A COMPARISON OF CARDIAC OUTPUT AND STROKE VOLUME IN PHASE III CARDIAC PATIENTS AND HEALTHY ADULTS

By

FEHMI TUNCEL

Bachelor of Science
Istanbul Sports Academy, Turkey
1979

Master of Science
Oklahoma State University
Stillwater, Oklahoma
1985

Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirements for
the Degree of
DOCTOR OF EDUCATION
May, 1989

A COMPARISON OF CARDIAC OUTPUT AND STROKE
VOLUME IN PHASE III CARDIAC PATIENTS
AND HEALTHY ADULTS

Thesis Approved:

Thesis Adviser

Dean of the Graduate College

ACKNOWLEDGMENTS

The author wishes to thank Dr. Frank Kulling, Assistant Professor of Health, Physical Education, and Leisure Services, for his willingness to be of assistance and offering his guidance.

I should like to express my deepest gratitude to the rest of my committee members for their helpful suggestions, support and thoughtfulness. Also, I especially wish to thank Dr. Aix B. Harrison for his help.

I would also like to express my appreciation to Dr. Kathryn D. Campbell, Mrs. Robin Purdie, Mr. Soo Peng Ng and Mr. Robert W. Holderer for their help. In addition, Dr. Steven Edwards was invaluable in setting up the computer program for the statistical treatment.

A special thank you goes to my friend, Amy, for her thoughtfullness and support.

Finally, this work is dedicated to my mother and father who never had a chance to see their son's achievement.

TABLE OF CONTENTS

LIST OF TABLES

CHAPTER I

INTRODUCTION

The leading cause of mortality today in the United States and the other advanced countries of the world is still cardiovascular disease. Cardiovascular disease accounts for 48% of total mortality in the United States. It is estimated that more than 63 million Americans have some form of cardiovascular disease. Mortality rates per 100,000 females have leveled off since 1960, whereas mortality rates in males have decreased significantly (Fardy, et. al., 1988). Furthermore, coronary artery disease (CAD), heart failure and shock, and hypertensive diseases are among the common cardiovascular diseases, and approximately two-thirds of these cardiovascular deaths are caused by myocardial infarction. The worst part of CAD is that it may come without warning and one out of five who suffer their first attack will die immediately. (Wilson, et al., 1981).

Americans spend approximately $35 billion on cardiovascular disease annually. The disease drains this country's economic resources by 62,000,000 man-days per year. In addition, the victim, his family and his friends undergo a psychological and social trauma. Furthermore, most of the victims are productive members of society. This grim pic ture shows a need for carefully planned strategies of prevention and rehabilitation. A well-planned program of physical and psychologic restoration is essential for returning the cardiovascular disease survivors to an active and productive life-style (Wilson, et al. 1981).

The relationship of physical activity to CHD has been studied by many investigators. These studies indicate that regular physical activity is helpful and not destructive to most cardiac patients (Zhou and Jin, 1984; Wilson, 1975; Efraim, et al., 1986; Breisch, et al., 1986; Thompson, et al., 1981; Simmons and Shephard, 1972; McArdle, et al., 1981; Seals, et al., 1986). Efraim, et al. wrote in 1986 that a comprehensive rehabilitation program that includes physical training, control of risk factors and cardiovascular follow-up may provide functional (physical work capacity) as well as economic and psychosocial benefits (resumption of work and feeling of well-being) to both the patient and the family. Breisch's (Breisch, et al., 1986) approach to the issue was not any different than Efraim's. Breisch stated that the general thought is that exercise training creates changes that are beneficial to the myocardium and also improves the capacity of the heart to perform in hypoxic situations. According to Breisch and his colleagues, recent studies in humans have shown that physical exercise reduces the incidence and severity of myocardial infarction. In 1975, Naughton (Wilson, 1975) commented on physical activity and its preventive effect on CHD:

> It is a well-established fact that physically active men differ from sedentary men in many aspects. For instance, physically active men usually have lower blood pressure and heart rate levels at rest and at comparable levels of physical exertion than do sedentary subjects, and physically active subjects usually experience fewer cardiac arrhythmias and have higher work capacity. Their peripheral and central circulatory adaptations to physical stress differ markedly. They usually have a more positive attitude about life and handle interpersonal conflict more effectively and at a reduced physiological cost (p. 5).

The inverse relationship between physical activity and coronary artery disease risk factors has also been shown by several investigators. Adner and Castelli (1980) suggest that exercise may be a causal factor in producing HDL level elevations. They also mention two prospective studies by Lopez et al and Hoffman et al that showed that physical exercise resulted in a rise of HDL-cholesterol levels. Hartung and the colleagues found negative correlation between HDL:total cholesterol ratio and total cholesterol (Hartung, et al., 1980). Thus, it is important for cardiac patients to participate in cardiac rehabilitation programs.

Cardiac rehabilitation began in the early to mid-fifties and had grown tremendously in the past 30 years. It has grown to the point of acceptance in the early to mid-eighties. The fifties and early sixties was a period of development and examination of policies in cardiac rehabilitation. The eighties are considered a period of refinement. Further acceptance of cardiac rehabilitation should be expected as a result of practicing the current policies and procedures. The organizational and administrative aspects of cardiac rehabilitation parallel the evolution (Pollock and Schmidt, 1986).

During the past 20 to 30 years many cardiac patients have participated in supervised physical activity programs. The programs are based on the principle of beginning at very low levels of physical activity (continuous exercises with low levels of METS - a MET is a multiple of the resting metabolic rate) and gradually increasing the intensity of exercise in accordance with each patient's capacity. Some forms of the exercises used are walking, jogging, swimming, and calisthenics. According to Wilson (1975), the following changes have occurred in patients who participated in cardiac rehabilitation programs:

1. significant increases in Max O2 consumption;
2. reduced systolic blood pressure and heart rate at rest and submaximal work;
3. significant body composition changes, such as increased muscle mass and decreased fat;
4. increased sexual ability;
5. attitude changes at home and on the job, and positive dietary and sleep pattern changes;
6. reduced myocardial work at rest and submaximal work;

7. significant improvements in the central and peripheral circulations (Wilson, 1975).

These changes have not occurred among those patients whose post-recovery status remained sedentary (Wilson, 1975).

Since cardiac output is one of the primary indicators of the functional capacity of the circulatory system, determining the resting cardiac output of patients going through cardiac programs is very important. The heart's cardiac output is determined by its rate of pumping (heart rate) and by the quantity of blood ejected with each stroke (stroke volume).

Thus, the relationship is:

Cardiac Output = Heart Rate x Stroke Volume

(McArdle et al, 1981).

Cardiac output varies at rest among individuals. Approximately, 5 liters of blood volume is pumped from the left ventricle each minute in both trained and untrained individuals. A heart rate of about 70 beats per minute sustains this 5-liter cardiac output for the average person. In cardiac output equation, this heart rate corresponds to a calculated 71. ml per beat stroke volume of the heart. Therefore, these values can be substituted in the above-mentioned cardiac equation for sedentary and trained persons at rest as follows:

Cardiac Output = Heart Rate x Stroke Volume

Sedentary = 5000 ml = 70 b.min-1 x 71 ml

Trained = 5000 ml = 50 b.min-1 x 100 ml

The decreased heart rate (bradycardia) and increased stroke volume in trained subjects can be explained as follows: a)- the training causes resting sympathetic activity and increased vagal tone which results with a lower resting heart rate. b)- the heart muscle strengthens as a result of training and so can contract more forcefully and eject more blood (Stroke Volume) with each contraction (McArdle, et al., 1981).

