see Figures 10 and 11).

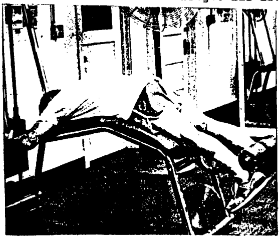

Figure 10. Start of Leg Curl Exercise.

Figure 11. Finish of Leg Curl Exercise.

Station #6

This station utilized a Universal Standard Resistance Free Standing Low Pulley (Model #9258). The exercise performed at this station was a standing bicep curl. The subject stood on the platform, facing the stack of weights with the feet shoulder-width apart. To begin the exercise, the subject loosely gripped the bar and held the arms extended at his/her sides. While keeping the elbows close to the body, the subject flexed the bicep pulling the bar up and towards the chest. The exercise was finished when the subject touched the bar to the chest and then slowly released the weight until the arms were fully extended again. The back was kept straight and still throughout the movement. The subject exhaled as the bar was pulled up and towards the chest (see Figures 12 and 13).

Figure 12. Start of Bicep Curl Exercise.

Figure 13. Finish of Bicep Curl Exercise.

Station #7

This station was a Universal Centurion DVR Pullover Machine (Model #9879). The subject was positioned sitting in the chair facing forward. The subject's head was even with the top of the chair and was relaxed back against the padding. The subject reached behind the head to grasp the curved portion of the handlebars. The subject began the exercise by pointing the elbows forward and pulling the bar over the head. To complete the exercise, the subject continued to pull the bar forward and down until it touched midchest, then slowly released the weight back to its original position (see Figures 14 and 15).

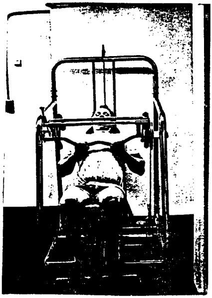

Figure 14. Start of Pullover Exercise.

Figure 15. Finish of Pullover Exercise.

Subject Orientation

Since the muscular strength/endurance exercise program was a new addition to the subject's exercise prescription, an orientation to this type of training was added to this study.

All subjects participating in this program also participated in a two week orientation period prior to the pretest. The following procedures were administered during the six orientation sessions:

Session 1 - The subject received one-on-one instruction for each piece of exercise equipment. The subject performed 3 to 4 repetitions on each machine using the lightest weight setting allowed by the machine.

Session 2 - The subject received instruction on proper lifting and breathing techniques for each machine, performing ten repetitions of each exercise. Heart rate and blood pressure were measured after the third exercise station and again after the last exercise station.

Session 3 - All subjects were instructed on how to record their exercise sessions (i.e., weight lifted, sets, repetitions, heart rate, blood pressure and body weight) on their record card (see Appendix D). Subjects then performed one set of 12 repetitions on each exercise machine. Heart rate and blood pressure were measured at the same times as in Session 2.

Session 4 - The subjects progressed through the exercise circuit at their own pace, pausing for a 30 second rest between each station. During this session, the subjects performed one set of 15 repetitions at each exercise station. Heart rate and blood pressure were measured at the same intervals as the previous sessions.

Session 5 - The subjects performed two sets of ten repetitions at each exercise station, with a five minute rest period between sets. Heart rate and blood pressure measurements were made at the end of each set of exercises.

Session 6 - This was the final orientation session that the subjects had before performing the exercise pretest. At this session, the subjects performed two sets of 15 repetitions at each exercise station, still using only the first weight plate on each machine. Heart rate and blood pressure were measured after each set of seven exercises.

Testing Equipment

During the course of this study, the following equipment was utilized for evaluation purposes:

1. A PhysioControl LifePak 6 Electrocardiographic Recorder, four lead cable and Medi-Trace Offset electrodes were used for all electrocardiographic monitoring and recording.

2. A standard anaeroid sphygmomanometer and stethoscope were used for all blood pressure measurements.

Testing Procedures

The following procedures were established and utilized for each test:

1. Explain testing procedures to subject.
2. Have subject read and sign informed consent.

3. Prep subject for ECG recordings of a V5 lead and three standard limb leads.

4. Take resting electrocardiographic recording and blood pressure measurements.

5. Take patient history and complete testing form (Appendix E).

6. Have subject get into position on exercise apparatus.

7. Subject begins exercise when ready, with electrocardiographic recording initiated by subject movement.

8. Subject completes up to 15 repetitions.

9. Within 30 seconds of completing the final repetition, an immediate post-exercise blood pressure measurement is taken.

10. Subject recovers for one minute, followed by another electrocardiographic recording and blood pressure measurement.

11. Subject rests in a chair for five minutes before beginning final exercise. Electrocardiographic readout is monitored but not recorded unless some abnormality is observed during this period of time.

