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THESIS – THÈSE

Title of Thesis – Titre de la thèse

ELECTROCARDIOGRAM ABNORMALITIES IN A FITNESS CENTRE

Degree for which thesis was presented
Grade pour lequel cette thèse fut présentée

M. Sc

Year this degree conferred
Année d'obtention de ce grade

1985

University – Université

UNIVERSITY OF ALBERTA

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ELECTROCARDIOGRAM ABNORMALITIES IN A FITNESS CENTRE

by

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A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE

OF MASTER OF SCIENCE

PHYSICAL EDUCATION AND SPORT STUDIES

EDMONTON, ALBERTA

FALL 1985

THE UNIVERSITY OF ALBERTA

RELEASE FORM

NAME OF AUTHOR GARY SNYDMILLER

TITLE OF THESIS ELECTROCARDIOGRAM ABNORMALITIES IN A FITNESS CENTRE

DEGREE FOR WHICH THESIS WAS PRESENTED MASTER OF SCIENCE

YEAR THIS DEGREE GRANTED FALL 1985

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Abstract

One of the electrocardiogram (ECG) abnormalities that has correlated with coronary artery disease (CAD) is a horizontal or downsloping ST segment depression of 1mm or greater. These ECG abnormalities indicative of ischemia can be elicited during maximal exercise in relatively few asymptomatic normotensive subjects. The purpose of this study was to determine if ST-segment depression during a treadmill stress test was related to cardiovascular fitness on a submaximal exercise test. The secondary aim was to determine if these abnormalities could potentially be detected in a fitness centre using a single lead ECG (CM_5). One hundred and eight (108) male clients (0-30 percentile $n=62$; 70-100 percentile $n=56$) and 47 female clients (0-30 percentile $n=10$; 70-100 percentile $n=37$) from two diverse fitness levels volunteered for a clinical exercise stress test. The male clients in the low fitness group were older, weighed more, had a greater percent body fat, lower predicted VO_2max on the Astrand and Bruce test, higher resting heart rate, lower total exercise time on the treadmill, and completed fewer 3 minute exercise stages on the Bruce protocol ($p<0.001$). There were more male clients in the high fitness group rated as having a hypertensive exercise blood pressure ($p<0.05$) and more clients in the low fitness group rated as having a low exercise tolerance on the Bruce protocol ($p<0.05$). The female clients showed similar results with the low fitness group having a higher resting systolic and diastolic blood pressure ($p<0.05$). No female clients had a hypertensive exercise blood pressure ($p>0.05$) but there were more female clients in the low fitness group rated as having a low exercise tolerance ($p<0.001$). The prevalence of ST-segment depression was not related to the fitness group for either the male or the female clients ($p>0.05$). The prevalence of ST-segment depression was 15.3 percent for male clients and 25.5 percent for female clients. A discriminant function analysis correctly classified 71.1 percent of the male clients into a group with or without ST-segment depression using age, percent body fat, VO_2max on the Astrand test, fitness percentile, resting diastolic blood pressure and physical activity status ($p<0.001$). There were no useful variables that would predict group membership for the female clients. The number of ECG abnormalities that could be detected in a fitness

centre using a single lead ECG cannot be determined with certainty from this study. A fitness unit may be able to identify a group of male clients with an increased chance of ST-segment depression during exercise.

Acknowledgements

The author would like to thank the staff of the University of Alberta Fitness Unit and the staff of the University of Alberta Hospital Cardiac Stress Laboratory whose help and assistance in this project goes beyond words. Special thanks goes to Dr. K.K. Teo, who gave numerous hours to cover the majority of the exercise tests and to Dr. Marg Kavanagh as a co-worker and friend who helped to start and complete this project.

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Chapter I

Introduction

There has been a great deal of research to indicate that a sedentary lifestyle increases and an active lifestyle reduces the incidence of coronary artery disease (Morris et al., 1973; Cooper et al., 1976; Erkisson et al., 1981). One of the electrocardiogram (ECG) abnormalities that has been correlated with coronary artery disease (CAD) is 1 mm or greater of horizontal or downsloping ST-segment 0.08 sec after the J point. These ECG abnormalities indicative of ischemia can be elicited during maximal exercise in relatively few (1.5-12%) asymptomatic normotensive males (Cummings et al., 1975; Froelicher et al., 1976; Bruce et al., 1980; Giagnoni et al., 1983). Among individuals with abnormal exercise ECG responses there is an increased incidence of coronary events (angina, myocardial infarction and sudden cardiac death).

In a pilot study conducted on clients presenting for a Fitness and Lifestyle Appraisal at the University of Alberta it was found that 23.8% (9 of 39) clients had abnormal maximal treadmill stress tests at the University of Alberta Cardiac Rehabilation Laboratory. The results indicated that 30% (6 of 20) of the clients were categorized into the 0-30 percentile and 16% (3 of 19) of the clients were categorized into the 70-100 percentile on a submaximal bicycle test for their age and sex. These results showed a significantly increased incidence of ST-segment depression during exercise ($p<0.01$). A larger sample was collected and tested to determine if these results would remain consistent.

A. Problem

The primary aim of this study was to determine if the prevalence of abnormalities in the exercise electrocardiogram (ECG) during a maximal treadmill stress test (Bruce, 1971) is related to cardiovascular fitness on a submaximal bicycle ergometer test (Astrand, 1960).

B. Sub-problem

A secondary aim was to indicate the number of ECG abnormalities that could potentially be detected in a fitness centre using a single channel ECG recorder to monitor heart rate with a modified chest lead (CM5).

C. Delimitations

1) The sample was 118 male and 47 female clients of the University of Alberta Fitness Unit. The age range was 17 to 72 years.

2) The clients asked to volunteer for further assessment were those individuals categorized into the 0-30 percentile and the 70-100 percentile on a submaximal exercise test (Astrand 1960) for their age and sex.

3) The clients were asymptomatic (Par-Q negative), normotensive individuals.

4) The duration of the study was December 1983 to November 1984.

D. Limitations

1) The subjects were volunteers.

2) The submaximal (Astrand 1960) and maximal exercise test (Bruce 1971) are predictors of maximal oxygen uptake.

3) ST-segment depression of 1 mm or greater does not necessarily indicate the presence of coronary artery disease and a normal exercise ECG response does not rule out the possibility of coronary events (Froelicher et al., 1976; Cummings et al., 1975).

4) There are many contributing risk factors to coronary artery disease but only exercise risk factors will be considered in this study.

5) The average duration between the time of the fitness test and the stress test was 2-3 weeks but occassionally a duration greater than one month occurred and thus the clients fitness level may have changed slightly on the second test.

E. Significance of the Study

The identification of individuals with a high risk of developing coronary artery disease (CAD) would allow for proper clinical diagnosis and risk factor intervention. Due to the high incidence of coronary artery disease among individuals with abnormal ECG responses, they are encouraged to take every measure possible to reduce the influence of known risk factors associated with clinical CAD (Cummings et al., 1975). Preventive measures applied to high risk individuals will consequently reduce the chance of the asymptomatic individual from becoming symptomatic, at which stage the CAD is almost irreversible and will require clinical attention. If a group of individuals with a higher incidence of abnormal exercise ECG responses can be identified through a simple fitness evaluation it would provide a more cost effective method of screening individuals than the current system of physician monitored stress tests.

F. Definition of Terms

Asymptomatic - symptomless; exhibiting or producing no symptoms (Blackiston's Gould Medical Dictionary, pp. 129, 1979).