Several methods are available to measure the cardiac output (McArdle, et al., 1981). Some of these methods are invasive, such as the Direct Fick Method and the indicator Dilution Method which require cardiac catheterization or venous and arterial punctures. For instance, the measurement of cardiac output by the Fick Method is complex and is usually limited to a clinical setting. The oxygen consumption is measured with open circuit spirometry methods. However, the sampling of arterial and mixed venous blood to obtain the a-VO2 difference is a difficult aspect of the method. An arterial blood sample can be drawn from any artery, such as brachial or femoral artery, though it might be traumatic to the patient because of the arterial puncture. Drawing a sample of mixed venous is more difficult than drawing a sample of arterial blood. In addition, using any vein to obtain a mixed venous blood sample does not meet the criteria, because each vein represents the metabolic activity in a particular body part. It is best to use an anatomic portion to obtain a mixed venous blood that reflects the average oxygen content of venous blood. The right atrium, right ventricle or pulmonary artery is usually used for this purpose. A catheter or small flexible tube is usually the device used to reach one of these anatomic body parts and a sample is drawn as the oxygen consumption is measured (McArdle, et al., 1981).

The Fick Method determines how much blood must have circulated a minute to account for the observed oxygen consumption, given the observed a-VO2 difference. The principle of the Fick Method is based on computing the person's oxygen consumption during one minute and the average difference between the oxygen content of arterial and mixed venous blood (a-VO2 difference). Thus, the equation is:

$$\text{Cardiac Output (ml.min-1)} = \frac{\text{O2 Consumption (ml.min-1)} \times 100}{\text{a-VO2 difference (ml per 100 ml blood)}}$$

(McArdle et al., 1981)

The CO_2 Rebreathing Method, on the other hand, is a non-invasive method which determines the cardiac output from values of carbon dioxide substituted in the Fick equation (McArdle et al., 1981). Valid estimates of venous and arterial carbon dioxide levels can be made by using a rapid carbon dioxide analyzer and making certain reasonable assumptions. The subject's O_2 consumption is displayed on the Met Cart (Metabolic Measurement Cart) screen. This gives an idea about the time that the mixture has occurred. The technique simply requires a breath-by-breath analysis of carbon dioxide.

Cardiac output is calculated in accordance with the Fick Principle after venous and arterial carbon dioxide concentrations are estimated:

$$\text{Cardiac Output} = \frac{\text{Carbon Dioxide Production} \times 100}{\text{V-a } CO_2 \text{ Difference}}$$

(McArdle et al., 1981).

There are obvious advantages of the CO_2 Rebreathing Method over the direct Fick and Indicator Dilution techniques. The method does not require close medical supervision, involves minimal interference with the subject and is "bloodless" (Mahler, et al., 1983; McArdle, et al., 1981; Jones, et al., 1975).

The reliability of the CO_2 Rebreathing technique and a comparison of this technique with other techniques, such as the Fick Method, has been studied by several investigators, and their data suggest that the CO2 Rebreathing cardiac output method may be useful in cardiac rehabilitation settings (Clausen, et al., 1970; Franciosa, et al., 1987; DeFares, et al., 1958; Davis, et al., 1978; Simmons and Shephard, 1972; Paterson, et al., 1982; Mahler, et al., 1983).

If a computerized system with rapid and repeatable measure of cardiac output is available, the assessment of cardiac performance can be enhanced. Mahler (Mahler, et al., 1983) and his colleagues have shown that the Metabolic Measurement Cart is as accurate as the Fick Method in determining the cardiac output. The CO2 Rebreathing technique is the most non-invasive method in comparison to the direct Fick method, the dye-dilution method, or the thermodilution method, all of which require heart catheterization. Some of the excellent applications of the CO2 rebreathing method include serial measurements of cardiac output, exercise testing, monitoring of ill patients, and response to drug therapy and rehabilitation (Mahler, et al., 1983).

Jones (Jones, et al., 1975) stated that investigators have used the CO2 rebreathing method extensively during the past ten years and found it to be a simple and effective technique which can be used in a wide variety of patients.

Background for the study

Some forms of the exercises which use large muscle groups such as walking, jogging, swimming have been used in cardiac rehabilitation programs for a long time. Also, these programs have been beneficial to the participants in recovering from their specific cardiac problem. Cardiac rehabilitation programs have also helped those who have had some forms of cardiovascular disease to return to life with full capacity. It is important to document the physiological gains the participants have as a result of participation in cardiac rehabilitation programs.

In 1986, A.B. Harrison and Kathryn D. Campbell tested 57 healthy subjects of ages 40 to 72 years as a follow up of the longitudinal study which was initiated in 1972 under the direction of A.B. Harrison (Harrison and Campbell, 1987, unpublished data). The mean age of the subjects was 42.3 years. The purpose of this longitudinal study was to reassess the effects of exercise on cardiorespiratory function, body composition and respiratory capacities during the aging process. One of the parameters measured in the study was cardiac output obtained with CO2 rebreathing method. These data which were obtained from healthy subjects would serve as a good base to compare the data which were obtained in this study with those who participated in a cardiac rehabilitation program.

Fifteen subjects who had gone through the cardiac rehabilitation program at Oklahoma State University, Health and Fitness Center and completed phases I,II and III were given a cardiac output test. The need exists for cardiac output data that has been collected from the healthy population and cardiac rehabilitation population in order to make comparisons.

Statement of the Problem

The purpose of this study was to compare the cardiac output of Phase III patients with the cardiac output of healthy subjects.

Phase III of cardiac rehabilitation usually follows Phase II, which begins after hospital discharge and lasts for 10 to 20 weeks. Phase I is the phase that the patient spends about a week in the hospital intensive care unit (ICU) as an in patient. Phases II and III involve the patient participated in exercise in conjunction with behavioral modification education sessions. Some of these sessions include instruction in smoking termination, weight reduction, nutritional habits and stress modification. Phase III of cardiac rehabilitation is conducted in settings such as university or college facilities, a commercial health club, YMCA, etc. A medical personnel (physician or nurse) should supervise the Phase III program, usually for a period of 3 to 6 months. The patient may be advanced to a nonphysician aspect of Phase III or to an adult fitness program, after he/she has been conditioned to a desirable level of exercise tolerance. The patient should then have a symptom-limited maximal exercise test (SL max) each year in an adult fitness program and should also have this test at the end of Phase II and prior to nonphysician aspect of Phase III. The Phase II program, on the other hand, may involve home exercise with visits to Outpatient Cardiac Rehabilitation Center (OCRC). Phase II facilities also involve electrocardiogram (ECG) telemetered exercise. The purpose of the participant in both the cardiac rehabilitation program and the adult fitness program should be to maintain the level of attained exercise tolerance (Wilson, et al., 1981).

Hypotheses

The hypotheses for this study were stated as follows:

1. There is no significant difference in cardiac output between the Phase III patients and healthy subjects.

2. There is no significant difference in stroke volume between the Phase III patients and healthy subjects.

3. There is no significant difference in resting heart rate between the Phase III patients and healthy subjects.

4. There is no significant difference in resting systolic blood pressure between the Phase III patients and healthy subjects.

5. There is no significant difference in resting diastolic blood pressure between the Phase III patients and healthy adults.

Limitations

The limitations for this study were stated as follows:

1. The subjects were volunteers.

2. There was no attempt to control sleep, diet or other personal habits.

3. Cardiac Output was non-invasively determined.

4. No attempt was made to control drug dosages prescribed for the subjects.

5. The hemoglobin was assumed to be 15 gr/dl.

Delimitations

1. The subjects were male patients ranging in age from 44 to 77.

Assumptions

1. The subjects put forth their best effort during the exercise rehabilitation program.

2. The subjects followed the treatment guidelines prescribed by their physician.

3. The hemoglobin was assumed to be 15 gm/dl.

Definition of Terms

Angina - Chest pain.

