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Physical Activity and Cardiovascular Fitness in the Elderly

Nomi Fridman
Ithaca College

PHYSICAL ACTIVITY AND CARDIOVASCULAR FITNESS IN THE ELDERLY

by

Nomi Fridman

An Abstract
of a thesis submitted in partial fulfillment
of the requirements for the degree of
Master of Science in the School
of Health, Physical Education,
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Thesis Advisor: Dr. G. A. Sforzo

ABSTRACT

In this study, the relationships between past and present activity levels and cardiovascular fitness in the elderly were examined. The relationships between primary cardiac risk factors and cardiovascular fitness and between primary cardiac risk factors and present activity level were investigated as well. Two sources of data were used for the study. The first one included the records from exercise stress tests of 15 males and 5 females over 60 years of age. The second source involved activity questionnaires used to determine work and leisure habits of the participants, and their energy expenditures in the past and present. Data analysis revealed significant positive correlations between $\dot{V}O_2max$ and past activity ($r = .42$), and between $\dot{V}O_2max$ and present activity ($r = .45$) ($p < .05$). Significant negative correlations were found between risk group and activity level ($r = -.55$), and between sex and weight ($r = -.63$) ($p < .01$). In a multiple regression analysis, activity level seemed to be the most important determinant of $\dot{V}O_2max$; when included in the analysis it was the only independent variable that showed statistical significance ($p < .05$). An F test of the overall influence of all independent variables

(age, weight, sex, activity level, risk group, and past activity) on $\dot{V}O_2max$ revealed a highly significant relationship ($p < .005$). Based on the results, the researcher concluded that increased physical activity at the present is related to greater cardiovascular fitness in the elderly, and that the presence of primary cardiac risk factors is inversely related to participation in exercise training.

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A Thesis Presented to the Faculty of
the School of Health, Physical
Education, and Recreation
Ithaca College

In Partial Fulfillment of the
Requirements for the Degree
Master of Science

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by
Nomi Fridman
September 1986

Ithaca College

School of Health, Physical Education, and Recreation

Ithaca, New York

CERTIFICATE OF APPROVAL

MASTER OF SCIENCE THESIS

This is to certify that the Master of Science Thesis of

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Submitted in partial fulfillment of the requirements for the degree of Master of Science in the School of Health, Physical Education, and Recreation at Ithaca College has been approved.

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DEDICATION

To my dearest parents, Zlamka and Tova Talmi,

to my loving husband, Samy,

to my precious children, Yoni and Tali,

thank you for your support.

TABLE OF CONTENTS

	Page
ACKNOWLEDGMENTS	ii
DEDICATION	iii
LIST OF TABLES	vii
Chapter	
1. INTRODUCTION	1
Statement of Problem	3
Scope of Problem	4
Hypotheses of Study	5
Definition of Terms	6
Assumptions of Study	7
Delimitations of Study	8
Limitations of Study	9
2. REVIEW OF RELATED LITERATURE	11
Introduction	11
Cardiac Parameters at Rest	12
Cardiac Parameters during Exercise	14
Other Physiological Changes	18
Coronary Vasculature	18
The Heart Structure	20
Cardiac Risk Factors	22
Hypertension	22
Hyperlipidemia	24
Diabetes	27
Obesity	29

Chapter		Page
	Effect of Present Versus Previous Training	32
	Beliefs and Perceptions	35
	Summary	36
3.	METHODS AND PROCEDURES	38
	Selection of Subjects	38
	Testing Instruments	39
	Methods of Data Collection	40
	Scoring of Data	42
	Treatment of Data	43
4.	ANALYSIS OF DATA	45
	Descriptive Statistics	45
	Correlation for All Variables	47
	Multiple Regression of Variables	49
5.	DISCUSSION OF RESULTS	54
	Exercise Training and Maximal Oxygen Uptake	54
	Cardiac Risk Factors and Exercise	58
	The Importance of Activity Level	59
	Tolerance and Multicollinearity	62
6.	SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS FOR FURTHER STUDY	64
	Summary	64
	Conclusions	66
	Recommendations for Further Study	67

Page

APPENDICES 69

A. Activity Questionnaire 69

B. Kattus Walking Protocol 73

C. Informed Consent Form (For General Study) 74

D. Medical History Form 76

E. Informed Consent Form (For Graded Exercise Test) . . 78

F. Data Sheet (Graded Exercise Test) 82

G. Characteristics of the Subjects 84

REFERENCES 85

LIST OF TABLES

Table		Page
1.	Descriptive Statistics for the Research Variables . .	46
2.	Pearson Product-moment Correlations Among All Variables	48
3.	Regression of $\dot{V}O_2max$ on All Independent Variables (Excluding Activity Level)	50
4.	Regression of $\dot{V}O_2max$ on All Six Independent Variables .	52

Chapter 1

INTRODUCTION

Can physical training slow the aging process? Does participation in sports and exercise programs at a young age provide health benefits in later life? These are questions researchers are trying to answer in light of the growing elderly population. Studies in the past have compared cardiovascular fitness in young versus old subjects (Bruce, Hossack, & DeRouen, 1982; deVries & Adams, 1972; Montgomery & Ismail, 1977; Pollock, Foster, Rod, & Wible, 1982; Suominen, Heikkinen, Parkatti, Forsberg, & Kiiskinen, 1977), but there are few longitudinal studies on the cardiovascular changes that occur in aging individuals (Adams & deVries, 1973; deVries, 1970; deVries & Adams, 1977).

It is well known that cardiovascular function is diminished with age. Three main factors contribute to the physiological changes that occur in the heart with time: (a) aging, as determined by chronological progression in years, (b) disease and disease processes, and (c) disuse phenomenon. Very little is known about the specific role of aging in these physiological changes; more is understood about diseases of the cardiovascular system. As a person gets older the body becomes more susceptible to diseases and disease processes. A primary example is atherosclerosis, which is an accumulation of fatty deposits in blood vessels and a major cause of heart attacks. The disease process can start in youth and advance through life, limiting one's functional capacity in a progressive manner. Evidence of coronary arteriosclerosis was found in 77.3% of 200 male corpses (mean age 22.1 years) studied during the Korean war (Enos, Holmes, & Bayer, 1953), providing evidence of the developmental nature of this disease. Despite this, there are strong reasons to believe that this disease process may be avoided or slowed by a combination of proper diet and exercise.

The third factor that contributes to physiological changes with age is the disuse phenomenon. Kraus and Raab (1961) named this phenomenon hypokinetic disease and defined it as the range of somatic and mental disfunctions induced by inactivity. Wessel and Van Huss (1969) have shown that as age increases, activity level decreases. They found that age-related losses in bodily operations were more highly related to the decreased habitual activity level than to age itself. This was also illustrated by Saltin, Blomqvist, Mitchell, Johnson, Wildenthal, and Chapman (1968) who showed that age-related physiological changes can be brought about in young, well conditioned men after only 3 weeks of enforced bed rest, and that these changes are reversible. Thus, in the absence of disease and aging factors, inactivity and disuse can cause physiological deterioration of bodily functions. This study, which was a retrospective one, attempted to assess the relationship between exercise and deteriorating cardiovascular function with age.

Statement of Problem

The purpose of this study was to investigate past and present activity patterns as related to the present level of cardiovascular fitness in healthy and high risk individuals over 60 years of age.

Past and present activity levels were estimated through individual activity profile questionnaires (see Appendix A) sent to the participants' homes. Any physical activity done 6 months or more prior to the testing was considered past activity, because detraining is complete in most individuals after 6 months. Cardiovascular fitness was evaluated by obtaining the records of maximal graded exercise tests (GXTs) performed by the subjects to determine their maximum oxygen consumption ($\dot{V}O_2max$).

Scope of Problem

An attempt was made to find out if there is any relationship between the daily activities in which people over 60 participate and their aerobic capacity. For this purpose information was gathered from records of GXTs for each individual who participated in the study. These GXTs used the Kattus treadmill walking protocol (see Appendix B) and were administered to the subjects for personal reasons. These maximal GXTs provided $\dot{V}O_2max$ records which were obtained and used in this study.

A second form of data collection involved activity profile questionnaires (see Appendix A) developed for the purpose of this study. Participants completed this questionnaires at their leisure. The questionnaires had two parts: a survey of past and present leisure activities and information concerning employment (i.e., work). The questionnaires were analyzed to yield past and present activity levels, which were transformed to measures of energy expenditure. Additional personal data that included the subjects' weight and cardiac risk factors (hypertension, smoking, hyperlipidemia, ECG abnormalities, family history, diabetes, obesity, and sedentary lifestyle) were recorded.

Hypotheses of Study

The following hypotheses concerning the relationship of physical activity level to cardiovascular fitness in adults beyond the age of 60 years were identified:

H_1: There is no relationship between present physical activity level, as indicated in the questionnaires, and cardiovascular fitness level, as measured in the graded exercise tests.

H_2: There is no relationship between past physical activity level (i.e., the most intense exercising period in the past), as indicated in the questionnaires, and present cardiovascular fitness level, as measured in the graded exercise tests.

H_3: There is no relationship between the presence of primary cardiac risk factors, as described by the American College of Sports Medicine (1980), and cardiovascular fitness level, as measured in the graded exercise tests.

H_4: There is no relationship between the presence of primary cardiac risk factors and present physical activity level, as indicated in questionnaires.

Definition of Terms

The following terms that were used in this study are defined here:

1. Left ventricular ejection fraction: a volume expressed as the ratio of stroke volume (volume of blood ejected from ventricles during systole, or heart contraction) to left ventricular end-diastolic volume (volume of blood filled in ventricles during diastole, or resting period).