Atherosclerosis - a variable combination of changes in the intima of arteries consisting of the focal accumulation of lipids, complex carbohydrates, blood and blood products, fibrous tissue and calcium deposits and associated medical changes (Blackiston's Gould Medical Dictionary, pp. 131, 1977).

Cardiovascular Fitness - refers to the circulatory capacity for oxygen transportation (Astrand and Rodahl, 1977).

Coronary Stenosis - narrowing of a coronary artery without complete blockage (Blackiston's Gould Medical Dictionary, pp. 320, 1977).

Electrocardiograph - a graphic record of the electrical forces that produce contraction of the heart (Blackiston's Gould Medical Dictionary, pp. 430, 1977).

Ischemia - local diminution in the blood supply, due to obstruction of inflow of arterial blood, or due to vasoconstriction; localized tissue anoxia (Blackiston's Gould Medical Dictionary, pp.

103, 1977).

Maximum Aerobic Power - VO_2max is quantified as the maximum amount of oxygen that can be consumed per unit of time by a person during a progressive exercise test to exhaustion and may be expressed in absloute (l/min) or relative terms (ml/kg/min) (Thoden, Wilson and MacDougall, 1982).

Chapter II

Review of Literature

A. Prevalence of ECG Abnormalities

Electrocardiogram (ECG) abnormalities indicative of ischemia can be elicited during maximal exercise in relatively few asymptomatic normotensive individuals. However, among the individuals with ischemic ECG's there is increased incidence of coronary events (angina, myocardial infarction, and sudden death). In asymptomatic individuals the the demonstration of an abnormal ECG during or near maximal exercise identifies a group at greater risk of developing a clinical manifestation of CAD (Froelicher et al., 1974).

Froelicher and colleagues (1974) found a prevalence of ST-segment depression of 2.7 percent in healthy airforce personnel on a maximal treadmill test. In a study by Bruce and colleagues (1974) 28.3 percent of healthy men had ST-segment depression of 1mm or more 0.06 seconds after the J point during maximal treadmill testing. When only horizontal or downsloping ST-segment depression was examined the prevalence rate was reduced to 16.8 percent (Bruce et al., 1974).

Cumming and colleagues (1975) found that ST segment depression greater than 1mm occurred in 61 of 510 (12%) of asymptomatic men aged 40 to 65 years on a bicycle erogmeter exercise test. Clinical CAD developed in 24.6 percent of the men with an ischemic exercise ECG and in 2.4 percent of the individuals with normal exercise ECG responses (Cumming et al., 1975).

In a study by Erikssen and colleagues (1976) 85 of 2014 (4.2%) healthy males aged 40 to 59 years had a positive ECG test during cycling to 90 percent of the age predicted maximal heart rate. When angiographic tests were done on these 85 individuals with positive ECG responses it was found that 29 (34.1%) had normal coronary arteries, 15 (17.6%) had 1 vessel disease, 20 (23.5%) had 2 vessel disease and 21 (24.7%) had 3 vessel disease (Erikssen et al., 1976).

Bruce and colleagues (1980) studied 2,365 men without known CAD and found that 264 (11.1%) had ischemic ST-segment depression during maximal treadmill testing. The presence of one or more conventional risk factors (family history of CAD, resting systolic blood pressure greater than 140 mmHg, smoking and serum cholesterol greater than 140 mg/dl) and two or more exercise predictors identified 1 percent of healthy men with 33 times increased risk of CAD events in a 6 year period (Bruce et al., 1980).

Allen and colleagues (1980) completed a five year follow-up study on 888 asymptomatic men and women following a maximal treadmill test. The prevalence rate for ST-segment depression was 15.4 percent in males and 5.1 percent in females. CAD developed in 14 of 89 (15.7%) males and 1 of 16 (6.3%) females with an ischemic ST-segment response to exercise testing (Allen et al., 1980).

In a study by McHenry and colleagues (1981) 49 of 723 (6.8%) asymptomatic men aged 27 to 55 years showed ST-segment depression during maximal treadmill testing. The incidence rate of coronary events for these 49 subjects was 25 percent over a 3 year follow-up period (McHenry et al., 1981).

Giagnoni and colleagues (1983) reported that 184 of 10,723 (1.6%) subjects had horizontal or downsloping in the ST segment of 1mm or more during or after exericse testing on an initial screening test. Of these 184 initial abnormal ECG responses 135 had a second abnormal screening session. In a 6 year follow-up 15.6 percent of the individuals with an abnormal ST-segment had coronary events compared to 3.4 percent in the subjects with a negative exercise ECG result (Giagnoni et al., 1983).

In a recent study by Cumming and Langford (1984) ST-segment depression occurred in 26 percent of 169 asymptomatic males aged 45 to 72 years during treadmill testing. Five years later the treadmill test was repeated and ST-segment depression occurred in 38 percent of the subjects. Twenty-five percent of the subjects with ischemic ST-segment changes at test 1 were normal at test 2 and 26 percent of the subjects with a normal response at test 1 were abnormal at test 2 (Cumming and Langford, 1984).

Most of the studies discussed previously were conducted on men and the exercise stress test results for healthy women are slightly different. There are more false positive tests in women than in men and the reason for this is unclear (Sketch et al., 1975; Barolsky et al., 1979). Profant and colleagues (1972) found a prevalence of 33 percent for women on visual interpretation of the ECG data and this rate was reduced to 18 percent when the ECG analysis was completed by a computer. An age specific prevalence indicated that women in the fourth, fifth, sixth and seventh decades was 14, 31, 51 and 100 percent respectively (Profant et al., 1972). In this study by Profant and colleagues (1972) only two women had significant horizontal ST-segment depression and all other ischemic responses were of the upsloping variety. Cumming and colleagues (1973) in a similar study on women found an overall prevalence of 25 percent for ST-segment depression. This data was examined over different age groups and the prevalence of abnormal ECG results increased with increased age: 20-29 14%, 30-39 14%, 40-49 34%, 50-59 36% and 60 and over 33% (Cumming et al., 1973). Sheffield and colleagues (1978) found a lower prevalence among asymptomatic women, 6 of 95 (6%) women had ST-segment depression during or after exercise. Only 1 of the 6 women with ST-segment depression had a horizontal ST-segment the rest were upsloping (Sheffield et al., 1978). The mean age of the women with ST-segement depression was 52 years and only one was under 38 years (Sheffield et al., 1978). Bruce and colleagues (1980) reported a prevalence rate of 19.6 percent for ischemic ST-segment depression in 547 healthy women aged 23 to 72 years during maximal treadmill testing.

B. ST-Segment Criteria

Myocardial ischemia is the result of a reduced oxygen supply to the heart muscle due to artherosclerosis in the coronary arteries or to excessive hemodynamic stress on the heart or a combination of these two factors (Cooksey, Dunn, and Massey, 1977). With exercise the hemodynamic stress on the heart is increased and the chance of an ischemic response is increased. During ischemia there is a change in permeability of the myocardial cell membrane to potassium ions (K^{+}), depolarization is delayed, and the duration of repolarization is increased (Schamroth, 1975). These changes in the myocardial cells are represented as a depression in the ST-segment in the exercise ECG (Cooksey, Dunn, and Massey, 1977; Schamroth, 1975).