Angioplasty (PTCA-Percutaneous Transluminal Coronary Angioplasty) - The most recent and innovative invasive therapy used for dilating narrowed coronary artery by a special balloon-tip catheter introduced through a peripheral artery (Fardy, et. al., 1988).

Arterial carbon dioxide tension (Pa-CO2) - the amount of carbon dioxide pressure in the arterial blood.

Arterial-venous oxygen difference (a-VO2) - the difference between the oxygen content of arterial and mixed venous blood.

Carbon dioxide production (VO2) - the amount of carbon dioxide produced.

Cardiac output - the quantity of blood ejected from the left ventricle of the heart in one minute.

Diastolic blood pressure - the amount of pressure applied to the inner walls of the blood vessels during ventricular relaxation.

Forced expiratory volume - 1 second (FEV1) - the percentage of the vital capacity that can be expired in 1 second.

Functional residual capacity - the volume of air that remains in the lungs after a full expiration.

Heart rate - the contraction rate of the heart in one minute.

High-Density Lipoprotein-Cholesterol (HDL-C) - The type of lipoprotein that transports its cholesterol to the center of the body where it can be used by the liver or excreted as waste.

Ischemia - Lack of sufficient blood to the heart muscle.

MET - A Met is a multiple of the resting metabolic rate.

Metabolic measurement cart (Met Cart) - preprogrammed, computerized equipment used to give the NICO (Non-Invasive Cardiac Output) Test which determines Oxygen consumption and CO_2 production.

Mixed venous carbon dioxide tension (PV-CO_2) - the amount of carbon dioxide pressure in the mixed venous blood.

Oxygen consumption (VO_2) - the amount of oxygen consumed by a person in 1 minute.

Spirometer - calibrated equipment to record respiratory data.

S-T Depression - Below the baseline, depressed or negative S-T segment which is the part of the T wave between the end of the QRS and the point at which the slope of the T wave appears to become steeper abruptly (Jules, 1973).

Stroke volume - the quantity of blood ejected from the left ventricle of the heart with each contraction.

Systolic blood pressure - the amount of pressure applied to the inner walls of the blood vessels as a result of ventricular contraction.

Tidal volume - the volume of air moved that can be voluntarily moved in one breath, from full inspiration to maximum expiration, or vice versa.

Venous-arterial carbon dioxide difference (V-a CO_2) - the difference between the carbon dioxide content of mixed venous and arterial blood.

CHAPTER II

REVIEW OF LITERATURE

Cardiac rehabilitation and effects of cardiac rehabilitation on cardiac output has been studied by many investigators. Zohman and Tobis (1970) stated that the emphasis in cardiac rehabilitation is on restoration of physical, mental and social function of individuals and permitting them to live a life of maximal usefulness in their community. Zohman and Tobis mentioned Grollman's (1929) study as one of the oldest cardiac output measurements using the acetylene method. Grollman found that when the patient was relaxed, the cardiac output rose only about 100 cc/min. while the cardiac output rose as much as 900 cc./min. when the patient was intentionally angered. King (1975) believes that cardiac rehabilitation strives for the achievement and maintenance of optimal cardiac conditioning and the control of cardiac risk factors. He also added that the patient with cardiac disease can improve the quality of life and may decrease morbidity with a better conditioned cardiovascular system.

Most authorities agree that physical reconditioning offers a safe and effective contribution toward cardiac rehabilitation. Organized exercise programs condition the cardiac patient to reach certain levels of activity without symptoms (Davis and Spillman). Some of the components of cardiac rehabilitation are as follows: the patient referral process, the exercise prescription, the basic program design, and the supervision of the patient. If these components are individualized for the patient, he/she will usually progress smoothly to the final outpatient discharge (Amundsen, 1981). Cardiac problems lower both the resting stroke volumes and the potential increase in stroke volume during exercise (Amundsen, 1981). Fry and Berra (1981) described cardiac rehabilitation programs, which were first introduced in the 1950s as one effort to lessen the incidence of new heart attacks and premature death. Fry and Berra summarized the benefits of the regular exercise to coronary patients as: a)- lower death rate within the first few years after an infarction, b)- less anxiety and depression, c)- less ischemia as measured by angina and ST depression.

The CO2 rebreathing method for the measurement of cardiac output (Q) at rest has been used in studies with normal individuals and patients with cardiac disease. Mahler et al (1983) found that the CO2 rebreathing technique is an accurate, non-invasive method for measuring cardiac output at rest with cardiac patients and healthy individuals. They determined the cardiac output of 18 patients by CO2 rebreathing and direct Fick method and found a significant correlation (r=0.91;<0.001) between the two methods.

The measurement of cardiac output by CO2 rebreathing method is not a new technique (Mahler et al., 1983). The use of this technique was employed early in this century (Ferguson, et al., 1968). Furthermore, the results of the studies that have used this technique are available. Through their testing of 13 healthy subjects Ferguson et al., (1968) found that cardiac output by CO2 rebreathing was reproducible when compared to the dye-dilution method with a low correlation (r=0.22). With exercise however, correlation improved from r=0.54 to 0.87. Ferguson et al also stated that the CO2 rebreathing method is a reproducible and convenient "bloodless" technique in exercise for determining cardiac output. Muiesan and colleagues (1968), on the other hand, measured the correlation at rest in 17 healthy individuals and found good correlation (r=0.94) between CO2 rebreathing and direct Fick values. Mahler and colleagues (1983) also found a highly significant correlation (r=0.91; p<0.001) between the CO2 rebreathing method and the Fick method in 18 patients at rest.

Clause and colleagues (1970) found a poor correlation between the CO2 rebreathing and the dye-dilution methods in 10 patients at rest with coronary artery disease or pulmonary disease. They also concluded that cardiac output values determined with the CO2 rebreathing method were only reproducible and reliable during exercise and in the absence of pulmonary disease. On the other hand, Davis et al. (1978) showed high correlation (r=0.94) with a plus and minus 15% variation between the CO_2 rebreathing technique and the direct Fick method in 18 critically ill patients. Mahler et al. (1983) showed in their study that the Metabolic Measurement Cart is as accurate as direct Fick method in determination of cardiac output.

While others found high correlations, Franciosa (1977) found a weak correlation (r=0.52) in 21 patients with congestive heart failure; on the other hand he found an excellent correlation in patients with shock (r=0.94) and acute myocardial infarction (r=0.95) between CO_2 rebreathing and standard dye-dilution or Fick methods. In 1977, Franciosa did simultaneous measurements of cardiac output by CO_2 rebreathing and dye-dilution or direct Fick techniques in 53 patients. Rebreathing cardiac output averaged 4.85 L/min. compared to 5.18 L/min. by dye-dilution or Fick in nine patients with pulmonary disease (r=0.16). Cardiac output was 5.53 L/min. by rebreathing and 5.87 L/min. by dye-dilution (r=0.94) in nine shock cases. Franciosa's data suggested that the CO_2 rebreathing cardiac output method may be useful in the CCU-MICU setting.

While Franciosa worked with the CO_2 rebreathing cardiac output method, Hatcher and SRB (1986) compared two different noninvasive techniques, transthoracic impedance plethysmography (Z) and the CO2 rebreathing (RB) method for the examination of cardiac output. They made paired estimates of Q on 60 different male subjects at rest and during graded increments of work on a cycle ergometer. They found a linear relationship between the Z and RB techniques at all work loads (r=0.75). Their study suggested that both techniques are equally reliable over a large range of work loads.

In addition to the research that has been done to determine the cardiac output (Q) with adults, some studies have also been done with children to determine cardiac output with CO2 rebreathing method. Paterson et al. (1982) used children subjects to determine cardiac output with CO2 rebreathing method. The investigators concluded that cardiac output estimates using CO2 rebreathing in exercising children showed a day-to-day and long term stability acceptable for use in research and clinical studies (Paterson, et al., 1982).