2. MET: a unit denoting a workload approximating the resting metabolic rate, equivalent to an oxygen uptake of 3.5 ml/kg/min. Many aerobic training programs use the MET as a simple measure of activity (Sperryn, 1983).

3. Oxygen pulse: a fraction derived from two cardiac parameters, the ratio of oxygen intake to heart rate, used mainly in clinical settings to indicate the amount of oxygen consumption per beat. It is also a product of stroke volume and arteriovenous O_2 difference.

4. Past activity: any physical activity done 6 months or more prior to the administration of the questionnaire.

5. Present activity: any physical activity in which the individual participated at the time of questionnaire administration, including leisure

activity and housework.

6. Hyperlipidemia: increased fat level in the blood (McArdle, Katch, & Katch, 1981). Critical levels for this study were set at triglycerides > 220 mg/dl and cholesterol > 275 mg/dl.

7. Hypertension: existence of chronically high blood pressure. Critical levels for this study were set at systolic pressure > 140 mmHg and diastolic pressure > 90 mmHg.

Assumptions of Study

The following assumptions concerning this study have been made:

1. There was no need to consider the "Hawthorne Effect" (Tuckman, 1978) because subjects participated in the treadmill test without previous knowledge of the study to be done. They took part in the exercise test for the purpose of having an exercise program prescribed for them rather than for this study.

2. Participants reached their true maximum $\dot{V}O_2$ during the GXT.

3. Subjects' occupations did not add significantly to their daily energy expenditures because all participants were either retired or worked in an administrative capacity.

4. All subjects were healthy at the time of the exercise test.

5. GXT scores were valid and reliable. These results were not affected by equipment errors or external factors such as food ingested prior to test, room temperature, and environmental humidity. Any such factors were controlled prior to stress testing.

6. Anxiety during the test was minimized by talking to the individuals and by letting them know what was happening.

7. Questionnaires measured what they were intended to measure.

Delimitations of Study

The following were the delimitations of the study:

1. All subjects ($N = 20$) were volunteers, males and females 60 years old or older.

2. All the participants in the study were retired or involved in some type of administrative job that required only a small amount of regular daily energy expenditure.

3. The records gathered were from the graded exercise testing of participants in the Tompkins Community Hospital "In-Shape" program in Ithaca, New York, and used the Kattus treadmill walking protocol.

4. The equipment used during the exercise test included the following: Quinton treadmill, Sensormedic Horizon 6 metabolic measurement cart, Hans Rudolf 2A non-rebreathing valves with adjustable head support, and Quinton Q2000 ECG machine.

5. The investigator was not present at all tests, but all testing was done by professionals.

Limitations of Study

The following limitations were noted in the study:

1. Study was limited to subjects who participated in the "In-Shape" wellness program at Tompkins Community Hospital for at least one of the following reasons: evaluation of their present fitness level, obesity control, cardiac health evaluation, and the ultimate purpose of exercise prescription, and were willing to release their exercise test records.

2. The results of this study can be inferred only to people aged 60 years or older and may not be generalized unless similar attributes to these subjects exist in another sample.

3. Selection bias may have existed because those in this age group who decided to participate in a program of this sort were more likely to be

better fit than those who did not participate.

4. Due to the voluntary participation of subjects, the researcher could not control the number of participants from each sex, which resulted in the recruitment of more male than female subjects.

5. Conclusions apply only to people who either work in administrative jobs or are retired.

6. The experiment did not involve a treatment condition, hence cause and effect can not be implied by the results.

Chapter 2

REVIEW OF RELATED LITERATURE

Introduction

Most studies on the cardiovascular system deal with moderate amounts of exercise and the role of exercise in maintaining a good functional capacity. Unfortunately, most of this work has been done with young individuals, and research is lacking to completely describe the effect of strenuous exercise upon middle-aged and older people. An early theory written by Pearl (1928) stated that "the greater the rate of energy expenditure and oxygen utilization, the shorter the life span." At that time it was believed that exercise may accelerate the aging process as a result of increased metabolic rate and stress hormone production during exercise. This postulate has never been disproven, but it is now more widely believed that exercise is beneficial and lack of activity during aging results in cardiovascular deconditioning and disuse atrophy.

This chapter will review the literature pertinent to the aging cardiovascular system and will include the following sections: (a) cardiac parameters at rest, (b) cardiac parameters during exercise, (c) other physiological changes, including coronary vasculature and heart structure,

(d) cardiac risk factors, (e) the effects of present versus previous training, and (f) the beliefs and perceptions of older individuals.

Cardiac Parameters at Rest

When comparing the young and the old heart one can make several observations. According to various reports, resting heart rate is not affected by age (Åstrand & Rodahl, 1977; Gerstenblith, Lakatta, & Weisfeldt, 1976; Kostis, Moreyra, Amendo, DiPietro, Cosgrove, & Kuo, 1982; Port, Cobb, Coleman, & Jones, 1980). However, a contradicting argument was raised by Strandell (1964). He studied time interval between the first and second heart sounds in two groups of men, 61-83 years old and 21-25 years old. Strandell found that cardiac contraction (systole) and relaxation (diastole) times at rest were prolonged in the aged, although these findings were not statistically significant. A possible reason for these results could be an increase in stiffness and degree of fibrosis in the aortic and mitral valves in older individuals. This change could alter the timing of the valve motion and, therefore, produce apparent prolongation of systole (Gerstenblith et al., 1976). It is still unclear whether the prolonged contraction and relaxation times are a result of intrinsic changes in myocardial function or alterations in workload, impedance, or properties of other tissues (Gerstenblith et al., 1976).

Cardiac output, a product of heart rate and stroke volume, decreases by 30-40% between the ages of 25-65 years (Gerstenblith et al., 1976; Mead, 1978). This decline is probably the result of atrophy and diminished function of the muscle mass which, in turn, reduces the need for blood flow, rather than reducing the myocardial capacity (Mead, 1978). Early symptoms of low cardiac output can include excessive fatigue, weakness, or even focal neurological symptoms (Mead, 1978).

Another cardiac parameter measured in comparisons of aged and young individuals is left ventricular ejection fraction (i.e., the ratio of stroke volume to left ventricular end-diastolic volume). Port et al. (1980) studied left ventricular ejection fraction in apparently healthy men and women, aged 20-95, and found no significant change in ejection fraction with age. In the same study, systolic blood pressure and mean arterial blood pressure at rest were also measured. Findings indicated increased systolic pressure with age but no change in mean arterial blood pressure.

Cardiac Parameters During Exercise

Cardiac response to exercise stress changes as a person gets older. Specifically, maximum heart rate, stroke volume, cardiac output, maximal oxygen uptake, blood pressure, and left ventricular ejection fraction are apparently affected by aging.

It is generally agreed that at a given workload heart rate is about the same for young and old individuals, but maximum heart rate (HRmax) decreases with age. This reduction in HRmax seems to be about the same in active and sedentary men and women (Åstrand & Rodahl, 1977; Gerstenblith et al.,1976; Kostis et al., 1982; McArdle et al., 1981). This decline is probably an adjustment by the heart to lower oxygen cost of performance by lowering maximal loads (e.g., 70% of HRmax is a lower absolute workload for an average elderly versus a young individual).

Stroke volume is lower in the older subject than in the younger subject at any level of oxygen uptake (Åstrand & Rodahl, 1977), possibly due to changes in myocardial contractility (McArdle et al., 1981). Therefore, as a result of the decline in stroke volume, cardiac output is reduced with age at any level of oxygen uptake, including maximal levels where the decline in HRmax also contributes (Åstrand & Rodahl, 1977;

Gerstenblith et al., 1976; Mead, 1978). The reason for the age differences in the above parameters may be the apparent ineffectiveness of sympathetic response to exercise stress in the aged. Kostis et al. (1982) claimed that the responsiveness of the sinus node to catecholamines decreases with age, and together with reduced capacity of the sinus node to increase heart rate with age, accounts for lower HRmax in the aged. In addition, studies using an animal model showed a decreased inotropic response of cardiac muscle to catecholamines with age, leading to reduced myocardial contractility (Gerstenblith et al., 1976). Catecholamines may alter the active state by two means: (a) shortening the duration of the active state by stimulating the cardiac relaxing system, and (b) increasing the intensity of the active state by delivering more calcium to the contractile element. The decrease in inotropic response to catecholamines is believed to result from an impaired ability of the catecholamines to increase delivery of calcium to the contractile element (Gerstenblith et al., 1976).

$\dot{V}O_2max$ also declines progressively with age. Data indicated average annual decline of .4 to .6 ml/kg/min over the age range of 20-52 years (the average $\dot{V}O_2max$ for sedentary 20-30 year olds is 35-39 ml/kg/min)

(Shephard & Sidney, 1978). $\dot{V}O_2max$ is a product of maximal cardiac output and maximal systemic arteriovenous O_2 difference, which also decreases with age. Because there is a decline in $\dot{V}O_2max$, at the same absolute workload the older person is closer to his maximal effort than the younger one (i.e., the older individual is at a higher percentage of $\dot{V}O_2max$). As a result, the level of daily energy expenditure and the quantity of work to be performed by the older individual should be reduced. It has been suggested that this decline in $\dot{V}O_2max$ can be altered by exercise, diet, and smoking habits (Gerstenblith et al., 1976).