12. Testing procedures repeated for final exercise.

Parameters Measured during Exercise Testing

During the pretest and the posttest, the same parameters were measured so that any changes occurring over the course of the study could be noted and analyzed. The parameters measured were heart rate, blood pressure, electrocardiographic changes, and amount of weight lifted. The following is a breakdown of how and when each of these parameters were measured:

Heart Rate - was determined from the electrocardiographic recording. It was measured for a 12 second period at rest, during exercise and after a one-minute recovery period. Heart rate was determined by multiplying the number of R waves in 12 seconds times five.

Blood Pressure - was measured by the auscultation method using an anaeroid sphygmomanometer. Systolic and diastolic measurements were made at rest, within 30 seconds of performing each exercise test and after a one-minute recovery from each exercise test.

Electrocardiographic Recordings - were made of any arrhythmias noted at rest, during exercise or in recovery using a V5 lead in combination with the three standard limb leads. A Physiocontrol LifePak 6 Electrocardiographic Recorder was used for the recordings.

Amount of Weight Lifted - was determined, in pounds, by the individual plate settings on each machine and the body weight of the individual. The weight load for each exercise was placed at the weight setting closest to the calculated amount to lift (i.e., if 40% of the body weight was 69 lbs and plate # 3 on the machine was 66 lbs and plate # 4 was 77 lbs then plate # 3 would be used for the pretest).

Exercise Testing and Training Rationale

A method of determining a baseline assessment of the subject's present strength capabilities was necessary in order to make comparisons of pretest to posttest strength. When dealing with asymptomatic adult populations, the most widely used method of assessing this baseline level is through a one-repetition maximum (Klafs & Arnheim, 1977; O'Shea, 1976; Vitale, 1973; Wescott, 1982). Though this is the most popular method today, there is no data currently available which demonstrates that a one-repetition maximum test is safe for cardiac patients to perform. Therefore, for the purpose of this study an alternate method of measuring baseline strength was chosen. The rationale for choosing this alternate method was to remove the possible increased risk of a cardiac event associated with maximal lift but to still allow for a baseline strength assessment. This method, developed by John Patrick O'Shea in 1976, determines a lifting weight load based on two different factors: 1) the subject's body weight and 2) the exercise being performed. For the two exercises being measured in this study, leg squat and bench press, the following percentages were used: leg squat - 40% of the subject's body weight and bench press - 30% of the subject's body weight. Because the subject did not have to perform a maximal lift utilizing this method, it was felt that this was safer and more feasible for the cardiac patient.

The subjects were tested on only two of the seven exercises included in the strength training program. One of the major reasons for this was to prevent unnecessary fatigue of the subject. The two exercises chosen, leg squat and bench press, were selected because they involved the largest numbers of muscles necessary to perform one movement, therefore allowing a strength assessment of many muscles at one time (O'Shea, 1976; Vitale, 1973). These two exercises were also chosen because they were the most difficult of all seven exercises and any possible abnormalities resulting from performing the strength training exercises (i.e., ectopic beats, ST segment depression, exercise hypertension, etc.) would be more likely to surface with these.

During the exercise testing session, the subjects were instructed to perform as many repetitions as they could, up to and including 15 repetitions. This limitation was set by the researcher because throughout the course of the study subjects would never be performing more than 15 repetitions therefore to test beyond this point would put undue stress on the subject and be superfluous to the scope of the study.

Exercise Prescription

After the pretest, all subjects were allowed to begin working with heavier weights. The exercise prescription was established in a progressive manner until the subject reached a plateau. The following is an example of the type of progression possible:

1st Session - two sets of 15 repetitions using the second plate setting

2nd Session - same

3rd Session - two sets of 15 repetitions using the third plate setting

4th Session - same

5th Session - two sets of 15 repetitions using the fourth plate setting.

The subjects continued to follow this progression until they could not achieve a minimum of 12 repetitions. At this point in time, the subject stayed at the weight load until 15 repetitions could be achieved during two consecutive workout sessions. If upon advancing to a heavier weightload, the subject could not perform a minimum of 12 repetitions the weight was lowered one plate for two more exercise sessions.