In another study, Ohlsson and Wranne (1986) evaluated the determination of cardiac output (Q) and stroke volume (SV) by Fick method in 13 patients during exercise. They stated that the correlation between the methods was so good that a valid estimate of cardiac output could be obtained from the CO2 rebreathing method with appropriate corrections. They also concluded that stroke volumes measured with the CO2 rebreathing method did not differ significantly from those obtained with the direct Fick technique, although there was a tendency to overestimate stroke volume with the rebreathing method (Ohlsson and Wranne, 1986).

Out of thirteen (13) studies, 11 compared the CO2 rebreathing technique to an invasive technique such as Fick method and one compared CO2 rebreathing technique with another noninvasive technique. All of these studies found high correlation between the two techniques they compared. Only one (1) out of thirteen studies found low correlation between the CO2 rebreathing technique and the invasive technique. Investigators of those twelve (12) studies stated that CO2 rebreathing technique is a valid and reliable way of determining the cardiac output of healthy subjects and patients with cardiopulmonary disease.

Since cardiac output (Q) is one of the primary indicators of the functional capacity of the circulatory system, it is worthwhile to look at the studies that investigate the effects of physical activity on cardiac output. Zhou et al. (1984) studied the effects of rehabilitation in 91 patients with coronary heart disease for 3.68 plus or minus 0.99 months, and found: 1) the patients' symptoms were relieved, 2) their treadmill exercise time increased, 3) their serum cholesterol lowered, 4) their high density lipoprotein (HDL) rose and 5) their aerobic exercise capacity improved. Additionally, they found left ventricular function, such as stroke volume and cardiac output increased 8 percent and 14 percent at rest; and 16 percent and 14 percent during exercise, respectively, and the abnormal responses of left ventricular function to exercise decreased. Based on their results, they concluded that exercise therapy may play an important role in the rehabilitation of coronary heart disease and can improve cardiovascular function and physical fitness, reduce some of the factors of coronary risk, and inhibit the progressiveness of the disease (Zhou et al., 1984).

Similarly, in another study, Boileau and colleagues (1984) looked at the relative contribution of cardiac output (Qmax), stroke difference (SVmax), heart rate (HRmax), and arteriovenous oxygen (a-v) O2 difference max to variation in arm and leg VO2 max in 40 male subjects, age 18-25 years. Their data indicated that the (a-v) O2 diff max contributed more than either SVmax or HRmax for the arm while SVmax contributed more than (a-v) O2 diff max or HRmax for the leg. Therefore, based on this evidence, they suggested that central factors as opposed to peripheral factors are more important in leg work, while peripheral factors play a primary role in arm work, particularly in arms that are relatively untrained (Boileau, et al., 1984).

On the other hand, Tesch (1985) investigated the effect of beta blockers on performance during physical activity. He stated that even though clinical doses may reduce the heart rate by 30 to 35 percent, during maximal exercise cardiac output is not equally reduced. The conclusion of the study was that the ability to perform athletic events requiring high levels of motor control under emotional stress, but not high levels of aerobic or anaerobic energy, is probably increased during beta-blockade (Tesch, 1985).

The effect of a weight training program designed to develop lower extremity muscular endurance on cardiac output and related measures was studied by Boone and Byrd (1982), who observed no significant difference between the adjusted post test means for steady state VO2, Q, SV, a-VO2 difference or maximum VO2, HR, physical working capacity or strength measures. The investigators concluded that significant hemodynamic changes do not occur at steady state exercises when the subjects are engaged in a localized muscular endurance weight training program. According to the investigators, the subjects should train via some aerobic sport, such as jogging, swimming, and cycling in order for favorable changes to occur (Byrd, 1982).

Thompson et al. (1981) have reported central cardiovascular changes in 10 healthy men after 11 weeks of either arm or leg exercise training. Astrand and colleagues (1964) determined cardiac output and stroke volume (dye-dilution technique) in 2 women and 12 men at rest when performing submaximal and maximal work. They found that maximal stroke volume reached at a workload with an oxygen uptake of about 40% of the maximum and a heart rate about 110, while the maximal cardiac output was 18.5 Liters/min for women and 24.1 Liters for men. They also found a high correlation between heart volume on one side and maximal stroke volume and cardiac output on the other side (Astrand, et al., 1964).

Massicotte and Avon (1980) investigated the effects of training intensity on cardiac output in young women. They stated that increased aerobic capacity observed during a relatively short exercise program in young active women might be due to a central adaptation with no appreciable variation in a-VO2. They added that the training intensity does not seem to influence these changes. In a similar study Simonson (1972) used maximal VO2 for evaluating cardiac performance with the idea that the limit of oxygen transport (VO2) and aerobic capacity is essentially determined by blood flow (cardiac output). Simonson also concluded that increase of heart rate is the principal mechanism for increase of cardiac output in exercise and has been used for predicting VO2 with an age correction.

The influence of training upon the distribution of cardiac output was investigated by Simmons and Shephard (1972). The researchers had 10 sedentary men perform arm ergometer exercise at 80 percent of aerobic power for thirty minutes biweekly. There was some decrease of postural work with an improved mechanical efficiency at the end of one month and an increase in directly measured maximum oxygen intake by 8 percent. The maximum cardiac output increased from 17.8 to 19.3 L/min. The investigator concluded that this increase was due to an augmentation of stroke volume. There was both a decrease of the heart rate and arteriovenous oxygen difference in submaximum exercise (Simmons and SHephard, 1972).

Giorgetti and colleagues (1980) did a study related to the behavior of cardiac function during a maximal work test and concluded the following: the output efficiency of the trained heart is superior, and it utilizes more economic mechanisms of adaptation which make it possible to reach a higher VO2 max and a better performance. Secondly, the non-invasive study of the dynamics of the left ventricle in a healthy subject gives objective elements which discriminate between trained and normal subjects in a maximal exercise (Giorgetti, et al., 1980).

Likewise, Versteed and Borgdorff (1986) compared the time constants of cardiac output adaptation at the onset of exercise with and without vagal blockade in normal and beta blocked dogs They also studied the relative influence of sympathetic and parasympathetic nerves on steady state values of heart rate, stroke volume and cardiac output during exercise. Their suggestion was that the rapid adaptation of cardiac output to a new exercise level in normal dogs is mainly mediated by a quick withdrawal of vagal tone (Versteed and Borgdorff, 1986).

CHAPTER III

METHODS AND PROCEDURES

Selection of Subjects

The subjects in the group I (cardiac patients) were selected from male volunteers in the Phase III cardiac rehabilitation program. They had been referred to the cardiac rehabilitation program of the Oklahoma State University Health and Fitness Center by their physician. A total of fifteen subjects were tested during the investigation. The mean age of the subjects in this group was 63.1 years, with participants ranging from 44 to 77 years.

Eleven of the fifteen subjects had had coronary artery bypass surgery. One subject was diagnosed as having a myocardial infarction (MI) and one of the subjects had both coronary artery bypass surgery and angioplasty. One other subject has atherosclerotic heart disease, anterior myocardial infarction and angioplasty while another one had coronary artery (atherosclerotic) disease and coronary artery bypass surgery. Most of these subjects were also on some kind of medication (Table I).