Systolic pressure and mean arterial blood pressure are higher in the elderly during any level of exercise (Åstrand & Rodahl, 1977). This was not supported by Port et al. (1980), in their study of 77 apparently healthy individuals, aged 20-95. They reported that these parameters are not affected by age, suggesting that there were no major differences in afterload or preload of older subjects. This argument seems rather strange because systolic blood pressure is known to increase with age due to narrowing of the coronary blood vessels (Guyton, 1976). A detailed study of 54 sedentary men and women, aged 18-68 years, tested the effect of workload on arterial pressure. Subjects engaged in progressive exercise on a bicycle ergometer, starting at 300 kgm/min and increasing workload in steps of 150 kgm/min every 4 minutes until fatigue. Results indicated that although systolic blood pressure was higher in the aged at rest and all submaximal workloads, there was no difference in systolic pressure between young and old individuals at maximal workload (Julius, Antoon, Whitlock, & Conway, 1967).

In a study of the response of left ventricular ejection fraction (LVEF) to exercise (Port et al., 1980), 31 females and 46 males, aged 20-95, were tested on a bicycle ergometer, starting at 200 kpm/minute and increasing gradually in workload to 85% HRmax or fatigue. LVEF was measured by means of radionuclide angiocardiography and was calculated using the following formula: (end diastolic counts - end systolic counts)/end diastolic counts. Among subjects under 60, only 8% had a ΔLVEF (exercise - rest LVEF) less than .05, which is considered to be the normal minimum increase in LVEF with exercise. On the other hand, of the subjects over 60, 83% had a ΔLVEF less than .05, while LVEF of 72% of these individuals actually decreased with exercise. It was concluded that LVEF declines with age and this becomes more apparent when expressed as

ΔLVEF. These results may indicate the presence of coronary artery disease, but because the subjects in this study were presumably healthy (there were almost no ECG abnormalities and no pain during exercise) this decline was probably an effect of aging rather than disease. The author suggested that although it was considered normal until that time to exhibit an increased LVEF with exercise, only subjects below 65 years old had been tested and it may be normal for older individuals to have a decreased LVEF with exercise.

Other Physiological Changes

Many researchers point out that it may not be the aging process that is responsible for changes in the cardiovascular system but rather accumulated injuries from disease. Such changes in the heart and blood vessels, manifested with aging, will be discussed in the next two sections.

Coronary Vasculature

Coronary artery disease is common in old age. Ischemic heart disease (the most prominent cardiovascular disorder in the elderly) is associated with segmental atherosclerotic plaques in the coronary arteries (Mead, 1978; Tomanek, 1980). Studies showed that in fatal ischemic heart disease at least one of three major coronary arteries was narrowed by more than 75% (Tomanek, 1980). Incidence of coronary atherosclerosis, associated with aging, peaks during the 6th decade of life. The basic changes in atherosclerosis are intimal thickening of the coronary arteries and a hyperplastic layer, formed by accumulated lipids in the lesioned areas of the arteries (Tomanek, 1980). An attempt by the body to control atherosclerosis with increased AMPase (adenosine monophosphatase) activity occurs with age. This represents an attempt to minimize thrombus formation (AMP inhibits platelet aggregation), which is a factor in the pathogenesis of atherosclerosis (Tomanek, 1980).

A change that is thought to be a result of the aging process itself is tortuosity of the epicardial coronary arteries, a very common finding among the elderly. This is probably induced by overall vascular growth brought on by increased coronary blood flow (Hutchins, 1980). An increase in peripheral vascular resistance is apparent in the aged (Gerstenblith et al., 1976), accompanied by decreased peripheral blood flow capacity (McArdle et al., 1981). Studies also indicated that with age there is a decrease in the ratio of capillary density to the number of muscle fibers (McArdle et al., 1981; Tomanek, 1980; Weisfeldt, Wright, Shreiner, Lakatta, & Shock, 1971). This decline may be due to two factors: (a) loss of capillaries as part of the degenerative process, and/or (b) enhanced branching of the myocardial cell, which showed an increased number of cells in a cross-sectional field. Some studies reported that the number of capillaries per square millimeter decreases but the number of muscle cells stays the same (Weisfeldt et al., 1971). This has not been proven in humans. According to data from the study of coronary flow in nonworking hearts of old male rats (Weisfeldt et al., 1971), it was suggested that a decrease in coronary flow was due to failure of the vascular bed to increase in proportion to the heart weight. So it is thought that a relative reduction in the capillary bed may be the major factor limiting maximal coronary flow (Tomanek, 1980).

The Heart Structure

There is a controversy as to what happens to heart weight over time. Hutchins (1980) mentioned a study by Linzbach and Akuomoa-Boateng, showing that heart weight increases until the age of 90 and then decreases. Another study indicated that heart weight is correlated with body size rather than age (Smith, 1928). A third study agreed that age does not influence the heart weight, but added that heart size is a function of epicardial fat, which apparently increases with age (Reiner, 1968). Hutchins (1980) supported this latter study by claiming that occurrence of adipose tissue between bundles of muscle cells (especially in the right ventricle, but also in the left one) is a common finding in the myocardium of elderly subjects. Evidence from x-rays taken in supine position indicates that heart volume is also larger in the elderly (Åstrand & Rodahl, 1977).

Increased fibrosis in various parts of the heart is very common with old age. It occurs in the myocardium, where connective tissue replaces areas of lost muscle cells, and also in the sino-atrial node, in the aortic and mitral valves, and in the left bundle branches. Weisfeldt et al. (1971) found that myocardium scarring and fiber loss were mainly subendocardial and not associated with vascular changes. There was no difference in the histologic appearance of the vascular bed between the young (12 months old) and old (24-27 months old) rats.

Another change that is a result of the aging process is lipofuchsin accumulation at the poles of the nuclei of the cardiac muscle cells (Hutchins, 1980). Lipofuchsin is a lipid containing material believed to be derived from lysosomal degradation of mitochondria. This accumulation is a function of reduced cardiac muscle cell size resulting from a decline in functional demands on the heart due to reduced physical activity (Hutchins, 1980).

Cardiac Risk Factors

Aging is considered by many to be a risk factor for coronary heart disease, and there is a good correlation between age above 40 years and incidence of heart disease. Three primary risk factors have higher incidence of occurrence in the aged: hypertension, hyperlipidemia, and diabetes. In addition, a secondary risk factor, obesity, is also associated with advancing age.

Hypertension

Hypertension is characterized by chronically high systolic pressure, diastolic pressure, or both. The vast majority of hypertensive cases are idiopathic in nature (i.e., of unknown origin). Causes for hypertension may involve genetic factors, stressful lifestyle, obesity, high sodium intake, or a combination of these (Pollock, Wilmore, & Fox, 1984). Consistent blood pressure readings of 140 mmHg / 90 mmHg are considered borderline hypertension, while 160 mmHg/ 100 mmHg is recognized as established hypertension. In established hypertension there is a persistent rise in blood pressure, thought to be caused by increased total peripheral resistance (TPR), while cardiac output stays normal. On the other hand, borderline hypertension is characterized by elevated heart rate (HR) and cardiac output at rest, while TPR remains in the normal range. Increased sympathetic and/or decreased parasympathetic activity seem to cause this rise in HR and cardiac output (Seals & Hagberg, 1984). Exercise has been used as a therapy in an attempt to control hypertension. Two mechanisms might be involved in the reduction of blood pressure that often accompanies exercise training in hypertensives. The first one is vasodilation due to acute exercise, which suggests that training on a regular basis will lead to chronic vasodilation followed by decreased TPR and blood pressure at rest. The second mechanism involves reduction of HR at rest due to training, which decreases the cardiac output and blood pressure. Reduction of sympathetic tone, which also occurs with training, may underlie either or both of these mechanisms (Seals & Hagberg, 1984).

Researchers have found that exercise training leads to a reduction in both systolic and diastolic blood pressures in normotensive as well as in hypertensive subjects, but blood pressure seems to return to pretraining values in both populations after an undetermined period of detraining

(Hagberg, Goldring, Ehsani, Heath, Hernandez, Schechtman, & Holloszy, 1983; Seals & Hagberg, 1984). The reduction of blood pressure following endurance training in normotensive individuals is still a controversial issue. Wilcox, Bennett, Brown, and MacDonald (1982) claimed that regular moderate exercise should suffice for maintenance of lower blood pressure for 4-10 hours, and that a "good walk" twice daily can achieve this goal. Treatment for hypertension includes the following: reduction in caloric intake for obese individuals, reduction in salt intake, exercise training in addition to pharmacological intervention in established hypertensives, and possibly exercise training without medication for borderline cases (Seals & Hagberg, 1984). Evidence is insufficient as of yet to promote exercise training as a definite treatment or cure for hypertension, but training is advisable.

Hyperlipidemia

Hyperlipidemia involves a high level of circulatory cholesterol (CHL) and/or triglycerides (TG). Contradicting studies of normal subjects have shown lower TG level following endurance exercise (Gordon, Witztum, Hunninghake, Gates, & Glueck, 1983; Schriewer, Gunnewig, & Assmann, 1983) and no change in TG level following endurance exercise. These differences may be due to lower than normal pretraining TG levels (Gaesser & Rich, 1984). Endurance training of hypertriglyceridemic subjects lowered the TG count markedly soon after exercise and several days thereafter, even with moderate exercise (Haskell, 1984). Diet or weight loss augmented this reduction in TG count. The mechanism responsible for lowering plasma TG concentration following exercise is thought to involve increased lipoprotein lipase (LPL) activity in the skeletal muscle, adipose tissue, or both. LPL is an enzyme that catabolizes TG to produce free fatty acids, which are then, through oxidation, used for energy production. In severe cases of hypertriglyceridemia there may be a genetic deficiency of LPL or an inhibition of LPL activity in the plasma (Haskell, 1984).