Daily Training Sessions

All subjects exercised three days a week, having a full day of rest between lifting sessions. Since the majority of subjects would perform their muscular endurance exercises after completing their aerobic exercise prescription, a warm-up was unnecessary. Those few that lifted weights before their aerobic exercise prescription warmed up in a similar manner to what was normally done before their aerobic exercise prescription (i.e., stretching and light calisthenics).

Upon entering the weight training area, all subjects obtained their record keeping cards (Appendix D) and reviewed their previous workout. The subjects then began performing the weight training circuit. The order of the lifting circuit was leg squat, bench press, leg extension, latissimus pulldown, leg curl, biceps curl and pullover. The majority of subjects proceeded through the circuit in this manner but were allowed to vary if a certain machine was being used. If they varied from the predetermined order, the subjects were instructed to alternate arm and leg exercises, thus allowing one muscle group to recover slightly. Each subject was instructed to allow a 30 second rest between each exercise station. At the end of each set of seven exercises, the subject would measure his/her own pulse and then have his/her blood pressure taken. The subject was responsible for recording this information on his/her daily workout card.

Posttest Procedure

The posttest was conducted within four days after each subject completed his/her eight weeks of training. All subjects continued to perform the muscular strength endurance exercises up to the day of the posttest. All parameters measured during the pretest were measured exactly the same for the posttest. The one exception to this was the amount of weight lifted for the posttest. The amount of weight the subject lifted for the posttest was chosen based on the following criteria:

1. If, for the most recent exercise session, the subject was utilizing a weight that he/she could lift for 14 or 15 repetitions then the posttest weight was set one plate higher.

2. If, for the most recent exercise session, the subject was utilizing a weight that he/she could lift for 12 to 13 repetitions then the posttest weight was kept at this level.

Data Analysis

The variables measured, heart rate, blood pressure and amount of weight lifted, were assessed by comparing the results of the pretest to the posttest. The statistical tool used to analyze the data in this manner was a one way analysis of variance. A .05 level of significance was set for this study. Basic descriptive statistics, means, standard deviations, and ranges, were also determined for each parameter. Frequency and type of arrhythmias were simply recorded, but not statistically analyzed due to the limited elicitation.

CHAPTER IV

RESULTS AND DISCUSSION

This study was conducted to establish basic guidelines for providing a safe but effective strength training program for cardiac patients. Certain physiological variables were selected to be examined before, during and after the eight week muscular strength/endurance training period. These variables were as follows: strength, blood pressure, heart rate, and electrocardiographic activity. Each of the variables measured, apart from the strength assessment, were measured at rest, at peak exercise or immediately following and during recovery. A one way analysis of variance was conducted to determine if there were statistically significant differences between pre and post measures.

This chapter presents and analyzes the data collected throughout the course of this study. These findings are then discussed relative to their statistical significance, effect on the subject and importance to the outcome of the study.

Demographic Data of Subjects

The study involved one group of 14 subjects from the Phase III and IV Cardiac Rehabilitation Unit of the La Crosse Exercise Program. Demographic data related to the 14 subjects are presented in Tables 3 and 4 and include: age, sex and medical status.

Table 3

Demographic Data of Subjects

	N	$\bar{X}$	SD	RANGE
Males	13			
Females	1			
Age		56.00	±8.25	40 - 72

Table 4

Medical Status

	Frequency
Coronary Artery Bypass Graft Surgery	3
Myocardial Infarction	3
Diagnosed Coronary Artery Disease	2
Peripheral Vascular Disease	2
Hypertension	2
Major Risk Factors	2

Strength Evaluation Results

Table 5 reports the amount of weight that the individual lifted for 15 repetitions of the leg squat exercise during the pretest in relation to the amount of weight that same individual could lift during the posttest. On the average, the subjects could lift approximately 20 lbs more after the experimental period. Using an analysis of variance, the observed F-ratio indicated a significant difference at the $p < .05$ level between the pretest and posttest values.

Table 5

Weight Lifted for Leg Squat
(in lbs)

	MEAN	STANDARD DEVIATION
Pretest	67.42	$\pm$ 11.77
Posttest	87.85*	$\pm$ 15.93

Note: * p .05; significantly different than pretest value

The data presented in Table 6 is indicative of the amount ot weight the subjects lifted for 15 repetitions of the bench press exercise before beginning and after completing the program. An average difference of + 6 lbs was observed in the amount of weight lifted after the experimental period. At the .05 level of significance, this indicated a statistical difference between pre and post values.