The most common criteria utilized to indicate myocardial ischemia is horizontal or downsloping ST-segment depression of 0.10 mV or greater 0.08 seconds after the J point (Froelicher et al., 1973; McHenry et al., 1981; Chaitman and Hanson, 1981; Lam and Chaitman, 1984). While others such as Erikssen and colleagues (1976) have included a ST-segment depression, regardless of ST-slope, that was 1.5 mV or greater below the isoelectric line 0.08 seconds after the J point in leads CH_5 to CH_7 or 1.0 mV below the ioselectric line in leads I, II, aVL, aVF, or V_5 to V_7. Erikssen and colleagues (1976) found no significant difference in the predictive value of the ST-segment criteria during exercise but post exercise results indicated that the slow ascending ST-segment had a lower predictive value in identifying CAD.

One of the limitations of using ECG responses in the the assessment of coronary heart disease is that an abnormal ECG response does not necessarily indicate the presence of coronary artery disease and that a normal ECG response does not rule out the possibility of coronary events (Froelicher et al. 1976; Cummings et al. 1975). Chaitman and Hanson (1981) support this viewpoint and state that in populations with low disease prevalence (asymptomatic subjects) the predictive accuracy of abnormal ECG criteria requires further study. One of the problems when comparing exercise lead systems is that researchers use different lead systems to analyze the ECG information, different exercise modes (bicycle verus treadmill), and recruit subjects by different methods. Therefore, the prevalence of ST-segment depression in an asymptomatic population will depend on: the definition of the asymptomatic population; the type and intensity of exercise performed; age of the population; country studied; ECG lead system; and the criteria for a positive test (Chaitman and Hanson, 1981). There is a large number of factors that can contribute to false a positve ECG test: valvular heart disease; congenitial heart disease; cardiomyopathies; pericardial disorders; drugs; electrolyte abnormalites; nonfasting state; anemia; bundle branch block; left ventricular hypertrophy; mitral valve prolapse; vasoregulatory abnormalities; hyperventilation repolarization abnormalities; and hypertension (Froelicher et al., 1976).

C. Risk Factors

There are numerous possible risk factors when considering CAD. For example, the incidence of CAD and the prevalence of abnormal ECG responses to treadmill testing is positively related to age (Froelicher et al. 1974; Erikssen et al., 1976; Bruce et al. 1980). In a study by Bruce and colleagues (1971) the prevalence of ST-segment depression increased from 0 to 19 percent with an increase in age from less than 30 to greater than 50 years. In a more recent paper by Bruce and colleagues (1980) a significantly greater ($p<0.05$) cardiac event rate was found for men split into two groups at the age of 55 years after a 5 year period (4.6 percent verus 1.5 percent). Froelicher and colleagues (1974) also found that the occurence of premature ventricular contractions (PVC) was positively related to age.

There are other risk factors that will also predispose an individual to an increased risk of CAD. Subjects with an abnormal initial exercise ECG in whom disorders developed were older, had a higher mean cholesterol level (Froelicher et al. 1974), a higher frequency of hypertension, positive family history, inactivity, low fitness level and smoking (Cummings et al. 1975; Giagnoni et al., 1983). Gilliam and colleagues (1977) indicated that hypertension, elevated blood lipids (serum cholesterol and triglycerides), cigarette smoking, obesity, ECG abnormalites at rest and exercise, family history of heart disease, diabetes, and inadequate physical activity were risk factors contibuting to coronary heart disease. All risk factors that have predictive value in detecting CAD should be used for screening individuals (Froelicher et al., 1974). Bruce and colleagues (1980) found that conventional risk factors as well as physical activity status and relative body weight were not reliably predictive. Exercise risk factors in combination with the conventional risk factors must be utilized to predict future coronary events (Bruce et al., 1983; Giagnoni et al., 1983).

Lam and Chaitman (1984) identified five ECG variables that have diagnostic value in the detection of CAD and these are: duration of ST-segment changes in the post-exercise period; the time that the ST-segment depression first appears; the rate-pressure product at the onset of ST segment depression; the sum of the ST-segment depression in all leads; the number of ECG leads that show depression. Bruce and colleagues (1980) found that the exercise risk factors with predictive value ($p<0.05$) were: duration of exercise less than 6 minutes; ischemic ST-segment depression; maximum heart rate less than 90 percent of the age predicted normal value; chest discomfort or pain on maximal exertion. Allen and colleagues (1980) found that for men over the age of 40 years the exercise factors that had a significant correlation between the development of coronary artery disease were: ST-segment criteria; an increase or no change in the R wave amplitude and an exercise duration of 5 minutes or less. An increase or no change in the R wave amplitude in lead CM5 or V5 immediately after exercise was thought to indicate severe CAD and left ventricular dysfunction (Bonoris et al., 1978). The use of R wave amplitude to detect the presence of CAD does not offer any more information than ST-segment depression (Fox et al., 1982) and R wave changes have been found to be related to heart rate (Wolthuis et al., 1979). According to McHenry and colleagues (1981) the variables with the best predictive value were downsloping ST-segment depression during exercise, a decrease in systolic blood pressure during exercise and negative U waves with exercise. Inverted or negative U waves may occassionally occur in the exercise ECG of patients with CAD or individuals with left ventricular hypertrohpy (Kishida et al., 1982). Other variables that have predictive value are a maximal systolic pressure of less than 140 mmHg (Irving et al., 1977) and a heart rate of 140 beats per minute or less at the onset of ST-segment depression (McHenry et al., 1981).

In females, age, relative overweight, systolic hypertension at rest (140 mmHg or greater) and serum cholesterol levels of 270 mg/100 ml or more was related to the prevalence of ST-segment depression (Profant et al., 1972). Allen and colleagues (1980) found that a positive maximal treadmill test by ST criteria did not correlate with subsequent development of coronary artery disease in women but an exercise duration of less than 3 minutes was of significant value. Sketch and colleagues (1975) found that the ability of ST-segment depression to correctly detect the presence of CAD to be 33 percent in women and thus a positive test is of little value but a negative test is useful in ruling out the presence of disease.

Physical inactivity is considered a risk factor for CAD (Morris et al., 1973; Hickey et al., 1975; Cooper et al., 1976; Montoye et al., 1980; Erikssen et al., 1981; Bruce et al., 1984). There is also an inverse relationship between the level of cardiorespiratory fitness and the conventional risk factors for CAD (Cooper et al., 1976). Hickey and colleagues (1975) found that the mean serum cholesterol, blood pressure, relative weight and number of cigarettes smoked tended to decrease with increased leisure activity but a similar trend was not evident for activity at the work place. The relationship between cigarette use and physical activity is controversial, some researchers have found no relationship (Morris et al., 1973; Montoye et al., 1981), while others have found an inverse relationship between cigarette use and physical activity (Hickey et al., 1975; Erikssen et al., 1981). The primary benefit of an increased level of physical fitness is an enhanced oxygen transport system and possible secondary benefits such as reduced resting heart rate, blood pressure and reduced incidence of of premature ventricular contractions (Bruce et al., 1984). Erikssen and colleagues (1981) found that systolic and diastolic blood pressure decreased with increased physical fitness, as did resting heart rate, but maximal systolic blood pressure during exercise was not related to physical fitness.

The early identification of individuals with a high risk of developing CAD will allow proper clinical diagnosis and risk factor intervention (Bruce et al., 1974; Froelicher et al., 1976; Bruce, 1983). Individuals with abnormal ECG responses can be encouraged to reduce the influence of known risk factors associated with clinical CAD (Cummings et al., 1975). By reducing identified risk factors, in particular smoking and a sedentary lifestyle, the clinical manifestations of CAD may be delayed (Bruce et al., 1983). Early detection is the key (Bruce et al., 1974) and the preventive measures adopted should strive for an extension and also an enhancement of the quality of life along the way (Fox et al., 1971).