Cholesterol is a sterol molecule that is strictly a product of animal metabolism. Foods high in saturated fat stimulate the body to produce CHL that in turn elevates blood CHL levels (Lamb, 1984). Cholesterol is removed from the blood by lipoproteins. Lipoproteins are molecules of lipids coupled with protein to facilitate their solubility in the blood plasma (lipids are insoluble). There are four major categories of lipoproteins according to their sizes and densities: chylomicrons, very low density lipoproteins (VLDL), low density lipoproteins (LDL), and high density lipoproteins (HDL). HDL contains the highest proportion of protein and is called the "good cholesterol" because it is thought to be responsible for carrying CHL to the liver, where it can be metabolized and excreted (Pollock et al., 1984). In men, CHL, TG, LDL, and VLDL plasma concentrations increase with age from puberty until the 6th decade of life. In women, the increase occurs at a slower rate but continues to a later age (Haskell,1984). HDL levels decrease about 10% in boys when they reach puberty, and then rise slowly in the 6th and 7th decades. In women, HDL levels are constant until the 3rd decade, then rise slowly until the 6th decade (Haskell, 1984). It appears that CHL levels are not influenced by exercise training (Schriewer et al., 1983), although HDL levels may be increased as a result of habitual exercise (Gaesser & Rich, 1984; Gordon et al., 1983; Haskell, 1984; Schriewer et al., 1983). There is consensus that a diet low in saturated fats and high in unsaturated fats will lower blood CHL level and stop or slow down the progressive accumulation of fatty-cholesterol deposits on the arterial wall (Lamb, 1985). The ratio of total CHL/HDL has been shown to be a very important factor in determining the risk for coronary heart disease. Pollock et al. (1984) have classified a ratio greater than 5.0 as high risk and less than 3.5 as low risk, but there is still a controversy over these suggested standards.

Diabetes

Diabetes mellitus is a disorder of carbohydrate metabolism characterized by inadequate production and utilization of insulin (Thomas,1985). Diabetes can be divided into two main classifications: Type I diabetes, also called juvenile or insulin dependent diabetes, usually occurs prior to age 25 and involves absolute insulin deficiency. Type II diabetes, also called noninsulin dependent diabetes, mainly occurs after age 40 and involves insulin production, but in insufficient amounts for body needs.

Diabetics of both groups were found to be at greater risk of developing atherosclerosis, leading to a greater risk of coronary heart disease. In studies of diabetics and nondiabetics, the diabetics demonstrated a considerably larger incidence of atherosclerosis, peripheral vascular disease, and coronary artery disease, and a shorter life expectancy (Berkow,1982). Also, Type II diabetes, obesity, hypertension, and hyperlipidemia are interrelated and often occur simultaneously, causing an even greater risk of cardiovascular disease.

A primary consideration for all diabetic patients is a proper, balanced diet. However, treatment for diabetes mellitus differs according to the type of the disorder. Type I diabetics require frequent feedings with an emphasis on consistency of intake and regularity in timing of meals. For Type II diabetics, most of whom are obese, a diet restricted in calories is the most important consideration, because obesity makes it harder to control the disease. Although diet is the most important treatment for diabetes, exercise plays a major role in controlling the disease and mantaining a more normal lifestyle. A steady, consistent level of exercise on a daily basis can improve metabolic control in noninsulin dependent obese patients (Type II) and increase their fitness level. The exercising muscle utilizes greater amounts of glucose with an attenuated requirement for insulin. Thus, exercise acts in a manner similar to insulin, facilitating glucose transport to the cell and consequently, regulating blood glucose level (Kemmer & Berger, 1983). In insulin dependent diabetics (Type I) exercise is not recommended as treatment for improved metabolic control, rather insulin therapy is needed. To prevent hypoglycemia in Type I diabetics as a result of physical activity, patients should reduce insulin dosage and increase intake prior to exercise (Kemmer & Berger, 1983). In summary, diabetes is a chronic, presently incurable disease, but the quality of life can be improved and life span prolonged if proper treatment is employed.

Obesity

Obesity is defined as having an abnormal amount of fat, in excess of 20-30% of average weight according to age, sex, and height (Thomas, 1985). It is a result of imbalance between caloric intake and energy expenditure, which may be secondary to underlying physiological mechanisms. Accumulation of body fat seems to increase with age, possibly due to reduced energy expenditure, while caloric intake stays the same (Berkow, 1982). It appears that the phenomenon of obesity more than doubles between the ages of 20 and 50 (Berkow, 1982). The increased weight is accompanied by a rise in body fat, which increases the fat storage in the body, leading to possible health problems such as diabetes, hypertension, and hyperlipidemia.

Fat increase in the body is a combination of increased number of fat cells (hyperplasty) and increased size of fat cells (hypertrophy). These fat depositions occur during three main periods in the human life: (a) in the first 9 months of life, (b) around the age of 7 years, and (c) during adolescence (Pollock et al., 1984). Studies of adults have shown that increased weight was accompanied by an increase in fat cell size rather than an increased number of cells (Salens, Horton, & Sims, 1971; Sims, 1974). An increase in fat cell number is also possible, although unlikely, after maturity is reached. Accordingly, obesity is probably the result of an expansion of existing cells to the maximum size, which could then trigger an increase in cell number (Pollock et al., 1984). Inactivity, rather than overeating, seems to be the main reason for childhood obesity. However, it is still unclear whether inactivity causes obesity, or obesity leads children and adults to inactivity.

Treatment of obesity includes diet modification, exercise, drug therapy, surgery, and behavior modification, not necessarily in this order. Dietary treatment is achieved by reducing caloric intake, but the inclusion of all essential nutrients in the diet is of utmost importance. However, once a reduced calorie diet is stopped, the obese person will regain any weight lost. This is especially true in the case of childhood obesity, because the larger-than-normal number of fat cells is unchanged and only fat cell size is reduced with weight loss. Exercise is a valuable adjunct for weight reduction. It regulates energy balance in the body by increasing expenditure and possibly controlling intake by suppressing the appetite following endurance training. Three clear findings about the relationship between obesity and metabolism as related to exercise are as follows:

1. With the same amount of physical activity, the obese individual expends more calories than the nonobese person (Berkow, 1982).

2. Thin individuals have an advantage, because when they overeat they apparently have a larger compensatory increase in metabolism (Hill, Heymsfield, McMannus, & DiGirolamo, 1984).

3. In the physically trained individual eating a meal stimulates greater metabolism, causing the trained to have a greater caloric expenditure after eating than the untrained (Davis, Tagliaferro, Kertzer, Gerardo, Nichols, & Wheeler, 1983; Hill et al., 1984).

A combination of exercise and diet appears to be the optimal solution for weight reduction. However, the main problem with participation in regular exercise is compliance. This is less of a problem with children and young adults than with the elderly. In addition, older individuals are more limited as to the type of physical activity that they can engage in. For these reasons, diet and behavior modification are the main treatments for obesity in the elderly, with the implementation of exercise when possible.

Effect of Present Versus Previous Training

Kent (1982) wrote about exercise as a preventive measurement of premature aging, slowing the rate of aging and helping to prevent cardiovascular diseases. However, exercise does not seem to affect the natural rate of aging in humans, measured by maximum life span. Conversely, Goodrick (1980) found that exercise lengthened life span in Wistar rats. He had a control group consisting of 32 females and 28 males, and an exercise group involving 40 females and 40 males. The control group was placed in standard laboratory cages, while the exercise group was put in cages with exercise wheels and allowed to exercise voluntarily. The results of this study showed that the mean life span for the female exercise group was 11.5% longer than that of the nonexercise group; for the male exercise group the mean was 19.3% greater than for the nonexercise group. In general, females in both groups lived 12-14% longer than males. The metabolic rate decreased in the control group but remained the same in the exercise group. Different studies suggested that

(a) exercise training may slow the deterioration in function of the cardiovascular system, and (b) it may protect against development of coronary artery disease and high blood pressure.

DeVries (1970) tested the effect of an exercise training program upon men, aged 52-88 years. The exercise program consisted of calisthenics, jogging/walking, and stretching exercises or aquatics, three times a week. There was a control group, which did not exercise, and a treatment group, which went through the training program. The subjects in the treatment group were given a graded exercise test before starting the program and at 6 weeks, 18 weeks, and 42 weeks of training. Improvement in the cardiovascular function was demonstrated after a 6-week period. However, there was no significant correlation between age and improvement on systolic blood pressure, diastolic blood pressure, and O_2 pulse. Despite the above mentioned finding about the cardiovascular parameters, the correlation between pretest of those parameters, which was the level of physical condition at entry and is the estimate of disuse of the system, and posttest after 6 weeks of training was significantly high. These data point to the potentially important consideration of the disuse phenomenon in determining agewise loss of functional capacities.

DeVries concluded that trainability of older men with respect to physical work capacity is larger than was suspected and it does not depend on activity level in the youth. This conclusion was based on deVries's recordings of mean lifetime physical activity history, calculated as the ratio of work metabolic rate to basal metabolic rate in the most active and the least active healthy years in the past. A trend showed that those who were least active in the past made the greatest gains.

Other possible changes with exercise training that affect the cardiovascular system are the following: (a) improved pumping capacity of the heart muscle; (b) maintenance or prevention of normally declining myocardial actomyosin ATPase activity; and (c) increasing efficiency of neural and hemostatic regulation of blood pressure, thus, less stress is exerted on the circulatory system (Kent, 1982). In addition, exercised rats in a study by Tomanek (1980) demonstrated larger capillary density than nonexercised rats, showing the ability of the old rat to enhance its capillary bed with exercise. Researchers in Finland have studied athletes and sedentary individuals, aged 31-72 years. They concluded that even if the exercise training is lifelong, it helps maintain a good level of health and fitness only during the middle years and it does not affect longevity

(Suominen et al., 1977). As one can see, the subject of exercise as a beneficial element for older people is still controversial, and the relationship between the period in life of exercise training and improvement in cardiovascular function is unclear.