Table 6

Weight Lifted for Bench Press
(in lbs)

	MEAN	STANDARD DEVIATION
Pretest	52.14	± 8.76
Posttest	58.14*	± 1.17

Note: * p .05; significantly different than pretest value

Blood Pressure Evaluation Results

The data in Table 7 indicates that at the $p < .05$ level there were no statistically significant differences in resting blood pressures as a result of the experimental period.

Systolic blood pressure during the leg squat exercise as shown in Table 8, was slightly, but not significantly, lower during the posttest evaluation. Diastolic blood pressure resulted in almost no change from one measurement to the next.

Table 7

Resting Blood Pressure
(in mmHg)

	MEAN	STANDARD DEVIATION
SYSTOLIC		
Pretest	114.80	± 13.60
Posttest	115.20	± 14.39
DIASTOLIC		
Pretest	74.00	± 9.67
Posttest	74.85	± 5.58

Table 8

Leg Squat Immediate Post-Exercise Blood Pressure
(in mmHg)

	MEAN	STANDARD DEVIATION
SYSTOLIC		
Pretest	139.10	± 16.74
Posttest	132.70	± 23.80
DIASTOLIC		
Pretest	71.00	± 8.54
Posttest	72.42	± 1.14

Table 9 indicates that there was no change in systolic blood pressure during recovery from the leg squat exercise. Diastolic blood pressure, taken at the same time, was found to be significant at the .05 level. Thus, the null hypothesis was rejected. An average increase of 8.14 mmHg was observed from the pre to the post-experimental period.

Table 9

Leg Squat Recovery Blood Pressure
(in mmHg)

	MEAN	STANDARD DEVIATION
SYSTOLIC		
Pretest	135.00	± 18.69
Posttest	135.20	± 19.96
DIASTOLIC		
Pretest	74.14	± 10.06
Posttest	82.00*	± 11.20

Note: * $p < .05$; significantly different than pretest value

Both systolic and diastolic blood pressures during the bench press showed slight increases from the pre to posttest. Neither were statistically significant (Table 10).

Table 10

Bench Press Immediate Post-Exercise Blood Pressure
(in mmHg)

	MEAN	STANDARD DEVIATION
SYSTOLIC		
Pretest	145.20	± 21.70
Posttest	149.70	± 22.11
DIASTOLIC		
Pretest	82.57	± 9.36
Posttest	84.85	± 1.28

Table 11 presents blood pressure responses during recovery from the bench press exercise. At the end of the treatment period, the systolic blood pressure was + 5.9 mmHg above the pretest value. An analysis of variance showed that the observed F-ratio, 6.59, was sufficient to reject the null hypothesis at a .05 level of significance. There was a slight increase in the diastolic pressure during recovery from the bench press exercise. This increase was not, however, statistically significant.

Tables 9 and 11 show a definite increase in recovery diastolic and systolic blood pressures, respectively. Because these blood pressure measurements were found to be significantly higher after the treatment period, a comparison was made with each subject's blood pressure measurement during equivalent dynamic exercise. All subjects in this study had recently undergone a maximal graded exercist test (GXT) as part of the routine procedures of the La Crosse Exercise Program.

Table 11

Bench Press Recovery Blood Pressure
(in mmHg)

	MEAN	STANDARD DEVIATION
SYSTOLIC		
Pretest	135.80	± 15.54
Posttest	141.70	± 19.34
DIASTOLIC		
Pretest	80.85	± 8.21
Posttest	86.00	± 8.55

Note: * $p < .05$; significantly different than pretest

Blood pressure measurements taken during weight lifting exercise and recovery as compared to blood pressure measurements taken at the same heart rate during graded exercise testing and recovery are shown in Tables 12 and 13.

Table 12 reports that the systolic blood pressure measured at an equivalent heart rate during dynamic exercise was significantly higher than the systolic blood pressure found during weight training. There was no statistically significant difference between diastolic blood pressure measurements found during weight lifting and that found during the GXT. It should be noted that blood pressures associated with weight lifting were taken immediately post peak exercise, and thus may not be an accurate representation of maximal blood pressures.