D. Comparison of Exercise ECG Lead Systems

A 12 lead ECG or multiple lead ECG mapping is a non-invasive procedure that gives information concerning: the anatomical orientation of the heart; relative sizes of its chambers; a variety of disturbances of rhythm and of conduction; the extent, location and progress of ischemic damage to the myocardium; the effects of electrolyte concentrations; and the influence of drugs (Berne and Levy, 1981). When compared to a sinlgle lead ECG system, a multiple lead system or full 12 lead ECG gives additonal information and the sensitivity of the test is increased (Lam and Chaitman, 1984; Chaitman and Hanson, 1981; Simons and Block, 1981). The advantage of a bipolar exercise lead system is that they are relatively simple to record, produce less noise artifact, require less time to apply electrodes and are less expensive than the 12 lead ECG (Chaitman and Hanson, 1981). In low risk asymptomatic individuals a single lead ECG is adequate but if arrythmia detection is important a multiple lead system is required to locate the focus of the beat (Lam and Chaitman, 1984; Simons and Block, 1981).

There are many bipolar ECG leads used to analyze an exercise test. The selection of the optimal lead is controversial and will depend upon the purpose of the ECG recording (Chaitman and Hanson, 1981). Simoons and Block (1981) suggested that the selection of the exercise ECG lead system should be determined by the type of ST-segment depression expected in that population. Two important factors to consider in the selection of an exercise ECG lead system is the sensitivity and specificity of that lead system. Sensitivity is the ability to detect the percent of the population that have CAD with a positive test (true positive/true positive + false negative). Specificity is the ability to detect the percent of the population that do not have CAD with a negative test (true negative/true negative + false positive).

Common bipolar exercise lead systems in use are the CM_5, CC_5, CS_5, CR_5, CX_5, CB_5, and the CH_5 (figure 1). The two most commonly used exercise ECG lead systems are the CM_5 and the CC_5. Chaitman and colleagues (1979) compared the sensitivity and specificity of the CM_5 and CC_5 lead in a patient population and found the sensitivity to be 73 percent and 68 percent respectively. The specificity for the CM_5 lead was 75 percent and for the CC_5 it was 81 percent (Chaitman et al., 1979). Blackburn and colleagues (1967) compared the ability of various leads to detect 0.05 mV or greater of horizontal or downsloping ST segment in a patient population with CAD. The CM_5 detected ST segement depression in 63.6 percent of the patients, CH_5 59.1 percent, CC_5 40.9 percent, CB_5 9.1 percent, and CS_5 31.6 percent (Blackburn et al., 1967). Wolthuis and colleagues (1979) found that the leads CC_5, CM_5, V_5, Yh, and Z showed a similar ST-segment slope response in a low risk asymptomatic population. When comparing the CC_5 to the CM_5, the repolarization changes in the CC_5 are more closely related to the changes in the standard V_5 lead (Froelicher et al., 1976). The CM_5 lead produces a QRS complex greater in amplitude than the CC_5 or the V_5 lead (Lam and Chaitman, 1984; Wolthuis et al., 1979). Lam and Chaitman (1984) reviewed the selection of bipolar exercise ECG lead systems and suggested that because the CM_5 is associated with more false positive results the leads CC_5 or CB_5 should be used. Simoons and Block (1981) suggested that the two ECG lead systems with the greatest sensitivity for detecting exercise induced ischemia are the CS_5 or the CM_5 lead. The optimal exercise ECG lead system has not been identified and the criteria for detecting CAD in an asymptomatic population on the various ECG lead systems needs further assessment (Lam and Chaitman, 1984; Simoons and Block, 1981; Chaitman and Hanson, 1981; Froelicher et al., 1981).

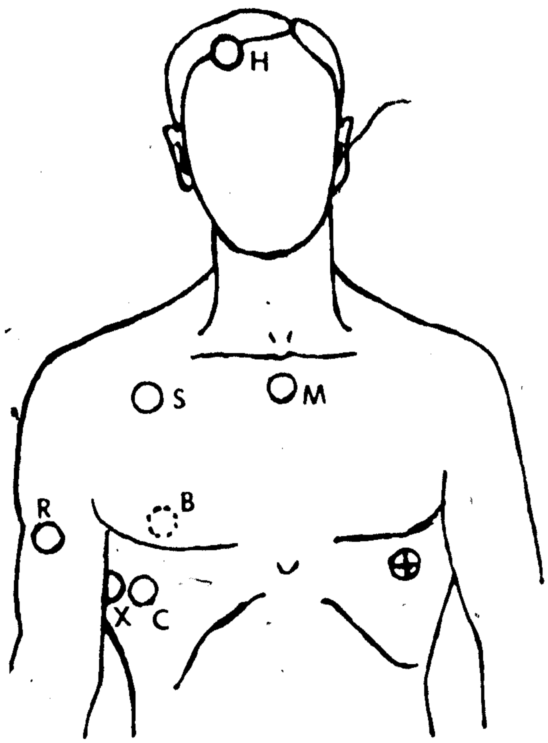


Figure 1. Negative references for the most commonly used bipolar ECG lead systems are illustrated with letters (CM_5, CC_5, CS_5, CH_5, CR_5, CX_5, and CB_5). The positive electrode is located in the V_5 position (adapted from Lam and Chaitman, 1984).

E. Submaximal Exercise Testing

Maximal oxygen consumption (VO_2max) is the most common reference of cardiorespiratory fitness. The direct measurement of VO_2max presents a problem in the average population since it exposes the individual to potential risk (Davies, 1968). The alternative procedure in the average population is to predict VO_2max from a submaximal exercise test. The major assumption of a submaximal exercise test is that there is a linear relationship between heart rate and oxygen consumption and that each individual can achieve a predetermined maximal heart rate for their age (Davies, 1968).

There has been a great deal of controversy to question the accuracy of the prediction of VO_2max from submaximal exercise tests (Davies, 1968; Kasch, 1984; Astrand and Rodahl, 1977). Astrand and Rodahl (1977) indicate four sources of error that will affect submaximal exercise test results: the assumption that a linear increase in heart rate corresponds to an increase in oxygen consumption does not hold true near maximal exercise; maximal heart rate declines with age and there is a standard deviation of maximal heart rate within any age group of ±10 beats per minute; mechanical effiency on a bicycle ergometer varies by ±6 percent; cardiac output is not strictly related to oxygen uptake and there is individual variation. Davies (1968) found that a linear relationship between heart rate and oxygen consumption does not exist and that an asymptotic curve occurs near maximal exercise causing an underestimation of VO_2max of 1,200 ml. Davies (1968) also found that when using the Astrand nomogram (1960) with heart rate values between 120-150 beats per minute the predicted VO_2max will be within ±1.22 l/min of the direct measurement. With higher heart rate values greater than 165 beats per minute the estimation of VO_2max was improved using the Astrand nomogram (Davies, 1968). Astrand (1960) found that the standard error of VO_2max was 10 percent in well trained individuals and 15 percent in moderately trained individuals. Kasch (1984) found that the Astrand age-corrected nomogram underpredicted VO_2max by 21 percent in healthy subjects and Sidney (1977) found a coefficient of variation of 20 percent in elderly male and female subjects on the same test. The VO_2max of untrained individuals is often underestimated and the VO_2max of extremely well trained athletes is overestimated during submaximal testing (Astrand and Rodahl, 1977). A submaximal test cannot replace a maximal treadmill test for the measurement of work capacity but repeated submaximal tests are useful in monitoring a training program or motivating an individual to continue a training program (Astrand and Rodahl, 1977).