Beliefs and Perceptions

Beliefs of senior citizens may also affect their level of physical activity. Some of these beliefs may include the following: (a) the need for exercise diminishes with age, (b) exercise is dangerous, (c) light and sporadic exercise is beneficial to health, and (d) their physical ability to exercise is limited (Shephard & Sidney, 1978). Sidney and Shephard (1977) tested men and women 60-70 years old for ratings of perceived exertion (RPE). They found that RPE as a function of heart rate was 2-3 units higher for older people than for younger ones. What they failed to mention was that HRmax decreases with age, thus, at the same level of exercise the older subjects were closer to their HRmax, which could have caused the higher ratings. In the same study, the researchers also noticed that RPE as a function of oxygen intake was higher for females than for males and higher for older than for younger individuals. However, when expressed as a percentage of maximal aerobic capacity, there was no significant difference in RPE between either males and females or older and younger individuals. Another finding was that even though a 34-week training program improved the older subjects' cardiovascular capacity, it did not reduce their RPE. There was no explanation for this observation.

It is of utmost importance to encourage physical activity at an older age, as well as at a younger age, in order to prevent or delay decline of physical bodily functions and to improve mental function. Thus, the older population should be informed of the benefits of exercise, and such misleading beliefs as the ones mentioned previously should be eliminated.

Summary

It has been demonstrated in this chapter that aging involves an array of changes in physiological as well as some mental functions. These changes result from disease processes, disuse of bodily functions, and chronological aging. The decrement of cardiovascular function with aging depends on many factors and can be mediated by regular participation in physical activity. It is still unclear how much exercise is optimal for maintenance of a healthy mind and body, but it is clear that exercise helps to slow down the deterioration of bodily functions and reduce the risk for coronary heart disease. Research has not provided conclusive answers about the relationship between past and present activity levels and cardiovascular fitness level in older individuals.

Chapter 3

METHODS AND PROCEDURES

The methods used in this study are explained in this chapter. It includes the following subsections: (a) selection of subjects, (b) testing instruments, (c) methods of data collection, (d) scoring of data, and (e) treatment of data.

Selection of Subjects

Participants were individuals over 60 years of age whose fitness levels were tested at Tompkins Community Hospital, Ithaca, New York. The group consisted of 15 males and 5 females. These subjects voluntarily took part in the hospital fitness program to achieve one or more of the following goals: evaluation of fitness level, guidance in obesity control, detection of cardiovascular diseases, and/or prescription of a personal exercise program. All subjects were tested during the period of November, 1983 to September, 1984. They had no knowledge of this study at the time of their tests. Their records were obtained with their permission and used for data in the present study. Four of the subjects were administrative workers (three as part-time employees and one full-time), three were full-time teachers, one was a full-time sales manager, and one was a medical doctor. The remaining 11 subjects were retired. Participants signed an informed consent form that explained the purpose and methods of this study and asked for their voluntary participation (see Appendix C).

Testing Instruments

A Quinton treadmill was used as the exercise modality for the maximal graded exercise test (GXT). It was calibrated periodically and was programmed for the Kattus (1967) walking protocol (see Appendix B). Initial speed was 1.5 mph and was increased every 2 minutes by .5 mph increments, to a maximum of 4.0 mph. Grade was initially 10% and was held constant for the first six 2-minute stages, then increased 2% each stage to a maximum of 25%. Participants were allowed a familiarization period on the treadmill and were also informed of the nature of the Kattus protocol. Subjects were urged to give a maximal effort by the tester prior to and throughout the evaluation.

A Quinton Q2000 ECG monitor was used to monitor subjects' heart function constantly, starting with a resting ECG and continuing during the exercise and recovery phases. Metabolic data were collected by a Sensormedic Horizon 6 metabolic measurement cart. Analyzers in this cart were calibrated at least twice daily using gases of known concentration. Room temperature and barometric pressure were measured and entered into the metabolic cart for use in oxygen consumption calculations. A Hans Rudolf 2A non-rebreathing valve with adjustable head support was used to collect all expired air during exercise, and a nose clip prevented unwanted escape of expired gases. Room air was inspired by the exercising individual.

Methods of Data Collection

Prior to the exercise test, each individual filled out a medical history form (see Appendix D) and a GXT informed consent form (see Appendix E). The medical history form was used for partial assessment of cardiac risk factors examined in the present study. Blood tests were used to determine circulating triglycerides, cholesterol, and HDL levels. Other measurements taken before the GXT were height, weight, skinfolds (used for calculation of body fat percentage), arm and leg strength, and flexibility. Heart rate (HR) and blood pressure (BP) were taken in two resting positions: supine and standing; they were also taken during the last 30 seconds of each stage of exercise and through recovery. A rating of perceived exertion (RPE) scale was used during each stage of exercise to estimate fatigue level. The scale started at 0 (i.e., no fatigue at all) and continued to a maximum of 10 (i.e., very, very hard work).

Heart rate (HR), ventilation (VE), $\dot{V}O_2$, and respiratory quotient (RQ) were recorded intermittently during exercise, about four times per minute, by the metabolic cart. In addition, personal data sheets were used to record GXT results at every stage of the test (see Appendix F).

Using a Quinton Q2000, a printout of 12-lead ECG tracings was produced once during each stage, but three leads (II, AVF, and V_5) were monitored constantly on the oscilloscope. Any ECG abnormalities were noted and recorded. Criteria for test termination were specific ECG abnormalities (e.g., ST-T segment depression or multiple PVCs), fatigue, inability to continue the test for any physical reason (e.g., painful calves), or attaining $\dot{V}O_2$max.

A questionnaire (see Appendix A) was used to determine the work and leisure habits of the participants in the study and calculate their daily energy expenditure. It included two separate sections: job-related energy expenditure, and leisure activity and housework. Not all data described above were used for the purpose of this experiment, but they were collected during the hospital's fitness testing. Those variables described below were actually used in the statistical analysis for the present study.

Scoring of Data

Four main variables were dealt with in scoring the data: $\dot{V}O_2max$, risk profile, present activity level, and past activity level. $\dot{V}O_2max$ was adjusted for body weight by recording it in ml/kg/min. Participants were divided into two groups according to risk profile: those with primary risk factors versus those with either no risk or only secondary risk factors. Subjects in the high risk group had one or more of the following: hypertension (systolic BP > 140 mmHg and/or diastolic BP > 90 mmHg), hyperlipidemia (triglyceride count > 220 mg/dl and/or cholesterol > 275 mg/dl), smoking habits, and ECG abnormalities (e.g., previous myocardial infarction, ischemic ST-T changes, conduction defects, arrhythmia, and/or left-ventricular hypertrophy). Subjects in the low risk group may have had one or more of the following: sedentary lifestyle, diabetes, obesity, and family history of heart disease.

Present and past activity levels were measured through questionnaires and included work and leisure habits. Answers to the questionnaires indicated that all participants were either retired or working in low energy expenditure, administrative-type jobs. Due to the fact that most of the energy was expended in leisure activities, including housework, rather than on the job, the work section of the questionnaires was excluded from the calculations of daily energy expenditure. Activity levels in the past and present were calculated from the answers to the questionnaires using energy expenditure tables in Guidelines for Graded Exercise Testing and Exercise Prescription (1980, pp. 43-45) and Åstrand and Rodahl (1977, p. 465).

Treatment of Data

Data included eight variables: $\dot{V}O_2max$ (ml/kg/min) from the GXT, age (yr), weight (kg), activity level (METS), sex, risk group, past activity (ml/kg/week), and present activity (ml/kg/week). The variables named "present activity" and "past activity" indicate the total work that each individual performed during a week and account for intensity, duration, and frequency of the weekly exercise. The variable named "activity level" was derived from the same data as "present activity," but it was calculated in METS and denotes the intensity of exercise for each individual, rather than the total work. Relationships among the different variables were examined by Pearson product-moment correlation with significance level set at $p < .05$. A regression equation was calculated to predict $\dot{V}O_2max$ from age, weight, present activity level, sex, risk group, and past activity. Partial correlations were also calculated for $\dot{V}O_2max$ with activity level, risk group, and past activity, controlling for age, weight, and sex.

Chapter 4

ANALYSIS OF DATA

In this investigation the relationships of past and present physical activity levels with present cardiovascular fitness were examined. The presence of cardiac risk factors and their relationship with physical activity level and cardiovascular fitness were also investigated. Results of analysis of data collected through questionnaires and graded exercise testing are detailed in this chapter using the following subsections: (a) descriptive statistics, (b) correlation for all variables, and (c) multiple regression of variables.

Descriptive Statistics

The raw data for the 20 subjects who participated in the study can be seen in Appendix G. Fourteen of the subjects were included in the high risk category, while six subjects were included in the low risk group. Table 1 presents the descriptive statistics for the following variables: $\dot{V}O_2max$, age, weight, activity level, past activity level, and present activity. Results indicated a normal distribution of most variables for subjects in this age group. Distribution of the variable past activity

Table 1

Descriptive Statistics for the Research Variables

	M	*Mdn*	*SD*
$\dot{V}O_2max$ (ml/kg/min)	31.4	31.3	10.0
Age (yr)	65.5	65.0	4.6
Weight (kg)	77.5	77.5	12.2
Activity Level (METS)	4.5	4.5	1.0
Past Activity (ml/kg/week)	9.4	4.6	10.5
Present Activity (ml/kg/week)	12.3	11.4	7.3

Note. Number of participants = 19.

had a wide range and was positively skewed (i.e., most scores were on the low side). This caused the median to be lower than the mean.