Table 12

Blood Pressure during Weight Lifting and GXT at Equivalent Heart Rate (in mmHg)

	MEAN	STANDARD DEVIATION
SYSTOLIC		
Weight Lifting	129.57	± 23.67
GXT (@ equal H.R.)	165.64*	± 20.34
DIASTOLIC		
Weight Lifting	70.85	± 11.83
GXT (@ equal H.R.)	79.42	± 11.40

Note: * $p < .05$; significantly different than weight lifting value

In Table 13, the systolic blood pressure measurements from the maximal GXT were taken after two minutes of recovery and were significantly higher than the systolic blood pressure measurements taken after one minute of recovery from weight training. The diastolic blood pressure measurements taken after a two minute recovery from maximal GXT were not statistically different from the diastolic blood pressure measurements taken after a one minute recovery from weight training.

Table 13

Blood Pressure during Recovery from
Weight Lifting and GXT
(in mmHg)

	MEAN	STANDARD DEVIATION
SYSTOLIC		
Weight Lifting (1 min post-max)	136.92	± 19.52
GXT (2 min post-max)	173.30*	± 20.58
DIASTOLIC		
Weight Lifting (1 min post-max)	82.15	± 11.64
GXT (2 min post-max)	81.38	± 8.69

Note: * $p < .05$; significantly different than weight lifting value

Heart Rate Evaluation Results

Table 14 demonstrates that there was essentially no change in resting heart rate from the pre to the post-experimental test.

Table 14

Resting Heart Rate
(in b/min)

	MEAN	STANDARD DEVIATION
Pretest	87.3	± 18.4
Posttest	87.8	± 16.9

The heart rates observed during the leg squat exercise and recovery were slightly but not significantly lower during the posttest, as indicated in Table 15.

Table 15

Leg Squat Exercise and Recovery Heart Rates
(in b/min)

	MEAN	STANDARD DEVIATION
EXERCISE		
Pretest	130.5	± 18.7
Posttest	126.4	± 13.4
RECOVERY		
Pretest	106.9	± 14.4
Posttest	105.6	± 18.9

Table 16 reports no statistical difference between the pre and posttest exercise and recovery heart rates for the bench press.

Table 16

Bench Press Exercise and Recovery Heart Rates (in b/min)

	MEAN	STANDARD DEVIATION
EXERCISE		
Pretest	113.4	± 19.9
Posttest	115.0	± 17.3
RECOVERY		
Pretest	88.9	± 16.4
Posttest	91.3	± 19.5

Discussion

The null hypothesis was rejected in four out of the 16 variables measured throughout the study. These variables were: 1) the amount of weight lifted on the leg squat exercise; 2) the amount of weight lifted on the bench press; 3) the diastolic blood pressure during recovery from the leg squat exercise and 4) the systolic blood pressure during recovery from the bench press exercise. Statistically significant differences ($p < .05$) were observed with these variables.

Strength Measurements

Tables 5 and 6 illustrated the amount of weight each subject lifted from the beginning to the end of eight weeks of training. This increase of 30% indicates a beneficial effect of the experimental program. The exact mechanism of the strength/endurance increase is probably twofold; occurring from either changes in the muscle tissue itself or changes in neuromuscular functioning. According to Fox and Mathews (1981), the majority of strength gains resulting from a weight training program occur from changes in the muscle tissue. There is some strong evidence, however, that some increases in strength may also result from changes in the central nervous system. Researchers, such as Lamb (1984), state that there is a definite contribution by the nervous system. Unfortunately, there is little or no research which states how much the nervous system contributes, where in the nervous system the changes occur or the physical or chemical alterations responsible for the adaptation. These neuromuscular changes appear to occur earlier during the training period than do muscular changes. As well, they are generally thought to be a more predominant mechanism of strength alterations in older populations. Since mechanism was not specifically investigated in this study, it is not possible to conclude what was responsible for the observed strength/endurance gains though some combination of neural and muscular involvement is likely.

The increases in strength found in this study are supported by other researchers such as Kelleman et al. (1984) who found a 24% increase in strength in cardiac patients participating in a ten week circuit weight training program. Saldivar et al. (1983) and Ewart et al. (1984) also found that cardiac patients could safely participate in a circuit weight training program and achieve significant strength gains.

Blood Pressure Measurements

Resting blood pressure measurements did not significantly change over the course of the study. This finding demonstrated that it is unlikely for weight training to contribute to increases in resting blood pressure. As well, lowered resting values were not observed from strength/endurance training as has been found with some aerobic exercise programs.

Near peak blood pressure values, measured immediate post-exercise were slightly but not significantly higher after the experimental period. There could be several explanations including: an increased weight load causing a greater strain by the subject; the possibility of some breath holding by the subject; or a greater amount of fatigue after performing the previous exercise.