The best method of determining heart rate is by the use of an ECG. Jette and colleagues (1976) found a systematic difference of 7.0±5,6 beats per minute when comparing heart rates measured by ECG (154.1± 22.2 beats per minute) and by palpation (147.0±20.2 beats per minute). Bonen and colleagues (1977) examined heart rates measured by ECG and palpation and found a mean error of 3.0± 12.1 beats per minute at a heart rate of 128.6±16.6 beats per minute and a mean error of 8.5±9.0 beats per minute at a heart rate of 147.4±20.2 beats per minute. Shephard (1980) found a correlation of 0.76 between heart rate measured by ECG and when an individual measured a partners pulse by palpation. A more expensive method of determining heart rate is by the use of a microcomputer (eg. sport tester). Karvonen and colleagues (1984) compared the heart rate measured by a microcomputer and an ECG and found that values differed at the most by 5 beats per minute. Karvonen (1984) concluded that the microcomputer was an appropriate device for measuring exercise heart rates. The use of a heart rate monitor is a necessity for accurate heart rate determination and it would be ideal to have an ECG tracing for the measurement of heart rate during an exercise test.

Chapter III

Methodology

A. Sample

The subjects for this project were 165 clients who had presented themselves for a Fitness and Life Style Appraisal at the University of Alberta Fitness Unit and had been categorized into a low and high fitness group on a submaximal cardiovascular test. From december 1983 to november 1984, 108 clients were classified into the 0-30 percentile group, 82 accepted further assessment at the University of Alberta Cardiac Rehabilation Exercise Laboratory of which 75 were actually tested. During this same time period 152 clients were classified into the 70-100 percentile, 112 volunteered for further assessment, of which 103 were tested. These numbers were reduced in the final assessment to 72 in the 0-30 percentile group and 93 in the 70-100 percentile group due to individuals not meeting the subject criteria.

B. Procedures

Fitness Unit

All subjects in this study completed a PAR-Q exercise readiness questionnaire (1978). This questionnaire indicated that the subjects were free of any known illness prior to the fitness test (appendix A). Each subject underwent a general test of fitness, which involved the measurement of skinfolds for body composition, height, weight, cardiovascular fitness, grip strength, forward trunk flexion, sit-ups, and push-ups. The percent body fat was determined from the measurement of the sub-scapular, tricep, bicep and supra-iliac skinfold sites using the formula of Durnin and Wormersley (1974). The test of cardiovascular fitness utilized in this study was an eight minute submaximal bicycle ergometer test, modified Astrand bicycle test (1960). All subjects were tested on constant work load Quinton bicycle ergometers (Model 845) at a speed between 50 and 60 rpm. The test consisted of two 4 minute exercise stages. The initial work load is set at 65 Watts for males and 50 Watts for female and elderly subjects. The second work load is set at an intensity that achieves a heart rate between 200 minus the client's age and 170 minus the client's age. Maximal oxygen consumption is predicted from the mean heart rate during the last two minutes of exercise and corrected for age. Heart rate and blood pressure are recorded at rest, the fourth, seventh and eighth minute of exercise and at the third minute of a 3 minute recovery period. Heart rate was determined by palpation of the radial pulse or by use of a heart rate recorder (exersentry or sport tester). Blood pressure was measured with a Tycos aneroid blood pressure cuff. All exercise testers in the fitness centre were registered fitness appraisers. The subjects were classified into a low fitness group if their predicted maximal oxygen consumption was in the 0-30 percentile for their age and sex (n=72) and into a high fitness group if their oxygen consumption was in the 70-100 percentile (n=93) on the Swedish norms established by Astrand (1954).

Exercise Stress Laboratory

At the Exercise Stress Laboratory each subject underwent a comprehensive personal medical history questionnaire which included family history of heart disease (myocardial infarction and angina), hypertension, stroke and diabetes. Also included in the questionnaire were smoking, alcohol, and physical activity habits (appendix C). Physical activity status of the subjects were categorized as sedentary (non-active), minimally active (1-2 times per week), active (3 times per week) and very active (4 times or more a week). All subjects received a physical examination by a physician prior to the maximal treadmill test. The subjects also underwent a 12 lead ECG using a Marquette Case computer assisted ECG recorder and analyzer. One hundred and three subjects were tested using a Marquette Case I ECG analyzer and 62 subjects were tested using a Marquette Case II ECG recording system. The Marquette Case I ECG analyzer gives a 3 lead summary (leads V_1, V_5, and aVF) at 3 minute intervals. The Marquette Case II ECG analyzer gives a minute by minute summary of all ECG leads ing and after the exercise test. The increased information that the Case II ECG analyzer gives may cause a higher prevalence of positive ECG tests.

The 12 lead ECG electrode placement was that described by Mason and Likar (1967) and is illustrated in figure 2. The arm electrodes were placed in the infraclavicular fossal medial to the border of the deltoid muscle and the left leg electrode in the anterior axillary line, halfway between the costal margin and iliac crest. The ground was placed in the right anterior axillary line at the same level as the left leg electrode. The six precordial leads were placed in their standard location. The electode sites were prepared by rubbing the skin with a rough stone.

A resting heart rate, blood pressure and a resting ECG were recorded with the subject resting in a chair. Systolic blood pressure was recorded as the first audible sound and the diastolic pressure as the phase IV sound. A mercury filled Baumanometer was used to measure the blood pressure. The subject then underwent a standardized Bruce treadmill test (Bruce, 1971). This test involves walking for 3 minutes at 1.7 mph and at a 10% grade; speed and grade are increased every 3 minutes in a continuous manner as described in Table 1. The subjects were exercised to a target heart rate of 90% of the age predicted maximal heart rate and were encouraged to exercise as long as possible. Predicted VO_2max was determined from the total exercise time. The exercise stage completed was assessed from the last stage of exercise that the subject completed 2 minutes of work. The subjects were encouraged to use the handrail on the treadmill only as a guide and not as a support. Exercise was terminated once the target heart rate had been achieved or if any of the following abnormalities occurred: chest pain; severe exhaustion; abnormal blood pressure response; abnormal heart rate response; or significant arrythmias.

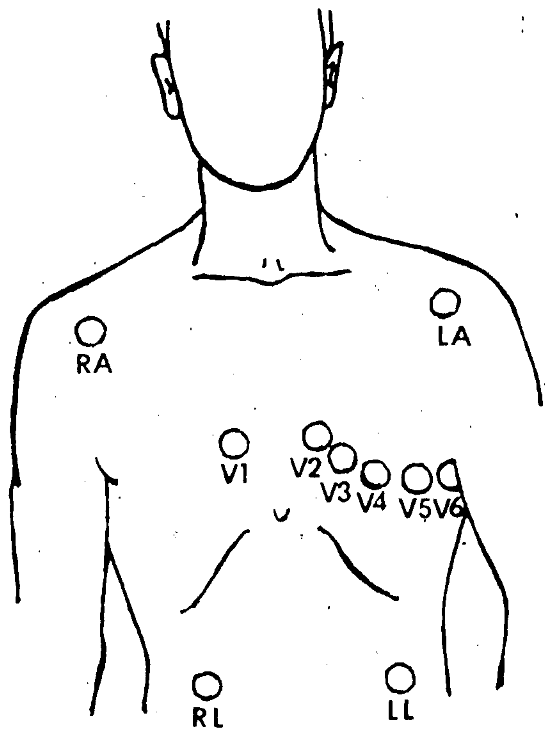


Figure 2. The Mason-Likar system for recording the exercise electrocardiogram. Placement of electrodes is as illustrated (adapted from Chaitman and Hanson, 1981).