Correlation for All Variables

To examine relationships among the various measurements in the study, Pearson product-moment correlations were computed (Table 2). Moderate, yet significant, positive correlations were found between $\dot{V}O_2max$ and past activity level, and between $\dot{V}O_2max$ and present activity level. As expected, a significant negative relationship, a point biserial coefficient used for one dichotomous variable and one ratio variable, was noted between sex and weight in kilograms ($p < .01$). Accordingly, female subjects of this study were lighter than the male subjects. This finding is supported by the fact that males' muscles are larger and stronger and their skeletons are heavier than females (Edwards & Gaughran, 1971). A high negative correlation was also seen between high risk and activity level (using a biserial correlation for one dichotomous with underlying normal variable and one continuous variable). This result points out the fact that subjects in the high risk category exercise less during their leisure time than those in the low risk group. The positive correlation between present

Table 2

Pearson Product-moment Correlations Among All Variables

	$\dot{V}O_2max$	Age	Weight	Act.Level	Sex	Risk	Past Act.
Age	-.335						
Weight	-.245	.213					
Act.Level	.624**	-.149	-.333				
Sex	-.295	-.305	-.631**	-.200			
Risk	-.016	.123	.271	-.549**	-.108		
Past Act.	.419*	-.209	-.238	.226	-.028	-.152	
Present	.446*	-.074	-.229	.588**	.133	-.327	.336

*$p < .05$.

**$p < .01$.

activity and activity level was significant, probably due to the similarity of what these two variables measure (i.e., the individuals' activity status at present). This high correlation indicated that individuals who exercise at a high intensity, measured by METS level, tend to spend more time each week exercising than those who exercise at a lower intensity.

Multiple Regression of Variables

Table 3 demonstrates the regression of $\dot{V}O_2max$ on age, weight, sex, risk group, and past activity. The letter b indicates the regression slope of each variable against $\dot{V}O_2max$. The second column, SE_b, shows the estimated standard error of the slope. The tolerance measure equals $1 - R^2$, or 1 minus the amount of variability in each variable that is explained by all other independent variables in the table. For example, 14.8% (1 - .852) of the variability in age is explained by weight, sex, risk group, and past activity. A low value in the tolerance column may indicate a problem of multicollinearity. This problem arises because when there are strong relationships among the independent variables, it is hard to assess their true effect on the dependent variable ($\dot{V}O_2max$ in this case).

Table 3

Regression of $\dot{V}O_2max$ on All Independent Variables (Excluding Activity Level).

Variable	*b*	SE_b	Tolerance	*t*
Constant	137.771	32.458		4.245*
Age	-.942	.403	.852	2.335*
Weight	-.563	.196	.506	2.872*
Sex	-18.557	5.219	.521	3.556*
Risk	3.310	3.741	.909	.885
Past Activity	.158	.177	.839	.895

Note. Number of participants = 19.

$^*p < .05$.

Multiple $R = .79$.

$R^2 = .63$.

Adjusted $R^2 = .48$.

$SE = 7.23$.

$F(5,13) = 4.34$, $p = .015$.

The effect of multicollinearity on this study will be discussed further in chapter 5.

When excluding activity level, the effects of age, weight, and sex, each as a separate entity, on $\dot{V}O_2max$ are statistically significant. Risk group and past activity are not significantly correlated with $\dot{V}O_2max$ as separate entities, but in conjunction with the other three independent variables they yield a significant multiple correlation (R = .79, $F[5,13]$ = 4.34, p < .015).

In Table 4, the regression of $\dot{V}O_2max$ on activity level is added. This is done in order to see the influence of activity level on $\dot{V}O_2max$ and on the relationship between the group of independent variables and $\dot{V}O_2max$. Table 4 indicates that when the variables are considered separately, only the effect of activity level on $\dot{V}O_2max$ is statistically significant, while age, weight, and sex lose their significant correlation with $\dot{V}O_2max$. The t value for risk group is relatively high (significant at .053 level) and very close to the critical significance level set for this study.

Table 4

Regression of $\dot{V}O_2max$ on All Six Independent Variables.

Variable	b	SE_b	Tolerance	t
Constant	70.644	40.234		1.756
Age	-.719	.362	.792	1.988
Weight	-.280	.208	.334	1.344
Sex	-10.041	5.808	.314	1.729
Risk	8.340	3.888	.628	2.145
Past activity	.185	.153	.835	1.205
Activity level	5.515	2.370	.392	2.327*

Note. Number of participants = 19.

*$p < .05$.

Multiple R = .86.

R^2 = .74.

Adjusted R^2 = .61.

SE = 6.25.

$F(6,12) = 5.75$, $p = .005$.

Still, the overall relationship of all independent variables with $\dot{V}O_2max$ is highly significant ($F[6,12] = 5.75$, $p < .005$). The coefficient of determination, R^2, is increased considerably, from 63% to 74%, just from the addition of activity level to the regression. The regression equation is $\hat{Y}$ = (-.72)Age + (-.28)Weight + (5.52)Activity Level + (-10.04)Sex + (8.34)Risk + (.18)Past Activity + 70.64.

Chapter 5

DISCUSSION OF RESULTS

A discussion of the results of this study is contained within this chapter. It includes the following sections: (a) exercise training and maximal oxygen uptake, (b) cardiac risk factors and exercise, (c) the importance of activity level, and (d) tolerance and multicollinearity.

Exercise Training and Maximal Oxygen Uptake

The four main variables discussed in this section are $\dot{V}O_2max$, activity level, past activity, and present activity. The mean $\dot{V}O_2max$ for subjects in this study was 31.4 ml/kg/min with a median value of 31.3 ml/kg/min, showing a normal distribution. Shephard and Sidney (1978) proposed that $\dot{V}O_2max$ declines progressively with age at a rate of .4-.6 ml/kg/min annually over the age range of 20-52 years. While the results of the present study do not support this proposal (predicted $\dot{V}O_2max$ for 65-year-old individuals would be about 20 ml/kg/min), the general trend of a declining $\dot{V}O_2max$ is clearly illustrated in that the average $\dot{V}O_2max$ for sedentary 20-30 year olds is 39-45 ml/kg/min

(McArdle et al., 1981) and the actual mean value for individuals in the present study was 31.4 ml/kg/min. Shephard and Sidney's (1978) predictions may not be applicable to individuals outside the age range of 20-52 years. Alternatively, this specific group of individuals might have been more active than the average 65-year-old person, as suggested by their mean activity level. The average activity level of 4.5 METS for participants in the present study was about 50% $\dot{V}O_2$max, indicating occasional undertaking of moderate intensity work. On the average, these individuals were more active at the time of the study than they had been in their youth, as indicated by a comparison of their past and present activity levels.

Shephard and Sidney (1978) referred to a normal decline of $\dot{V}O_2$max values in sedentary individuals, but most subjects in this study were physically active. It appears that training done by the participants in this study brought about improvements or allowed maintenance of cardiovascular function better than the average 65-year-old individual. This is a reasonable suggestion given that trainability of older individuals has been documented by deVries (1970). Two other recent studies support the possibility of higher maximal oxygen consumption capacity in trained older individuals as opposed to sedentary ones (Seals, Hagberg, Hurley, Ehsani, & Holloszy, 1984; Thomas, Cunningham, Rechnitzer, Donner, & Howard, 1985). In both studies, intensity of exercise seemed to be the main determinant in the extent of improvement in cardiovascular function. Seals et al. (1984) tested 11 men and women, aged 61-67, for the effect of endurance training on $\dot{V}O_2max$. The subjects' average initial $\dot{V}O_2max$ was 25.4 ± 4.6 ml/kg/min, which is close to the value predicted for a 60 year old according to Shephard and Sidney (1978). After 6 months of low intensity training at least 3 times a week (HR < 120 beats/min), $\dot{V}O_2max$ increased to 28.2 ± 5.2 ml/kg/min. After an additional 6-month training period at high intensity (75-85% of HR reserve, at least 3 times a week) $\dot{V}O_2max$ increased further to 32.9 ± 7.6 ml/kg/min, indicating an overall significant increase of 30% above baseline. These values support the contention that the older adults of the present study have a greater $\dot{V}O_2max$ than a sedentary population of the same age because of their participation in endurance training. Furthermore, the data displayed a positive correlation between activity level and $\dot{V}O_2max$ ($p < .01$), indicating that increased intensity of physical activity at the present is related to better cardiovascular fitness in the elderly. This finding is in agreement with the work of Seals et al. (1984) concerning exercise intensity and $\dot{V}O_2max$.

Past activity and $\dot{V}O_2max$ were found to be positively correlated ($p < .05$). Contrary to this finding, deVries (1970) claimed that there is no relationship between past activity and present fitness level, and that only participation in physical activity at the present contributes to cardiovascular capacity. One possible explanation for the findings of the present study could be attributed to the relationship between past and present activity levels. Although it was not statistically significant, there was a positive correlation between these two variables ($r = .34$), which indicated that subjects who participated in sports in their youth were more active later in life. This possibility merits further investigation.

Cardiac Risk Factors and Exercise

In support of the null hypothesis, the negative correlation between $\dot{V}O_2max$ and the presence of primary risk factors was not significant. A previous study (Klausen, Andersen, & Nandrup, 1983) found a slightly lower aerobic capacity in young adults who smoked, showing a relationship between cardiovascular fitness and one primary risk factor, smoking. However, no other correlations between $\dot{V}O_2max$ and cardiovascular risk factors have been observed in the literature reviewed. Neither hypertension nor hyperlipidemia has been shown to negatively affect $\dot{V}O_2max$.