The peak blood pressure measurements found during weight training are within the safe limits for exercise and appear to pose no more of a risk to the cardiac patient than do values obtained during regular dynamic exercise. If properly performed, weight training can produce substantially lower blood pressure responses than dynamic exercise at an equivalent heart rate. Additionally, more weight can be lifted at the same blood pressure as a result of training. However, some caution needs to be taken with these interpretations since blood pressures during exercise were not actually measured until immediately post-activity.

Two recovery blood pressure measurements were found to be significantly higher after the experimental period: 1) diastolic blood pressure during recovery from the leg squat exercise and 2) systolic blood pressure during recovery from the bench press exercise. When these measurements were compared to recovery from equivalent dynamic exercise, however, they were found to be significantly lower. This finding indicated that the subjects recovered faster from the weight training exercise.

The results shown in Tables 12 and 13 are supported by Vander et al. (1985) who compared the hemodynamic responses of cardiac patients performing Nautilus training to those of graded exercise testing. These researchers found that though some of the variables measured after Nautilus training were significantly higher from pretest to posttest, they were still significantly lower than those values found during GXT max.

Heart Rate Measurements

Resting heart rate did not change throughout the course of the study. This finding would appear to indicate that circuit weight training in conjunction with aerobic exercise does not help to significantly lower the resting heart rate.

There was no significant difference observed between pre and post exercise heart rates on either the leg squat or bench press exercise. An important consideration concerning these measurements was that during the posttest evaluation each subject lifted a significantly heavier amount of weight with no change or a slight decrease in exercising heart rate, indicating a possible positive training effect.

The peak heart rates observed throughout the weight training exercises were significantly lower or equivalent to the subjects' prescribed aerobic target heart rates (Appendix F). This finding suggests that a supplemental weight training program may be added to the cardiac patient's aerobic exercise prescription and still be well within the safe exercising limits prescribed for that particular individual.

Electrocardiographic Responses

Electrocardiographic changes exhibited during the course of the study were not statistically analyzed as there were too few to make a comparison. There were several isolated premature ventricular contractions (PVCs) observed in three subjects; however, these individuals also exhibited isolated PVCs at rest and during dynamic exercise. There was one subject who had to drop out of the study after experiencing an episode of ventricular bigeminy during the weight lifting session, but this was later determined to be medication-related.

Summary

Overall, the results of this study were in favor of muscular strength/endurance training for cardiac patients. All subjects experienced significant strength gains, while there were no detrimental heart rate changes or electrocardiographic responses. Only two of the blood pressure measurements taken were statistically higher after the experimental period. These two measurements were significantly lower than those found during equivalent dynamic exercise. In general, if certain guidelines and restrictions are implemented, a circuit weight training program can be safely incorporated into the cardiac rehabilitation setting.

The following nine recommendations are suggested when considering the design and implementation of a weight training program for cardiac patients:

1. To establish a baseline strength assessment, a one repetition maximum lift should be a consideration if performed under direct physician superivision. During this assessment, instantaneous blood pressure and electrocardiographic recordings should be taken. If this is not possible, the evaluation methods utilized in this study are adequate, particularly if interested in strength/endurance gains.

2. A circuit of seven to ten exercise stations provides a basic well-rounded training program.

3. Two sets of 12 to 15 repetitions will achieve significant strength/endurance gains.

4. Participants should be instructed in proper breathing and lifting techniques before attempting to perform any of the weight training exercises.

5. The weight training circuit should be performed a minimum of two to three times a week with, ideally, a 24 hour rest period between workouts.

6. A 30 second to one minute rest between exercise stations should be encouraged to prevent excessively high blood pressure and heart rate readings.

7. Blood pressure measurements should be taken and recorded at least once during the weight lifting session.

8. Periodic electrocardiographic readouts should be taken on all participants (a minimum of once every two to three weeks) after the initial testing session. High risk individuals may need more frequent observation.

9. A participant's heart rate during weight training exercise should not at any time exceed his/her aerobic exercise target heart rate.

CHAPTER V

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Summary

This study was conducted in an effort to establish basic guidelines and information concerning the safety and effectiveness of a circuit weight training program for cardiac patients. Fourteen cardiac rehabilitation volunteers (3 CABG, 3 POST-MI, 2 CAD, 2 PVD, 2 HTN and 2 with Known Risk Factors) from the Phase III and IV Cardiac Rehabilitation Unit of the La Crosse Exercise Program served as participants. The weight training circuit incorporated two sets of the following seven exercises: leg squat, bench press, leg extension, latissimus pulldown, leg curl, bicep curl and pullovers. Training sessions were held three times a week for an eight week period.