Table 1

Bruce Treadmill Protocol

Stage	Speed (mph)	Grade (%)	Duration (min)	VO (ml/kg/min)
I	1.7	10	3	18
II	2.5	12	3	25
III	3.4	14	3	34
IV	4.2	16	3	46
V	5.0	18	3	55
VI	5.5	20	3	

Heart rate and ST segment depression were recorded every minute during the exercise test and each minute of a five minute resting recovery. The ECG was recorded at rest, maximal exercise, immediately post exercise and five minutes post exercise. Blood pressure was measured during the third minute of each stage of the exercise test, immediately post exeriese and at the fourth minute of recovery. Occassionally the blood pressure could not be measured during near maximal exercise and in these instances it was measured immediately post exercise. The resting blood pressure was categorized as hypertensive if the systolic pressure was greater than 145 mmHg or if the diastolic pressure was greater than 90 mmHg. The exercise blood pressure was categorized as hypertensive if the systolic pressure was greater than 210 mmHg during the first stage of the treadmill test or greater than 220 mmHg at any time during or after exercise. An abnormal blood pressure response was recorded if the systolic blood pressure failed to rise above resting values during exercise or if there was fall in the systolic pressure of 10 mmHg or greater with an increased exercise intensity. The criteria for an abnormal exercise test was 0.10 mV (1mm) or greater of horizontal or downsloping ST-segment depression 0.08 seconds after the J point in any of the leads. To reduce the chance of a false positive test: the clients with bundle branch block in the resting ECG or left ventricular hypertrohpy, as indicated by voltage criteria in the resting ECG (Dubin, 1974), were eliminated from the final assessment of the exercise ECG. Sixty subjects underwent a resting ECG following forty-five seconds to 1 minute of hyperventilation to determine labile ST segment and T wave changes. Subjects with labile ST segment and T wave changes were not included as positive tests. The R wave amplitude in lead V_5 during exercise was categorized as having no change, an increase, decrease, "U" shaped or inverted "U" shaped compared to the R wave amplitude at rest. An increase or decrease of 0.10 mV was the criteria for recording a change in the R wave amplitude and was assessed by visual interpretation. The subjects were asked to return for a standardized resting ECG that was analyzed by a cardiologist and a 10-12 hour fasting blood sample in which serum cholesterol, triglycerides, glucose and lipid ratios were measured. The conventional risk factors: smoking; alcohol; family history of heart disease, diabetes, hypertension, stroke; and blood lipid analysis.

were not included in this study.

The results were initially entered into a computer data base at the University of Alberta Hospital and then re-entered into the University of Alberta MTS computer system for analysis with a Statistical Package for the Social Sciences (SPSSx). Descriptive statistics, student's t-test and chi square analysis were utilized to interpret the data. A discriminant function analysis (step-wise method) was used to identify which combination of variables would give the best prediction of group membership for ST-segment and no ST-segment depression.

Chapter IV

Results and Discussion

A. Results

Comparison of Fitness Groups

Male Clients

The characteristics of the male clients in the low (0-30 percentile; $n=62$) and high fitness group (70-100 percentile; $n=56$) are presented in Table 2. The high fitness group was younger ($p<0.001$), weighed less ($p<0.001$) and had a significantly lower percent body fat ($p<0.001$). The selection of clients for this study was determined from the fitness percentile ranking on the Astrand submaximal bicycle test and therefore a significant difference between fitness groups was expected for VO_2max as predicted by the Astrand test ($p<0.001$) and VO_2max predicted on the Bruce treadmill test ($p<0.001$). Mean values for height, resting systolic and diastolic blood pressure were not significantly different ($p>0.05$) between the two fitness groups. The highest systolic blood pressure measured during the Bruce test was higher in the high fitness group, 191.4 ± 19.9 mmHg compared to 184.6 ± 18.1 mmHg, but the difference was not statistically significant ($p>0.05$). The resting heart rates were lower ($p<0.001$) for the high fitness group. The high fitness group reached a slightly higher final heart rate on the Bruce test than the low fitness group, 169.8 ± 11.1 verus 166.0 ± 12.3 bts/min, but this difference was not significant ($p>0.05$). The percent of the age predicted maximal heart rate achieved during the Bruce test was slightly higher for the low fitness group ($p<0.01$). The total exercise time and the number of 3 minute exercise stages completed on the Bruce protocol were significantly lower for the low fitness group ($p<0.001$). This is reflected in the lower VO_2max scores for the low fitness group on the Bruce test.

Table 2

Characteristics of Male Clients

Factor	0-30%ile Group	70-100%ile Group
N	62	56
Age (yrs)	41.7 ± 10.8	33.5 ± 8.9***
Ht (cm)	177.2 ± 6.1	178.2 ± 6.2
Wt (Kg)	82.4 ± 11.5	74.4 ± 7.6***
BF (%)	25.7 ± 5.1	18.3 ± 5.7***
VO_2FU (ml/kg/min)	31.1 ± 6.7	55.7 ± 7.9***
VO_2FU (l/min)	2.53 ± 0.59	4.13 ± 0.61***
VO_2TM (ml/kg/min)	40.9 ± 9.4	54.0 ± 8.3***
VO_2TM (l/min)	3.36 ± 0.84	4.01 ± 0.66***
RtSBP (mmHg)	124.9 ± 12.5	123.8 ± 15.3
RtDBP (mmHg)	82.6 ± 8.8	81.8 ± 9.5
RtHR (bts/min)	72.9 ± 11.4	62.6 ± 10.2***
Bruce Stage	3.5 ± 0.9	4.9 ± 0.9***
HRmax (bts/min)	166.0 ± 12.3	169.8 ± 11.1
Percent HRmax	92.6 ± 4.7	90.9 ± 4.4*
Exercise SBP	184.6 ± 18.1	191.4 ± 19.9
Total Exer Time (min)	10.6 ± 2.6	14.5 ± 2.6***

Values = Mean ± S.D.
BF = Body Fat; VO_2FU = Astrand Predicted VO_2max; VO_2TM = Bruce Predicted VO_2max; Fit%ile = Astrand Fitness Percentile; RtSBP = Resting Systolic Blood Pressure; RtDBP = Resting Diastolic Blood Pressure; RtHR = Resting Heart Rate; HRmax = Maximum Heart Rate; Exercise SBP = Exercise Systolic Blood Pressure; Total Exer Time = Total Exercise Time on Bruce Protocol;
* $p<0.05$ ** $p<0.01$ *** $p<0.001$

Female Clients

Table 3 illustrates the data for female clients in the low fitness group (n = 10) and the high fitness group (n = 37) on the same variables that were presented in Table 2. The sample size of the two groups are quite different and with the small number of subjects in the low fitness group the differences must be interpreted with caution. The results for the female clients in the low and high fitness groups are similar to that of the male clients. The females in the high fitness group are younger ($p<0.01$), have a lower total body mass ($p<0.001$) and a lower percent body fat ($p<0.001$) than the low fitness group. The VO_2max as predicted on the Astrand test and the VO_2max on the Bruce test are significantly different between the two groups ($p<0.001$). Resting systolic and diastolic blood pressure were significantly lower for the high fitness group ($p<0.001$). The high fitness group of female clients had a longer exercise time on the treadmill ($p<0.001$) and completed a greater number of 3 minute stages on the Bruce protocol ($p<0.001$). Height, maximum heart rate achieved on the treadmill, percent of the age predicted maximum heart rate and the highest systolic blood pressure during the Bruce test were not found to be different for the two fitness groups ($p>0.05$).