Conversely, exercise training has been shown to affect the prevalence of risk factors. Numerous past studies have reported that endurance training aids in reduction of blood pressure (Hagberg et al., 1983; Seals & Hagberg, 1984; Wilcox et al., 1982), reduction of triglycerides level (Gordon et al., 1983; Haskell, 1984; Schriewer et al., 1983), and elevation of HDL cholesterol, thus lowering the risk for heart disease. However, no study has yet examined if individuals at low risk tend to exercise more. Activity level at present was found to be inversely correlated with primary cardiac risk factors ($p < .01$) in this study. The correlation indicated that those who exercised more intensely had a tendency to be in the low risk group. This relationship may arise because (a) as supported by past studies (deVries, 1970; Goodrick, 1980; Kent, 1982), it may be that individuals who exercise more intensely lower their risk of heart disease, and (b) individuals who belong to the low risk group (i.e., do not smoke, do not have hypertension and/or hyperlipidemia, and do not demonstrate ECG abnormalities) tend to exercise more than those in the high risk group. It is probably a combination of both of the above explanations that contributes to the inverse relationship between exercise training and risk factors. On the one hand, exercise is known to lower the risk for heart disease, and on the other hand, knowledge of presence of cardiac risk factors may discourage participation in sports or exercise.

The Importance of Activity Level

As mentioned in previous studies (deVries, 1970; Goodrick, 1980; Kent, 1982), cardiovascular function is enhanced by regular participation in physical activity. This fact was supported by the present study, showing the importance of activity level as related to maximal oxygen uptake. The addition of activity level to the regression added 11% to the prediction of $\dot{V}O_2max$, a considerable contribution. Kerlinger and Pedhazur (1973) defined the unique contribution of an independent variable as "the variance attributed to it when it is entered last in the regression equation." After the addition of activity level, all six independent variables as a group accounted for 74% of the variance in $\dot{V}O_2max$. The statistical significance of this coefficient of determination was determined by the F ratio. It was found to have a $p < .005$, indicating a significant contribution of activity level to the variance in $\dot{V}O_2max$ after taking the other five variables (age, weight, sex, risk group, and past activity) into account. Furthermore, the t value for activity level was statistically significant at the .05 level. The t ratio is a test of the b's, the partial regression coefficients, and it indicates the effect of one independent variable on the dependent variable while all other independent variables are held constant (Kerlinger & Pedhazur, 1973). The interpretation of the t ratio in this study indicated that the b value for activity level was significantly different from 0 and that for each unit change in activity level there was a change of 5.52 units in $\dot{V}O_2max$ when other independent variables were held constant.

Therefore, it is clear to see that the intensity of exercise, presented here as activity level, is a major determinant of maximal aerobic capacity.

Another change that occurred with the addition of activity level to the regression also requires explanation. The three independent variables that showed statistical significance at the .05 level (age, weight, and sex, see chapter 4, Table 3) lost their significance when activity level was introduced (Table 4, chapter 4). It is known that the addition of a variable to a regression equation changes the regression coefficients of all other independent variables involved (Kerlinger & Pedhazur, 1973). In this case, the resulting partial regression coefficients (bs) of age, weight, and sex decreased after adding activity level. This reduction suggests that most, if not all, of the effect of these variables on $\dot{V}O_2max$ was mediated by activity level. Unfortunately, this conclusion is not so easily assessed. Activity level was affected by age, weight, and sex. These relationships were the reason for the lower partial regression coefficients of age, weight, and sex with the introduction of activity level to the regression equation. Also worth mentioning is the increase in the significance of the t value ($p < .053$) of the risk variable after adding activity level to the regression table. This is a strange phenomenon because there is a high inverse correlation between risk and activity level (see chapter 4, Table 2), which normally causes decreases in the t values of both variables when entered into the regression equation. However, the multiple interaction among all the independent variables makes it hard, or even impossible, to single out the effect of these two independent variables (i.e., activity level and high risk) on each other and on $\dot{V}O_2$max.

Tolerance and Multicollinearity

It was mentioned in chapter 4 that a problem of multicollinearity may have complicated interpretation of the results of this study, although activity level is still believed to be the most important determinant of $\dot{V}O_2$max in this study. With two independent variables, multicollinearity can be detected just by looking at the simple correlation between these variables. A high correlation indicates the possibility of incorrect values regarding the effect of the independent variables on the dependent variable. However, when dealing with more than two independent variables, even if the simple correlations are low, the problem of multicollinearity can still exist, so multiple correlations among the independent variables should be utilized.

In this study, multicollinearity was high regarding weight, sex, and activity level, with multiple correlation values of .82, .83, and .78, respectively (see tolerance column, chapter 4, Table 4). Age, risk group, and past activity had low multiple correlation values and may be considered irrelevant for the discussion of multicollinearity (Maddala, 1977). Of the three variables involved--weight, sex, and activity level--each was highly influenced by the combined effect of all other independent variables. These strong interrelations limit our ability to separate the individual effects of weight, sex, and activity level on $\dot{V}O_2max$.

In this study, the problem of multicollinearity was magnified by a small sample size. Moreover, a large number of variables relative to the sample size caused a reduction in degrees of freedom. This problem could have been eliminated by planning an experiment that allowed the explanatory variables to be statistically independent, or uncorrelated (Kennedy, 1979). However, such experimental designs with orthogonal independent variables are highly unlikely.

Chapter 6

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS FOR FURTHER STUDY

Summary

The purpose of this study was to examine the relationships between past and present activity levels and cardiovascular fitness in the elderly. The effects of the presence of primary cardiac risk factors (i.e., hypertension, hyperlipidemia, smoking, and diabetes) on cardiovascular fitness and on present activity level were also investigated.

The records of 15 males and 5 females over 60 years of age, who participated in an exercise stress test (GXT) for their own benefits, were used as a source of data. Reasons for taking the GXT included the following: evaluation of fitness level, guidance in obesity control, detection of cardiovascular diseases, and/or prescription of personal exercise program. Subjects also completed a medical history form for partial assessment of cardiac risk factors, took a blood test for determination of hyperlipidemia, and had their blood pressure measured. They were asked to allow the release of their medical records for use in this study. Finally, all subjects filled out a questionnaire to determine work and leisure habits. After calculations of energy expenditures of leisure and work, it was found that most energy was expended during leisure activities and housework. As a result, the work section of the questionnaire was excluded from the calculations of energy expenditure. Past and present activity levels were based on the answers to the questionnaire.

A Pearson product-moment correlation with significance level set at $p < .05$ was computed to find the relationships among $\dot{V}O_2max$ (ml/kg/min), age, weight (kg), activity level (METS), sex, risk group, past activity (ml/kg/week), and present activity (ml/kg/week). Significant positive correlations were found between $\dot{V}O_2max$ and past activity, and between $\dot{V}O_2max$ and present activity. A positive correlation between activity level and present activity was also significant. A high positive correlation between $\dot{V}O_2max$ and activity level was significant as well. High negative correlations ($p < .01$) were found between sex and weight and between risk group and activity level.

The effect of each of the variables, namely activity level, age, weight, sex, risk group, and past activity, on $\dot{V}O_2max$ was calculated using multiple regression analysis. In the same analysis, the overall relationship of all independent variables with $\dot{V}O_2$max was also investigated through an $\underline{F}$ test and was found to be highly significant ($\underline{p} < .005$). When activity level was excluded from the regression, the separate effects of age, weight, and sex on $\dot{V}O_2$max were statistically significant. However, the addition of activity level to the regression equation caused these variables to lose significance, while the influence of activity level on $\dot{V}O_2$max remained significant.

Conclusions

Based on the analyses of the findings from the questionnaires and the graded exercise test, the following conclusions can be made:

1. Increased level of physical activity intensity (METS) was related to greater cardiovascular fitness ($\dot{V}O_2$max) in the elderly.

2. The relatively high $\dot{V}O_2$max results for the subjects in this study and their high activity level may indicate improved cardiovascular function resulting from exercise training, as suggested in earlier studies (deVries, 1970; Goodrick, 1980; Kent, 1982).

3. Increased amount of physical activity in the past (more than 6 months prior to the graded exercise test) was related to increased fitness level at the time of the study, as measured by $\dot{V}O_2max$. However, this relationship might have been influenced by the positive correlation between past and present activity levels and by the fact that present activity level was positively correlated with $\dot{V}O_2max$.

4. Activity level (METS) was negatively related to primary cardiac risk factors (hypertension, hyperlipidemia, diabetes, and smoking), which may have indicated that either individuals who exercised less intensely increased their risk of heart disease, or individuals at high risk tended to exercise less intensely.

Recommendations for Further Study

The present study was limited in time and resources, and as a result many questions remained unanswered. The following recommendations for further study emerge from the present one:

1. Increase the number of subjects to reduce the problem of multicollinearity and provide more accurate results.

2. Design a longitudinal study of the effect of endurance exercise on cardiovascular fitness and the physiological changes that occur in the aging heart.

3. Construct a better method for quantification of past activity, and provide a better definition of the period considered as past activity, especially for studies that involve older subjects.

4. Further investigate the effect of participation in exercise and sports in the past on present cardiovascular fitness in older individuals.

5. Investigate the relationship between $\dot{V}O_2max$ and hypertension, and between VO_2max and hyperlipidemia.

6. Include in the activity queationnaire a specification of the number of hours per week that were spent on each activity*.

7. Duplication of the present study using existing questionnaires should be considered.

*Hours spent in each activity were accounted for in the present study by calling each subject following completion of the questionnaires.

Appendix A

ACTIVITY QUESTIONNAIRE

Name: ______________________________ Age: ________ Sex: _____

<u>Leisure</u>

1. What activity(ies) do you do in your free time? Check more than one if applicable.

   a) Mowing the lawn and gardening.

   b) House work. Specify __________.

   c) Participation in sports (e.g., golf). Specify __________.

   d) Participation in an exercise program. Specify ________.

   e) Walking.

   f) Other. Specify __________.