During the pretest and posttest, all subjects were evaluated on the leg squat and the bench press exercises. The pretesting consisted of each subject performing up to and including 15 repetitions of the leg squat at 40% of their body weight and at 30% of the body weight for the bench press exercise. The limitation of a 15 repetition maximum was set by the researcher to ensure the safety of the subjects. Four subjects "maxed out", performing only 12 to 13 repetitions on the two exercises. The 15 repetition maximum, though not a true "max" test, appeared to be close to the maximum for the majority of the subjects tested and therefore did not prohibit a fairly accurate baseline strength assessment. The posttest was the same as the pretest except for determining the amount of weight to be lifted. Each subject was assigned a weightload to lift similar to his/her most recent exercise session. During the testing period, the following resting, exercise and recovery variables were measured: blood pressure, heart rate and electrocardiographic activity. Additionally, strength was assessed in terms of pounds lifted for 15 repetitions.

Upon completion of this study, the following findings were noted. All subjects participating in this study lifted a significantly heavier amount of weight on the leg squat and bench press exercises after the training period. An overall increase in strength of 30% was found during the posttest evaluation. There were no significant changes in resting or exercising heart rates from the pretest to the posttest measurements. Weight training heart rates were found to be significantly lower than each subject's corresponding aerobic exercise target heart rate. Two blood pressure measurements were statistically different after the eight week training period. These included diastolic blood pressure during recovery from the leg squat exercise and systolic blood pressure during recovery from the bench press exercise. Though these two measurements were significantly higher after the training period, when compared to equivalent dynamic exercise these blood pressure measurements were well within safe exercising limits.

Conclusions

Within the limitations and boundaries of this study, the following conclusions can be made:

1. A circuit weight training program for cardiac patients produces significant increases in strength/endurance.

2. Strength/endurance training does not help to lower resting or exercising heart rates.

3. A circuit weight training program may produce some significant, but not unsafe, increases in blood pressure during recovery.

4. No abnormal electrocardiographic responses occur as a direct result of strength training.

5. A circuit weight training program for cardiac patients can be a safe, effective, and beneficial addition to the aerobic cardiac rehabilitation program.

Recommendations for Future Studies

To further evaluate the safety and benefits of circuit weight training in Phase III and IV cardiac rehabilitation programs, the following studies are recommended:

1. A psychological profile of participants to assess self-image/self-concept benefits of circuit training.

2. A one-repetition maximum lift conducted under physician supervision to better assess "true" strength gains.

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APPENDIX A

INFORMED CONSENT
UNIVERSITY OF WISCONSIN - LACROSSE
LACROSSE, WISCONSIN 54601

Project Title: Effects of an exercise program for muscular endurance on Cardiac Rehabilitation Participants.

Principal Investigator: Karen J. Toomey

As a subject participating in this study I will be performing certain exercises for increasing muscular endurance. These exercises and their benefits have been fully explained to me. There are always possible discomforts or risks which may occur in any type of exercise program of this nature (i.e., muscle soreness or stiffness) all of which I assume. Because of my history of heart disease there is also the possibility of certain changes occurring during the exercise sessions. They include abnormal blood pressure, pulse rate and very rare instances of "heart attack" I have been instructed on the proper breathing and lifting techniques necessary for this study, which will help to minimize the possibility of such undesirable changes.

1. I, ____________________, being of sound mind and ______ years
(Name of Subject)
of age, do hereby consent to, authorize and request the person named above (and her coworkers, agents, and employees) to undertake and perform on me the proposed procedure, treatment, research or investigation (herein called "Prodeure").

2. I have read the above document, and I have been fully advised of the nature of the Procedure and the possible risks and complications involved in it, all of which risks and complications I assume voluntarily.

3. I understand that I may withdraw from the program at any time.

Signed at __________________________this__________ day of ______________, 19__, in the presence of the witnesses whose signatures appear below opposite my signature.

WITNESSED BY:

____________________________ ____________________
(Subject)
____

I,_____________________, (husband, wife, parent, other) of the above-named subject _________________________, have read the foregoing consent and the document attached hereto and made a part of such consent, and I hereby consent to said Procedure.