TABLE I

MEDICATION, DISEASE, AND MEDICAL PROCEDURE EXPERIENCED BY THE SUBJECTS IN THE GROUP I (CARDIAC PATIENTS)

Subject #	Drugs	Disease and Medical Procedure
1	None	Atherosclerotic Heart Disease; Anterior Myocardial Infarction and Angioplasty
2	Tenormin and Lasix	Coronary artery disease (Atherosclerotic) and Coronary Artery Bypass Surgery
3	Zantac, Inderal, and Cardizem	Coronary Artery Bypass Surgery
4	Procan	Coronary Artery Bypass Surgery
5	Persantine	Coronary Artery Bypass Surgery and Ecotrin
6	Lanoxin and Quinidene	Coronary Artery Bypass Surgery
7	Persantine and Ecotrin	Coronary Artery Bypass Surgery
8	Lasix and Coated Aspirin	Myocardial Infarction (MI)
9	None	Coronary Artery Bypass Surgery
10	Procardia	Angioplasty and Coronary Artery Bypass Surgery
11	Zantac, Persantine, and Cardizem	Coronary Artery Bypass Surgery
12	Quinidex and Hydergine	Coronary Artery Bypass Surgery

TABLE I (Continued)

Subject #	Drugs	Disease and Medical Procedure
13	Persantine, Tenormine, Lanoxin, and Aspirin	Coronary Artery Bypass Surgery
14	Quinidex and Lanoxin	Coronary Artery Bypass Surgery
15	Aspirin	Coronary Artery Bypass Surgery

The possible effects of these drugs on resting cardiac output was also investigated. According to the "physicians' desk reference" (1988), only Tenormin and Lanoxin had effect on the resting cardiac output (Q) (Table II).

The subjects in the group II (healthy adults) were fifty-three male faculty and administrators at Oklahoma State University with varied exercise habits and fitness levels. They had been participating in the Harrison longitudinal study since 1972-1974. The mean age of the subjects in this group was 55.5 years, with participants ranging from 40 to 77 years. The subjects in this group were also all volunteers.

TABLE II

THE MEDICATION GROUP ONE SUBJECTS (CARDIAC PATIENTS) WERE UNDER AND THEIR EFFECTS ON RESTING CARDIAC OUTPUT (Q)

Subject #	Drugs	Effects on Resting Q
1	None	No Effect
2	Tenormin	Has been demonstrated by reduction in resting and exercise heart rate and cardiac output
	Lasix	No Effect
3	Zantac	No Effect
	Inderal	No Effect
	Cardizem	No Effect
4	Procan	No Effect
5	Percantine	No Effect
	Ecotrin	No Effect
6	Lanoxin	Increased Cardiac Output
	Quinidene	No Effect
7	Persantine	No Effect
	Ecotrin	No Effect
8	Lasix	No Effect
	Coated Aspirin	No Effect
9	None	No Effect
10	Procardia	No Effect
11	Zantac	No Effect
	Persantine	No Effect
	Cardizem	No Effect
12	Quinidex	No Effect
	Hydergine	No Effect

TABLE II (Continued)

Subject #	Drugs	Effects on Resting Q
13	Persantine	No Effect
	Tenormin	Has been demonstrated by reduction in resting and exercise heart rate and cardiac output
	Lasix	No Effect
	Aspirin	No Effect
14	Quinidex	No Effect
	Lanoxin	Increased Cardiac Output
15	Aspirin	No Effect

Personal Data Collected

A complete medical history was taken for each subject. The medical form and questionnaire used by the Health and Fitness Center cardiac rehabilitation program was also used for this study (Appendix B). This included family history of coronary heart disease, exercise habits, drinking and smoking habits, brief relevant medical history and current medication.

The investigation was conducted at the School of Health Physical Education and Leisure Services (HPELS), Health and Fitness Center laboratory. Even though there was no risk involved in the study, a registered cardiac nurse was present. After recording the previous information, the subject was informed about the investigation and all procedures. All the subjects signed an informed consent document as required by Oklahoma State University and the Health and Fitness Center. The informed consent stated that the subjects understood the conditions of the experiment (Appendix A). The forms were held in confidence and the names were not published with the research findings.

Administration of the Test

The subjects were tested in the Health and Fitness Center Laboratory in the School of HPELS at Oklahoma State University. Each test took about 10 to 15 minutes. The equipment used was a Metabolic Measurement Cart (Sensomedics MMC HorizonTM Systems). Each subject was tested once at a convenient time towards the end of the Phase III program.

The CO2 Rebreathing Method was used for this investigation. In order to employ this method, the subject was in a sitting position connected by a mouthpiece and hose to a computerized Met Cart (Metabolic Measurement Cart). The subject,s hose was connected to a gas analyzer and computer. Basically, the total analysis was achieved through use of the data collected by the gas analyzer.

Some other data were also keyed in by the investigator to help with the total analysis. These were FEV1 (Forced Expired Volume in 1 second), which shows how flexible the lungs are, and the amount of hemoglobin the subject had in his blood, which was assumed to be 15 gm/dl. Depending upon the program being run, the MET Cart can determine VO2, resting and exercise cardiac output and metabolic body functions.

Each subject breaths through a low resistance two-way valve. The system is then flushed for six minutes; expired gas volume and VCO2 are measured every 30 seconds with the Met Cart. Carbon Dioxide production was determined in this manner. The Met Cart also estimated arterial CO2 tension (Pa-CO2) from end-tidal PCO2. (Mahler, et. al., 1983).

Mixed venous carbon dioxide tension (Pv-CO2) was estimated by the equilibration method of Collier with the subject rebreathing from a bag containing 10% CO2 in oxygen (Collier, 1956). The volume placed in the rebreathing bag was approximately 1.5 times the tidal volume. At the end of a normal expiration (functional residual capacity), the two-way valve was switched and rebreathing of CO2 was started. Subjects were instructed to increase the frequency of breathing to 20 to 25 breaths per minute in order to facilitate gas mixing. Expired CO2 tension was measured at the mouth, analyzed by the Met Cart, and displaced on a two channel recorder (7402 A Hewlett - Packard Waltham, MA).

After several breaths of 10% CO_2 from the bag, an equilibrium was achieved between the carbon dioxide tension in the bag, the alveolar gas in the lungs and the pulmonary capillary blood. Mixed venous and arterial CO_2 contents were calculated from Pv-CO_2 and Pa-CO_2 by the Met Cart (Mahler, et al., 1983). V-aCO_2 difference was determined in this manner.

In order to measure FEV1 (Forced Expired Volume in 1 second), the subject was asked to stand up front of the vitolograph (Vitolograph TM Spirometer), and a clip was put on his nose. After the vitolograph was cleared and calibrated, the subject took a deep breath and took the clean mouth piece into his mouth and blew the air into the hose through the mouth piece as hard as he could. After the subject exhaled and removed the mouth piece, the investigator pushed the "record" button and the subject repeated the same procedure. At the end of the blow, the investigator pushed the "print" button and got the FEV1 as well as other lung capacity measurements.

Analysis of Data

Means and standard deviations were computed for all physiological variables of interest. Those variables included all resting measurements: heart rate, blood pressure (systolic/diastolic), stroke volume, cardiac output and FEV1. The SAS data analysis system statistical package (SAS Institute, 1982) of IBM 3081 mainframe computer at the Oklahoma State University computer center was used to complete the statistical analysis of all data. The stated hypotheses were tested by comparing these two groups. To test these hypotheses, a t-test was used for each physiological variable. The ANOVA (Analysis of Variance) techniques were used to determine any differences between groups on the physiological variables that have been selected as relevant to the study. Those variables included all resting measurements: heart rate, blood pressure (systolic/diastolic), stroke volume, cardiac output and FEV1. However, both the t-test and the ANOVA techniques gave the same results. Therefore, two tail t-test was used to analyze the results. The null hypotheses were rejected if the T value were significant at the .05 level.

The correlation between the age and the other physiological variables was also tested. Pearson Moment Correlation Coefficients technique was used for this purpose.