2. How many hours a week do you spend on the above activity(ies)*?

*Hours spent in each activity were accounted for in the present study by calling each subject following completion of the questionnaires.

3. Did you participate in the past in any sport, or were you involved in any exercise program (even if it was on an individual basis)?

   a) Yes. Specify __________.

   b) No. Proceed to question #7.

4. How long ago did you participate in the above activity?

5. What was the duration of the period during which you were involved in this activity?

6. Approximately how many hours a week did you exercise then?

7. How would you rate your activity level at the present as compared with others your age?

   a) Much less active than others.

   b) Somewhat less active than others.

   c) About the same.

   d) Somewhat more active than others.

   e) Much more active than others.

Work

1. What is your present occupation? Check more than one if applicable.

   a) Administrative, clerical, or managerial worker.

   b) Sales and service worker.

   c) Agricultural worker, fisherman, or hunter.

   d) Labor worker or transport equipment operator.

   e) Armed forces.

   f) Retired or non-working due to other reasons.

   g) Other. Specify ________

For working individuals only

2. How many hours a week do you work?

3. How long have you been doing this kind of work?

4. Have you had any other occupation prior to this one? (Use same categories as in question *1).

5. If yes, for how long?

For non-working individuals only

6. How long has it been since you last worked?

7. What was your occupation then? (Use same categories as in question #1).

8. How long did you do this kind of work?

9. How many hours a week did you work then?

Appendix B

KATTUS WALKING PROTOCOL

Time	Speed	Grade
2 min.	1.5 mph	10%
2 min.	2.0 mph	10%
2 min.	2.5 mph	10%
2 min.	3.0 mph	10%
2 min.	3.5 mph	10%
2 min.	4.0 mph	10%
2 min.	4.0 mph	14%
2 min.	4.0 mph	18%
2 min.	4.0 mph	22%
2 min.	4.0 mph	25%

Note. From "Physical training and heterodrenergic blocking drugs in modifying coronary insufficiency" by A. A. Kattus. In G. Marchetti & B. Toccardi (Eds.), Coronary circulation and energetics of the myocardium. New York: Karger, 1967.

Appendix C

INFORMED CONSENT FORM

(For General Study)

1. a) Purpose of the study. The purpose of this study is to test for any relationship between activity level and cardiac fitness level.

   b) Benefits. Data collected will allow for construction of guidelines as to the type and level of exercise that are appropriate for the aged.

2. Method. Subjects will have to answer the attached questionnaire. The rest of the data will be obtained from measurements collected through the "In-Shape Program" at Tompkins Community Hospital.

3. Will this hurt? There is no apparent physical or mental harm in answering the attached questionnaire.

4. Need more information? For more information or any question that may arise, contact Nomi Fridman at 257-1338 or Dr. Paul Thomas at 274-3139.

5. Withdrawal from the study. Subjects may withdraw from the study at any time without any additional obligation or penalty.

6. <u>Will the data be maintained in confidence</u>? Data will be kept confidential and will be used as "group data" rather than identifying individual scores.

7. I have read the above and I understand its contents and I agree to participate in the study.

Signature Date

Appendix D

MEDICAL HISTORY FORM

Name____________ Address____________________ Home phone_________

Age__________ Sex____________ Date of birth______________________

Occupation____________________ Physician_________________________

Date of last physical___________ Person to notify in emergency________

1. Do you smoke? No___ Yes____

2. Women: Are you now pregnant? No___ Yes____

   Date of last delivery__________. Complications______________

3. Has anyone in your family had?

   Heart attack

   Diabetes

   Epilepsy

   High blood pressure

   Elevated cholesterol

   Strokes

   Heart surgery

4. In your lifetime, have you had?

   Heart disease

   Rheumatic fever

   Cancer

   Chest pain/heart palpitations

   High blood pressure

   Diabetes

   Lung disease

Phlebitis

Congenital heart disease

Metabolic diseases

Back injuries

Arthritis

5. In the past 6 months, have you had?

Persistent infections

Chronic muscle pain

Muscle cramps

Phlebitis

Foot problems

Swollen ankles

Chronic cough

Hernia

Prostate disorders

Ulcers

6. Have you been hospitalized in the last 6 months? No __

Yes. Explain__________

7. Do you have any physical limitations which should be considered before you undertake an exercise program? No______. Yes. Explain__________

8. Do you experience any of the following with exercise?

Shortness of breath

Fainting spells

Chest pain

Back pain

Knee or other joint pain

Chronic muscle pain

9. List any drugs and/or medications you are taking.

Appendix E

INFORMED CONSENT FORM

(For Graded Exercise Test)

Name____________ Age at last birthday__________ Physician__________

Address____ Telephone no._______

1. In order to determine an appropriate plan to get in shape, I ______________ hereby consent to voluntarily engage in performance testing to be performed by or under the direction of the lab director or physician.

2. It is my understanding that I will be questioned and examined prior to taking the test and will be given a resting electrocardiogram to exclude contraindications to such testing.

3. The purpose of the test is to determine the state of my heart and circulation, and the information thus obtained will help in advising me as to the activities in which I may engage. My physician or the hospital physician must grant approval for me to undergo the testing and, in his best clinical judgment, there are no contraindications to such testing.

4. I will perform an exercise tolerance test on a motor-driven treadmill. The work levels (efforts) will begin at a level I can easily accomplish and will be advanced in stages, depending on my abilities (work capacity). The test may be discontinued at any time because of fatigue, breathlessness, discomfort, or other signs and symptoms that dictate the test be stopped. We do not wish you to exercise at a level which is abnormally uncomfortable for you; however, for maximum benefit from the test, exercise as long as is comfortable.
5. Your pulse, blood pressure, and electrocardiograms will be monitored. In addition, other tests will be performed. These tests will include oxygen uptake and other pulmonary function measures, skinfold measures, flexibility measures, and strength testing.
6. I have been informed that the selection and supervision of my test is a matter of professional judgment, that there are no satisfactory alternative methods of treatment or diagnoses, and that there exists the possibility of certain changes occurring during the test. These include, but are not limited to, abnormal blood pressure, shortness of breath, fainting, disorders of the heart beat (too rapid, too slow, or

ineffective) and, in rare instances, heart attack. Every effort will be made to avoid or minimize such occurrences by the preliminary examination and by observation during testing. Emergency equipment and trained personnel are available to deal with unusual situations which may arise.

7. I understand that I have the right to ask that the test be stopped at any time if I feel that I cannot continue and that my desires will be respected.

8. I understand that the explanations that I have received are not exhaustive and that other, more remote risks and consequences may arise. I have been advised that if I desire a more detailed and complete explanation of any of the foregoing, such explanation will be given to me.

   I do not request such explanation ______________________(signature).

9. The information which is obtained will be treated as privileged and confidential, and will not be released or revealed to any person except my physician without my written consent. The information obtained, however, may be used for a statistical or scientific purpose with my

right to privacy retained.

10. Further, I the undersigned, release and discharge Tompkins Communuty Hospital, its administrators, physicians, technologists, and any other connected therewith from all claims or damages whatsoever that the undersigned or his representative may have arising from or incident to this test.

11. I acknowledge that I have read this document in its entirety, that it has been read to me, and that I fully understand it. Any questions which may have occurred to me have been answered to my satisfaction.

12. I have been informed that this exercise test may be photographed or videotaped for teaching purposes or program publicity.

Date________________ Signature__________________

Appendix F

DATA SHEET

(Graded Exercise Test)

Name:__________ Base B. P.__________ Pre-Exercise B. P.__________

Age:__________ Base HR__________ Pre-Exercise HR__________

Age predicted maximum heart rates: 100%______ 85%______ 70%______

Stage	Min.	Speed (mph)	% Grade	HR	BP	$\dot{V}O_2$ (ml/kg/min.)	ST-T Changes
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							
16							
17							

Stage	HR	BP	$\dot{V}O_2$ (ml/kg/min.)	ST-T Changes
Recovery 1				
2				
3				
4				
5				

Appendix G

CHARACTERISTICS OF THE SUBJECTS

$\dot{V}O_2max$ (ml/kg/min)	Age (yr)	Weight (kg)	Act. Level (MET)	Sex[a]	Risk[b]	Past Act. (ml/kg/wk)	Present (ml/kg/wk)
33.05	67	87.3	2.893	0	1	----	7.917
32.00	64	70.5	4.442	0	1	28.35	4.664
27.40	67	80.9	4.821	0	0	14.70	6.750
48.00	62	80.0	6.280	0	0	20.16	30.990
22.10	62	70.9	2.531	1	1	4.32	1.595
22.10	60	99.1	3.503	0	1	1.26	6.069
42.60	67	74.1	4.555	0	1	11.03	5.739
27.80	68	90.0	4.682	0	1	3.54	8.848
31.00	65	61.8	4.498	1	1	0.00	13.854
44.30	68	61.4	5.605	0	1	0.00	13.340
21.20	75	77.7	5.350	0	0	5.99	12.920
10.00	73	94.5	2.450	0	1	0.00	4.370
38.00	63	79.0	5.010	0	1	4.78	15.784
21.60	63	59.1	5.120	1	0	6.72	20.427
45.00	60	75.0	5.660	0	0	20.57	13.382
26.30	61	63.6	4.300	1	0	2.10	9.925
28.30	74	93.2	3.780	0	1	0.00	16.255
34.40	61	94.5	4.530	0	1	0.00	9.899
42.00	66	77.3	3.590	0	1	23.89	15.479
31.70	65	69.1	4.310	1	1	31.50	23.666

[a]Value of: 0 = male; 1 = female

[b]Value of: 0 = presence of primary cardiac risk factors; 1 = presence of only secondary risk factors or no risk.

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