Table 3

Characteristics of Female Clients

Factor	0-30%ile Group	70-100%ile Group
N	10	37
Age (yrs)	43.0±9.4	31.6±9.6**
Ht (cm)	166.0±7.5	165.5±16.4
Wt (Kg)	75.5±20.9	58.3±7.3***
BF (%)	35.1±6.5	27.4±5.0***
VO_2FU (ml/kg/min)	26.9±6.0	53.2±10.6***
VO_2FU (l/min>	1.48±0.52	3.08±0.62***
VO_2TM (ml/kg/min)	29.6±10.2	46.3±8.7***
VO_2TM (l/min>	2.15±0.66	2.69±0.53**
RtSBP(mmHg)	127.5±12.7	109.9±11.9***
RtDBP(mmHg)	83.5±6.3	73.9±9.9**
RtHR(bts/min)	77.9±13.9	68.0±10.1*
Bruce Stage	2.4±1.2	4.1±0.8***
HRmax (bts/min)	164.7±17.3	171.2±10.7
Percent HRmax	92.6±5.2	90.6±4.4
Exercise SBP	165.2±16.9	159.7±14.5
Total Exer Time(min)	6.9±2.9	12.0±2.3***

Values = Mean±S.D.
BF=Body Fat; VO_2FU=Astrand Predicted VO_2max; VO_2TM=Bruce Predicted VO_2max; Fit%ile=Astrand Fitness Percentile; RtSBP=Resting Systolic Blood Pressure; RtDBP=Resting Diastolic Blood Pressure; RtHR=Resting Heart Rate; HRmax=Maximum Heart Rate; Exercise SBP=Exercise Systolic Blood Pressure; Total Exer Time=Total Exercise Time on Bruce Protocol
* $p<0.05$ ** $p<0.01$ *** $p<0.001$

Categorized Variables and Fitness Group

Male Clients

Various risk factors were separated into categorizes and then analyzed using a Chi square test. Results for the male clients in the two fitness groups are presented in Table 4. Resting blood pressure rated as being hypertensive (systolic>145 mmHg; diastolic>90 mmHg) was not related to to the fitness group of the clients ($p>0.05$). There were very few clients in either group who had a resting ECG rated as being outside the normal limits, 11.3 percent in the low fitness group and 17.9 percent in the high fitness group. There was no relationship between the classification of the resting ECG and the fitness group of the client ($p>0.05$). There was a significant relationship ($p>0.05$) between the exercise systolic blood pressure rated as being hypertensive (systolic > 220 mmHg) and the fitness group of the clients. Eight clients in the high fitness group (14.3 %) were rated as having a hypertensive exercise response compared to only 1 client in the low fitness group (1.6 %). There was only one client in the high fitness group with a blood pressure rated as being abnormal. There was no relationship between ST-segment depression and fitness group ($p>0.05$). Nine clients in the high fitness group (16.1 %) and 9 clients in the low fitness group (14.5 %) had 0.10 mV horizontal or downsloping ST-segment depression 0.08 seconds after the J-point with exercise. In this study there was no relationship between fitness group and the incidence of PVC's (multiform or couplets) or PAC's. There was a significant relationship between the fitness group of the client and low exercise tolerance on the Bruce test ($p<0.05$). There were 6 clients in the low fitness group (9.7 %) that could not complete 6 minutes of exercise on the treadmill compared to none in the high fitness group. The classification of the R wave amplitude in lead V_5 during exercise was not related to the fitness group. Similar patterns for R wave amplitude changes were observed in both fitness groups. The most common changes in R wave amplitude were no change, an increase or an inverted "U" shape. A decrease in the R wave amplitude or a "U" shaped classification were less common. As should have been expected more clients in the low fitness group had their physical activity habits classified as sedentary and minimally active (2 times per week) and more clients in the high fitness group as active 3 times per week and 4 times per week ($p<0.001$).

Female Clients

Table 5 contains the results for female clients in the two fitness groups for the same categorized variables presented in Table 4. There was no relationship for fitness group and resting blood pressure, resting ECG or exercise blood pressure classification ($p>0.05$). There were no female clients rated as having a hypertensive blood pressure but there was 1 client in the high fitness group (2.7%) rated as having an abnormal blood pressure response. There were 2 clients in the low fitness group (20%) and 10 clients in the high fitness group (27.0%) that had ST-segment depression with exercise ($p>0.05$). The occurence of PVC's and PAC's were not related to the fitness group of the clients ($p>0.05$). Changes in the R wave amplitude during exercise was not related to the fitness group of the female clients ($p>0.05$). The most common changes were no change and a decrease in the R wave amplitude. A "U" shaped pattern was the least common change observed in the R wave amplitude. Low exercise tolerance on the Bruce protocol was related to the fitness group of the client ($p<0.001$). Five clients in the low fitness group (50%) could not complete 6 minutes on the Bruce protocol compared to none in the high fitness group. Physical activity status as rated from the response to the medical history questionnaire was related to the fitness group of the client ($p<0.001$). One hundred percent of the females in the low fitness group were rated as active 2 times or less per week and 75.7 percent of the clients in the high fitness group were active 3 or more times per week.

Table 4

Categorized Variables and Fitness Group for Male Clients

Risk Factor	Group			
	Low no.	%	High no.	%
N	62	52.5%	56	47.5%
Resting B.P. (>145/>90mmHg)	9	14.5%	8	14.3%
Abnormal Resting ECG	7	11.3%	10	17.9%
Exercise B.P.				
SBP>220mmHg	1	1.6%	8	14.3%*
Abnormal	0	0.0%	1	1.8%
Exercise ECG (1mm Horizontal Dep.)	9	14.5%	9	16.1%
PVC	6	9.7%	7	12.5%
PAC	5	8.1%	4	7.1%
R Wave Amplitude				
No Change	19	30.6%	12	21.4%
Increase	24	38.7%	16	28.6%
Decrease	6	9.7%	11	19.6%
"U" Shape	1	1.6%	1	1.8%
Inverted "U" Shape	12	19.4%	16	28.6%
Low Exercise Tolerance	6	9.7%	0	0%*
Activity Rating				
Sedentary	24	38.7%	4	7.1%
Active 2x/wk	17	27.4%	4	7.1%
Active 3x/wk	19	30.6%	29	51.8%
Active 4x/wk	2	3.2%	19	33.9%***

* $p < 0.05$
** $p < 0.01$
*** $p < 0.001$
PVC=Premature Ventricular Contractions (Multiform or Consecutive); PAC=Premature Atrial Contractions

Table 5

Categorized Variables and Fitness Group for Female Clients

Risk Factor	Group			
	Low no.	%	High no.	%
N	10	21.3%	37	78.7%
Resting B.P. (>145/>90mmHg)	2	20.0%	1	2.7%
Abnormal Resting ECG	0	0.0%	2	5.4%
Exercise B.P.				
SBP>220mmHg	0	0.0%	0	0.0%
Abnormal	0	0.0%	1	2.7%
Exercise ECG (1mm Horizontal Dep.)	2	20.0%	10	27.0%
PVC	2	20.0%	3	8.1%
PAC	1	10.0%	1	2.7%
R Wave Amplitude				
No Change	5	50.0%	16	43.2%
Increase	3	30.0%	3	8.1%
Decrease	1	10.0%	14	37.8%
"U" Shape	0	0.0%	1	2.7%
Inverted "U" Shape	1	10.0%	3	8.1%
Low Exercise Tolerance	5	50.0%	0	0%***
Activity Rating				
Sedentary	4	40.0%	3	8.1%
Active 2x/wk	6	60.0%	6	16.2%
Active 3x/wk	0	0.0%	24	64.9%
Active 4x/wk	0	0.0%	4	10.8%***