CHAPTER IV

RESULTS AND DISCUSSION

Fifteen male cardiac rehabilitation participants were given the resting cardiac output (Q) test at the phase III of the cardiac rehabilitation program. These subjects were also tested on diastolic blood pressure (DBP), systolic blood pressure (SBP), resting heart rate (RHR), stroke volume (SV), height, weight and body surface. The same physiological measurements were taken from fifty-three male faculty and administrators at Oklahoma State University. For simplification of discussion, the first group of cardiac patients will be referred to as group one. The healthy group will be referred to as group two. This chapter presents the results of the tests and discusses these results.

A correlated T test was performed on all variables. Means, standard deviations and results of the T test are presented in Table III. Hypothesis one stated that there was no significant difference in cardiac output between the phase III patients and healthy subjects. Cardiac output(Q) for group one was 4.2 L/min while it was 4.8 L/min for group two. This difference was not significant at the .05 level. Therefore, the null hypothesis was not rejected for this variable.

TABLE III

MEANS AND STANDARD DEVIATIONS OF PHYSIOLOGICAL VARIABLES

Variable	Group one	Group two	t
Diastolic Blood Pressure	79.5+4.71	83.2+-7.47	-3.56 a
Systolic Blood Pressure	120.4+-7.94	124.4+-12.78	-1.14
Resting Heart Rate	69.7+-9.72	67.7+-10.79	0.64
Cardiac Output	4.2+-1.03	4.8+-1.16	-1.80
Stroke Volume	61.9+-17.99	72.2+-18.67	-1.89
Height	69.6+-1.53	70.2+-2.26	-0.95
Weight	171.1+-20.17	178.7+-28.67	-0.96
Body Surface	1.9+-0.12	2.0+-0.18	-1.00

a $p<.01$

Hypothesis two stated that there is no significant difference in stroke volume between the phase III patients and healthy subjects. The stroke volume (SV) for the group one was 61.9, while it was 72.2 for group two. This difference was not significant at the .05 level. Thus, this hypothesis was not rejected.

The third hypothesis examined the resting heart rate and stated that there is no significant difference in resting heart rate between phase III patients and healthy subjects. The resting heart rate was 69.7 for group one and 67.7 for group two. This difference was not significant at the .05 level, and this hypothesis was not rejected.

The fourth hypothesis stated that there is no significant difference in resting systolic blood pressure (SBP) between phase III patients and healthy subjects. These values were 120.4 for group one and 124.4 for the group two, and there was no significant difference at the .05 level.

The last hypothesis stated that there is no significant difference in resting diastolic blood pressure (DBP) between phase III patients and healthy subjects. These values were 79.5 for a group one and 83.2 for group two, and there was a significant difference at the 0.05 level (Table III).

In addition to testing these hypotheses, some additional measurements were taken. These were height, weight and body surface and none of these measurements was significantly different at .05 level (Table III).
(DBP) was significantly different at the .05 level (Table III).

A Pearson Product Moment Correlation was used to test the correlation between age and certain physiological variables. These results are presented in Table IV. They show that only low, insignificant relationships existed between age and the other physiological variables. The range of the correlation was r=-.307 for cardiac output and r=.148 for systolic blood pressure.

TABLE IV

CORRELATION BETWEEN AGE AND SELECTED PHYSIOLOGICAL VARIABLES

Variable	R-value	Relationship
Diastolic Blood Pressure	-.142	low
Systolic Blood Pressure	.148	low
Resting Heart Rate	.011	low
Cardiac Output	-.307	low
Stroke Volume	-.271	low
Height	-.264	low
Weight	-.195	low
Body Surface	-.251	low

Tenormin and lanoxin effect resting cardiac output and heart rate as can be seen in table II. Subjects two (2) and thirteen (13) were on tenormin and subjects six (6) and fourteen (14) were on lanoxin. These subjects were taken out of the cardiac group and a t-test was used for each physiological variable to determine whether or not this would make any difference in the results between the two groups. None of the variables was significantly different at the .05 level.

The insignificant difference between the two groups in resting cardiac output and stroke volume shows that the cardiac rehabilitation participants were at the same level of cardiac output and stroke volume as their healthy counterparts. This might be interpreted as good evidence of the cardiac patients' recovery rate and the possible benefit of a cardiac rehabilitation program.

These findings are even more significant when one realizes the fitness level of group two subjects was good, based upon a comparison of their Max Vo2 values (Campbell, 1987) with cooper's fitness chart (Cooper)(Appendix B). However, additional data are needed to support more specific findings. It appears that group one subjects should be given a functional treadmill test. This would provide data to compare the two groups in maximal oxygen consumption (MaxVo2) and help explain the reasons for having similar cardiac output and stroke volume between the two groups.

The significant diastolic blood pressure (DBP) difference at the .05 level between the two groups may be attributed to the medication they were on. The combination of the several drugs that group one (Phase III patients) was on might have caused this significant difference.

There was a low correlation between age and other selected physiological variables among group two subjects (Harrison and Campbell, 1987, unpublished data). The same low correlation was found between age and selected physiological variables in group one subjects. This was one of the similarities found between the two groups.

Hemoglobin levels were not measured and assumed to be 15 gr/dl. for group one subjects. One reason for that was to have consistency. It was not measured for group two subjects. It appears that someone should determine the hemoglobin levels and measure cardiac output. Furthermore, it might even be a good idea to do cardiac output study with assumed different hemoglobin levels to find out the effects of such treatment on the results of cardiac output.

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

Fifteen male phase III cardiac patients and fifty-three healthy faculty and administrators from Oklahoma State University were given resting cardiac output test. These two groups were compared on cardiac output and several other variables. The purpose of the study was to determine whether or not the cardiac rehabilitation participants vary from their healthy counterparts on certain physiological variables. A correlated t-test and Pearson Product Moment Correlation Coefficient was used for this purpose.

Conclusions

From the results of this study the following conclusions were made relative to the hypotheses under the study:

1. A statistically significant difference was not shown between the Phase III patients and healthy subjects on resting cardiac output (Q), stroke volume (SV), resting heart rate (HR) and resting systolic blood pressure (SBP). The only significant difference was shown between the two groups on diastolic blood pressure (DBP).

2. There was a low correlation between age and other selected physiological variables.

Recommendations

1. It is recommended that a larger sample size be used to make generalized conclusions and additional data be collected such as body composition and cholesterol levels.

2. The effects of different hemoglobin levels on both resting and exercise cardiac output should be investigated to determine whether or not different levels of hemoglobin change the cardiac output results.

3. In a similar study, the physician of the cardiac patients should be informed about the protocol to eliminate the possible changes in prescribed drugs and their dosages, and subjects should be followed more closely to determine their health and activities.

REFERENCES

Adner, M. & Castelli, W. (1980). Elevated High Density Lipoprotein Levels in Marathon Runners. Journal of American Medical Association. 243(6): 534-536.

Amundsen, L.R. (1981). Cardiac Rehabilitation. Churchill Livingstone.

Astrand, P.O., Cuddy, T.E., Saltin B. & Stenberg J. (1964). Cardiac Output During Submaximal and Maximal Work. Journal of Applied Physiology. 19: 268-274.

Boileau, R.A., McKeown B.C. & Riner, W.F. (1984). Cardiovascular and Metabolic Contributions to The Maximal Aerobic Power of The Arms and Legs. International Journal of Sports Cardiology. 1(2): 67-75.

Boone, T. & Byrd R. (1982). The Influence of Lower Extremity Muscular Endurance Training on Cardiac Output and Related Measures. Journal of Sports Medicine and Physical Fitness. 22(4): 450-460.