WITNESSED BY:

____________________________ ____________________
(Signature)
____

APPENDIX B

La Crosse Exercise Program

Mitchell Hall
University of Wisconsin-La Crosse
La Crosse, Wisconsin 54601

Dear Dr.

March 8, 1985

At this time the LaCrosse Exercise Program is considering implementation of an exercise program for muscular endurance. The program would be offered to the Cardiac Rehabilitation participants as an adjunct to their regular aerobic exercise prescription. Initially, for the first twelve weeks, the program will be run as part of a thesis study for the Master's Degree Program for Adult Fitness/Cardiac Rehabilitation, then will become incorporated into the general routine of the program.

The following is a brief overview of the program:

1. One to two weeks orientation period with instruction on proper lifting and breathing techniques.
2. Pre & Post - testing, consisting of performing repetitions at a low weight load (10% - 20% of their body weight).
3. Exercise program will be conducted immediately after the aerobic program. There will be seven exercise stations; three lower body parts and four upper body parts.
4. Intermittent blood pressure and ECG monitoring during exercise period.
5. Individual exercise programs, to be set up for each participant based on medical history, orthopedic problems, and personal goals.
6. Cool - down exercises to be conducted with each participant immediately following the exercise program.

During this exercise program the participants will be closely monitored and supervised. Any serious changes or irregularities in the patient's condition will be reported to the respective physician.

Your patients, , and , have expressed an interest in participating in this program. At this time I would like to ask permission for your patients to participate in this program. Please indicate your concurrence or non-concurrence on the enclosed form and return. If more information is necessary to make this decision, please feel free to contact Dr. Linda Hall or Dr. Kim Wood.

Sincerely,

Karen J. Toomey
Graduate Student
LaCrosse Exercise Program

PHONE NUMBERS

Administrative Office
(608) 785-8684

Adult Fitness Unit
(608) 785-8683

Cardiac Rehabilitation Unit
(608) 785-8683

Education Services Unit
(608) 785-8686

Insurance Office
(608) 785-8688

Job Placement Service
(608) 785-8688

Master's Degree Program
(608) 785-8685

Nutrition Services Unit
(608) 785-8694

APPENDIX C

PERMISSION REQUEST

At this time I recommend that my patient,

be allowed to participate ______________

not be allowed to participate ______________

in the exercise program for muscular endurance now being offered by the Cardiac Rehabilitation Unit of the La Crosse Exercise Program.

I have read the enclosed letter and I have been fully advised of the above mentioned program's policies and procedures. By completing and returning this document to the La Crosse Exercise Program I officially give my concurrence or non-concurrence for my patient's participation in the exercise program for muscular endurance.

________________________ M.D. ________________________

(Signature) (DATE)

APPENDIX D

WEIGHT TRAINING - DAILY RECORD CARD

NAME ______________________________

EXERCISES	Dt___			Dt___			DT___			DT___			Dt___			Dt___			Dt___		
	Wt	1	2	Wt	1	2	Wt	1	2	Wt	1	2	Wt	1	2	Wt	1	2	Wt	1	2
SQUAT MACHINE																					
BENCH PRESS																					
LEG EXTENSION																					
LAT. PULLDOWNS																					
LEG CURL																					
BICEP CURL																					
PULLOVERS																					
BLOOD PRESSURE																					
HEART RATE																					
WEIGHT																					

APPENDIX E

TESTING DATA

NAME: ______________________ DATE: ______________________

AGE: __________ WEIGHT: __________ HEIGHT: __________

RESTING BLOOD PRESSURE: __________

RESTING HEART RATE: __________

RESTING E.K.G.: __________

EXERCISE #1 SQUAT MACHINE

LIFTING WEIGHT LOAD: ______ # REPETITIONS: ______ TIME: ____

	EXERCISE	1-MINUTE RECOVERY
BLOOD PRESSURE:	__________	__________
HEART RATE:	__________	__________
E.K.G.:	__________	__________

EXERCISE #2 BENCH PRESS

LIFTING WEIGHT LOAD: ______ # REPETITIONS: ______ TIME: ____

	EXERCISE	1-MINUTE RECOVERY
BLOOD PRESSURE:	__________	__________
HEART RATE:	__________	__________
E.K.G.:	__________	__________

PRESCRIPTION

	Weight	Sets	Repetitions
1. Squat Machine			
2. Bench Press			
3. Leg Extension			
4. Lat. Pulldowns			
5. Leg Curl			
6. Bicep Curl			
7. Pullover			