Breisch, E.A, White, F.C., Nimmo, L.E., McKirnan, M.D. & Bloor, C.M. (1986). Exercise-Induced Cardiac Hypertrophy: A Correlation of Blood Flow and Microvasculature. Journal of Applied Physiology. 60(4): 1259-1267.

Clausen, J.P., Larsen, O.A. & Trap-Jensen, J. (1970). Cardiac Output in Middle-Aged Patients Determined with CO2 Rebreathing Method. Journal of Applied Physiology. 28(3): 337-342.

Constant, J. (1973). Learning Electrocardiography-A Complete Course. Boston: Little Brown and Company.

Davis, C., Norman, L.J., & Sealey, B.J. (1978). Measurements of Cardiac Output in Seriously Ill Patients Using a CO2 Rebreathing Method. Chest. 73(2): 167-172.

Davis, J.A. & Spillman, S.J. Cardiac Rehabilitation for Patient and Family. Reston Publishing Company.

DeFares, J.G. (1958). Determination of PVCO2 from The Exponential CO2 Rise During Rebreathing. Journal of Applied Physiology. 13(2): 159-164.

DuQuesnay, M.C., Stoute G.J. & Hughson, R.L. (1987). Cardiac Output in Exercise by Impedence Cardiography During Breath Holding and Normal Breathing. Journal of Applied Physiology. 62(1): 101-107.

Efraim, B., Kellermann, J.J., Fisman, E.Z., Pines, A., Peled, B., & Drory, Y. (1986). Benefits of Long-Term Physical Training in Patients After Coronary Artery Bypass Grafting-A 58-Month Follow-up and Comparison with A Nontrained Group. Journal of Cardiopulmonary Rehabilitation. 6:165-170.

Fardy, P.S., Yanowitz, F. G., & Wilson, P. K. (1988). Cardiac Rehabilitation, Adult Fitness, and Exercise Testing (second edition). Philadelphia: Lea & Febiger.

Ferguson, R.J., Faulkner, J.A., Julius, S. & Conway, J. (1968). Comparison of Cardiac Output Determined by CO2 Rebreathing and Dye-dilution Methods. Journal of Applied Physiology. 25(4): 450-454.

Franciosa, J.A. (1977). Evaluation of The CO2 Rebreathing Cardiac Output Method in Seriously Ill Patients. Circulation. 55(3): 449-455.

Giorgetti, C., Paolinelli, C., Scarselli, S., Cartoni, A., and Viti, V. (1980). Behaviour of Cardiac Function During Maximal Work Test. Sports Cardiology. 93-98.

Harrison, A.B. and Campbell, K.D. (1986). Unpublished Data.

Hartung, G.H., Foreyt, J.P., Mitchell, R.E., Vlasek, I., & Gotto, A.M. (1980). Relation of Diet to High-Density-Lipoprotein Cholesterol in Middle-aged Marathon Runners, Joggers, and Inactive Men. The New England Journal of Medicine. 302(7): 357-361.

Hatcher, D.D. & SRB, O.D. (1986). Comparison of Two Noninvasive for Estimating Cardiac Output During Exercise. Journal of Applied Physiology. 61(1): 155-159.

Jones, N.L., Campbell, E.J., Edwards, H.T. & Robertson, D.G. (1975). Clinical Exercise Testing. W.B. Saunders Company.

King, O.M. (1975). Care of The Cardiac Surgical Patient. The C.V. Mosby Company.

Mahler, A.D., Matthay, R.A., Snyder, P.E., Langou, R., Zaret, B.L. & Loke, J. (1983). Rapid, Non-invasive Determination of Cardiac Output at Rest by CO2 Rebreathing Using A Computerized System: Application in Normal Adults and Patients with Cardiac Disease. Computers in Critical Care and Pulmonary Medicine. 3:73-82.

Massicotte, D., Avon, G. (1981). Effects of Training Intensity on Cardiac Output in Young Women. International Congress on Women and Sport (1980:Rome). Medicine Sport. 14:148-154.

McArdle, W.D., Katch, F.I. & Katch, V.L. (1981). Exercise Physiology-Energy, Nutrition and Human Performance. Lea and Febiger.

Muiesan, G., Sorbini, C.A., Solinas, E., Grassi, V., Casucci, G., & E. Petz. (1968). Comparison of CO2-Rebreathing and Direct Fick Methods for Determining Cardiac Output. Journal of Applied Physiology. 24(3): 424-429.

Newman, W.P., Freedman, D.S., Voors, A.W., Gard, P.D., Srinivasan, S.R., Cresanta, J.L., Williamson, D.G., Webber, L.S., Berenson, G.S. (1986). Relation of Serum Lipoprotein Levels and Systolic Blood Pressure to Early Atherosclerosis. The New England Journal of Medicine. 314(3): 138-143.

Ohlsson, J. and B. Wranne. (1986) Non-invasive Assessment of Cardiac Output and Stroke Volume in Patients During Exercise. European Journal of Applied Physiology and Occupational Physiology. 55(5): 538-544.

Paterson, D.H., Cunningham, D.A., Plyley, M.J., Blimkie, C.J.R. & Donner, A.P. (1982). The Consistency of Cardiac Output Measurement (CO2 Rebreathe) in Children During Exercise. European Journal of Applied Physiology and Occupational Physiology. 49: 37-44.

Physicians' Desk Reference. (1988). Publisher - Edward R. Barnhart. Medical Economics Company Inc.

Pollock, M.L. & Schmidt, D.H. (1986). Heart Disease and Rehabilitation. John Wiley and Sons.

Simmons, R. and Shephard, R.J. (1972). The Influence of Training Upon the Distribution of Cardiac Output. Training-Scientific Basis and Application. Springfield, IL: Charles C. Thomas. 134-138.

Simonson, E. (1972). Evaluation of Cardiac Performance in Exercise. The American Journal of Cardiology. 30: 722-726.

Tesch, P.A. (1985). Exercise performance and beta-blockade. Sports Medicine (Auckland, N.Z.). 2(6): 389-412.

Thompson, P.D., Lewis, S., Varady, A., Popp, R., & Haskell, W. (1981). Cardiac Dimensions and Performance After Either Arm or Leg Endurance Training. Medicine and Science in Sports and Exercise. 13(5): 303-309.

Versteed, P.G.A & Borgdorff, P. (1986). Influence of Vagal Cooling on Cardiac Output in Normal and Beta-blocked Exercising Dogs. European Journal of Applied Physiology and Occupational Physiology. 54: 617-623.

Wilson, P.K. (1975). Adult Fitness and Cardiac Rehabilitation. University Park Press.

Zhou, S., Li, J. & Jin, Y. (1984). The Clinical Efficiency of The Rehabilitation in Patients with Coronary Heart Disease. Chinese Journal of Sports Medicine. 3(3): 164-172.

Zohman, L.R. & Tobis, J.S. (1970). Cardiac Rehabilitation. Grune and Stratton.

APPENDIXES

APPENDIX A

INFORMED CONSENT

Oklahoma State University
Health and Fitness Center
Cardiac Output Study

Informed Consent

Explanation of Test

The test you are about to undergo is part of a research study. You will be connected to the gas analyzer and you will be breathing room air. The air you exhale will be collected by the machine and analyzed by the computer. You might feel some discomfort due to the fact that you are not accustomed to breathing through a mouth piece and hose.

The test will take about 10 (ten) minutes. At the end of the test the data gathered will be entered into the computer. The computer will print out the cardiac output value which tells us the amount of blood circulated in the body in one minute. We will compare these results with the standard values found in other research reports. Through research such as this, it is hoped that reasons for cardoivascular disease can be identified so that preventative measures can be taken.

Consent by Subject

The information which is obtained will be treated as privileged and confidential and will not be released or revealed to anyone without your express consent. The information will be used for research purposes only as a part of group data. Results will be given to you following the completion of the study.

A registered cardiac nurse, trained for emergencies and the use of a defibrillator and emergency drugs, will be present during testing. The investigator is also a certified member (Exercise Test Technologist) of the American College of Sports Medicine and a Red Cross CPR instructor. In the event of a research related injury, the above staff will be in charge and will notify the OSU Student Health Center physicians if necessary. Questions pertaining to the research, subject's rights and who to contact in case of research-related injury may be addressed to the investigator.

I have read and understand the foregoing. Any questions which may have occured to me have been answered to my satisfaction and I am aware of any risks associated with my taking the tests. I understand that I may withdraw from or discontinue my participation at any time I feel it necessary.

DATE: ______________________________

SUBJECT: ______________________________
(signature) (printed name)

WITNESS: ______________________________
(signature) (printed name)

INVESTIGATOR ______________________________
(signature) (printed name)

Phone: (H:) 743-2084; (W:) 624-5507

APPENDIX B

DATA COLLECTION FORMS

HEALTH AND FITNESS CENTER
Oklahoma State University

The following information is needed for our records and in assessing your current health and fitness status. By providing as much of this information as possible in advance, time will be saved during the evaluation. All information provided will be held in strict confidence.

NAME ______________________ DATE ______________

ADDRESS: Street ______________ City ____________ State ______ ZIP ______

HOME PHONE ______________ EMPLOYER ______________________

OCCUPATION ____________ BUSINESS ADDRESS ______________ PHONE ______

AGE LAST BIRTHDAY ______ BIRTH YEAR _____ Does your job require physical activity? _____

Do you currently smoke? _____ If so, what? ______________ number/day ________
If not, have you ever smoked? ____ If yes, what? __________ no/yrs _____ yrs. quit _____

Do you ever drink alcoholic beverages? _____ If yes, approx. no.: less than 1/day _____
1-2 per day ______ 3 or more per day ______

Do you currently participate in any form of exercise on a regular basis? _______
Indicate no. of times/weekly of participation: walking _____ jogging _____ swim _____
golf _____ basketball _____ handball/racquetball _____ tennis _____ other (name) _____
If you walk, job or swim, please indicate distance and time covered each session and approximate pace ______________________________

What is your estimate of your current medical condition? ex.__ good__ fair__ poor__
What is your estimate of your current physical fitness? ex.__ good__ fair__ poor__

Circle the number of blood relatives (parents, grandparents, brothers, sisters, that have been diagnosed as having some form of heart disease:
Under 60 years of age: 1 2 3 4 5 6 7 8 9 Over 60 years of age: 1 2 3 4 5 6 7 8 9

Have you ever been told that you have any form of heart disease? _____
Have you ever been told that you have diabetes? _____
Do you have blood relatives with diabetes? _____ If so, how many? _____

Do you consider yourself to be overweight? _____ If so, approx. how many lbs.? _____
Do you have any medical conditions (other than heart disease or diabetes) that might affect your exercise performance? _____ If so, please list ______________

Who is your family physician? ______________ City ______________
Address, if known ______________ date last medical exam ____________
Would you like your stress test records sent to this physician? _____
If you would prefer to have your records sent to another physician, please list name and address ______________________________

Are you currently taking any kind of medication? _____
If yes, is it non-prescription? _____ If so, name ______________
If yes, is it prescription? _____ If yes, give name if possible ______________

Have you ever been told that you have high cholesterol or high triglyceride levels in the blood? Cholesterol: yes___ no___ Triglyceride: yes___ no___

If you know your cholesterol and/or triglyceride levels, please list

Cholesterol __________ Triglyceride __________

RECORDING SHEET

NAME:

BIRTHDAY:

HEIGHT (Inches):

WEIGHT:

FEV1:

HEART RATE:

DATE:

BRIEF RELEVANT MEDICAL HISTORY:

Grade	METS / 02		Heart Rate	BP	EKG Comments
21	13.2	46.0			
22	13.6	47.0			
23	14.0	49.0			
24	14.9	51.9			
25	15.3	53.6			
26	15.8	55.7			
27	16.3	56.9			
28	16.7	58.5			
29	17.2	60.2			
30	17.7	61.8			
31	18.13	63.5			
32	18.6	65.1			

Cooper's Fitness Classification: Men

Category	Measure O^2ml/kg/min	Age 13-19	20-29	30-39	40-49	50-59	60+
I. Very Poor		< 35.0	< 33.0	< 31.5	< 30.2	< 26.1	< 20.5
II. Poor		35.0-38.3	33.0-36.4	31.5-35.4	30.2-33.5	26.1-30.9	20.[illegible]-26.0
III. Fair		38.4-45.1	36.5-42.4	35.5-40.9	33.6-38.9	31.0-35.7	26.[illegible]-32.2
IV. Good		45.2-50.9	42.5-46.4	41.0-44.9	39.0-43.7	35.8-40.9	32.[illegible]-36.4
V. Excellent		51.0-55.9	46.5-52.4	45.0-49.4	43.8-48.0	41.0-45.3	36.[illegible]-44.2
VI. Superior		> 56.0	> 52.5	> 49.5	> 48.1	> 45.4	> 44.3

Coopers Fitness Classification: Women

Category	Measure O^2ml/kg/min	Age 13-19	20-29	30-39	40-49	50-59	60+
I. Very Poor		< 25.0	< 23.6	< 22.8	< 21.0	< 20.2	< 17.5
II. Poor		25.0-30.9	23.6-28.9	22.8-26.9	21.0-26.4	20.2-22.7	17.[illegible]-20.3
III. Fair		31.0-34.9	29.0-32.9	27.0-31.4	24.5-28.9	22.8-26.9	20.[illegible]-24.4
IV. Good		35.0-38.9	33.0-36.9	31.5-35.6	29.0-32.8	27.0-31.4	24.[illegible]-30.2
V. Excellent		39.0-41.9	37.0-40.9	35.7-40.0	32.9-36.9	31.5-35.7	30.[illegible]-31.4
VI. Superior		> 42.0	> 41.0	> 40.1	> 37.0	> 35.8	> 31.5

VITA

Fehmi Tuncel

Candidate for the Degree of

Doctor of Education

Thesis: A COMPARISON OF RESTING CARDIAC OUTPUT AND STROKE VOLUME IN PHASE III CARDIAC PATIENTS AND HEALTHY ADULTS

Major Field: Higher Education

Minor Field: Health, Physical Education, and Recreation

Biographical:

Personal Data: Is born in Ankara, Turkey, June 20, 1957, the son of Hilmi and Fatma Tuncel.

Education: Graduated from Balgat High School, Ankara, in 1975; received the Bachelor of Science degree from Marmara University, Sports Academy, Istanbul with a major in Health/Sports Medicine in 1979; received the Master of Science degree from Oklahoma State University in 1985; completed the requirements for Doctor of Education degree at Oklahoma State University in May, 1989.

Professional Experience: Taught Physical Education at private high schools in Istanbul for one year. Taught and coached basketball and swimming at high school and college level. Taught sports medicine (Kinesiology/Biomechanics and Applied Sports Massage) classes at college for three years in Istanbul. Taught weight training, physical fitness as a Teaching Assistant at Oklahoma State University. Also taught non-credit theory and application of scientific massage. Presently working as Graduate Associate at the Health and Fitness Center of Oklahoma State University and teaching educational sessions such as Stress Management and working in the Cardiac Rehabilitation and Preventive Exercise Program since 1987.

Publications: Published three articles in the Oklahoma Association for Health Physical Education and Recreation: 1987, "Massage Therapy"; 1988, "American College of Sports Medicine Certification - A Strong Point for Today's Professional" and "Cinematographic Analysis of Ordinary Walking and Duck Walking".