* $p < 0.05$
** $p < 0.01$
*** $p < 0.001$
PVC=Premature Ventricular Contractions (Multiform or Consecutive); PAC=Premature Atrial Contractions

Comparison of Clients With and Without ST-Segment Depression

Male Clients

There were 18 of 118 (15.3%) male clients with horizontal or downsloping ST-segment depression of 0.10 mV or greater during or after exercise. The group of clients that showed ST-segment depression were older, had a greater percent body fat, had a lower predicted VO_2max on the Bruce test expressed as an absolute value (l/min) and relative to body weight (ml/kg/min), had a lower exercise time, and a lower final heart rate on the Bruce protocol ($p<0.05$; Table 6). All other variables were not significant at the 0.05 level.

Nine of the 18 (50%) clients had ST-segment depression in the inferior leads (II, III, aVF) and 9 (50%) had ST-segment depression in the lateral leads (V_4-V_5). The mean heart rate at the occurence of ST-segment depression was 152.2±11.4 beats per minute (mean±S.D.). This resulted in a mean of 85.9±6.3 percent for the age predicted maximum heart rate.

Female Clients

Twelve of 47 (25.5%) female clients had ST-segment depression during or after exercise (Table 7). The female clients with ST-segment depression were taller, had a lower percent body fat, and had a lower resting heart rate ($p<0.05$). All other variables tested were not significantly different between the two groups.

Seven of the 12 (58.3%) female clients had ST-segment depression in the inferior leads and 5 (41.7%) had ST-segment depression in the lateral leads. The mean heart rate at the occurence of of ST-segment depression was 159.6±12.4 beats per minute (mean±SD). The percent of the age predicted maximum heart rate at the occurence of ST-segment depression was 84.9±6.2 percent (mean±SD).

Table 6

No ST-Segment Depression vs ST-Segment Depression in Male Clients

Factor	No ST Depression	ST Depression
N	100	18
Age (yrs)	36.9 ± 10.8	42.8 ± 9.1*
Ht (cm)	177.6 ± 6.2	178.3 ± 6.1
Wt (Kg)	78.1 ± 10.7	81.2 ± 9.8
BF (%)	21.5 ± 6.6	25.2 ± 5.5*
VO_2FU (ml/kg/min)	42.8 ± 14.3	42.7 ± 15.0
VO_2FU (l/min)	3.27 ± 0.98	3.42 ± 1.12
VO_2TM (ml/kg/min)	48.2 ± 10.8	41.0 ± 10.7**
VO_2TM (l/min)	3.73 ± 0.81	3.29 ± 0.80*
Fit%ile	50.0 ± 38.2	51.1 ± 38.4
RtSBP (mmHg)	124.3 ± 13.9	124.8 ± 13.9
RtDBP (mmHg)	81.7 ± 8.7	85.4 ± 10.7
RtHR (bts/min)	68.1 ± 12.4	67.7 ± 9.9
Bruce Stage	4.3 ± 1.1	3.6 ± 1.2**
HRmax (bts/min)	169.1 ± 11.6	160.5 ± 10.7**
Percent HRmax	92.0 ± 4.5	90.6 ± 5.1
Exercise SBP	187.3 ± 18.9	190.7 ± 21.4
Total Exer Time(min)	12.7 ± 3.1	10.9 ± 3.4*

Values = Mean ± S.D.
BF = Body Fat; VO_2FU = Astrand Predicted VO_2max; VO_2TM = Bruce Predicted VO_2max; Fit%ile = Astrand Fitness Percentile; RtSBP = Resting Systolic Blood Pressure; RtDBP = Resting Diastolic Blood Pressure; RtHR = Resting Heart Rate; HRmax = Maximum Heart Rate; Exercise SBP = Exercise Systolic Blood Pressure; Total Exer Time = Total Exercise Time on Bruce Protocol
* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

Table 7

No ST-Segment Depression vs ST-Segment Depression in Female Clients

Factor	No ST Depression	ST Depression
N	35	12
Age (yrs)	35.0±11.7	31.3±6.0
Ht (cm)	163.0±7.5	173.1±26.0*
Wt (Kg)	63.9±14.3	56.4±8.4
BF (%)	30.3±6.3	25.3±4.7*
VO_2FU (ml/kg/min)	46.0±14.7	52.4±14.0
VO_2FU (l/min)	2.82±0.76	2.93±0.76
VO_2TM (ml/kg/min)	41.9±11.8	45.4±9.9
VO_2TM (l/min)	2.59±0.63	2.53±0.50
Fit%ile	70.3±33.7	78.3±20.2
RtSBP (mmHg)	115.4±14.4	108.4±11.7
RtDBP (mmHg)	76.5±10.2	74.3±9.8
RtHR (bts/min)	72.3±11.5	63.6±9.6*
Bruce Stage	3.6±1.2	3.9±0.8
HRmax (bts/min)	170.1±12.8	168.9±12.0
Percent HRmax	91.5±4.0	89.5±5.9
Exercise SBP	161.7±15.0	158.5±15.4
Total Exer Time(min)	10.6±3.4	11.8±2.3

Values = Mean±S.D.
BF=Body Fat; VO_2FU=Astrand Predicted VO_2max; VO_2TM=Bruce Predicted VO_2max; Fit%ile=Astrand Fitness Percentile; RtSBP=Resting Systolic Blood Pressure; RtDBP=Resting Diastolic Blood Pressure; RtHR=Resting Heart Rate; HRmax=Maximum Heart Rate; Exercise SBP=Exercise Systolic Blood Pressure; Total Exer Time=Total Exercise Time on Bruce Protocol
* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

Categorized Variables and ST-Segment Response

Male Clients

The categorized variables for the male clients with ST-segment depression and the male clients with no ST-segment depression are presented in Table 8. There were no significant relationships found for any of the variables ($p>0.05$). The percentage of male clients that were rated as having an elevated resting blood pressure was slightly greater (22.2% vs 13.0%) for the group with ST-segment depression. The percentage of clients in the ST-segment depression group that rated their activity level as sedentary was slightly greater (38.9 percent compared to 21.0 percent) than the group with no ST-segment depression. Only 5.6 percent of the clients with ST-segment depression rated their activity as four or more times per week compared to 20.0 percent in the group with no ST-segment depression.

Female Clients

The categorized variables for the female clients with ST-segment depression and the female clients with no ST-segment depression are presented in Table 9. There were no significant relationships between any of the variables and the female clients group by ST-segment response ($p>0.05$). There was a slightly greater percentage of female clients in the group with no ST-segment depression that had a resting blood pressure rated as hypertensive (8.6 percent compared to 0.0 percent). Five of the female clients who had a low exercise tolerance on the tradmill were in the group with no ST-segment depression.

Table 8

Categorized Variables and ST-Segment Response for Male Clients

Risk Factor	Group			
	ST-Segment Depression no.	%	No ST Depression no.	%
N	18	15.3%	100	84.7%
Resting B.P. (>145/>90mmHg)	4	22.2%	13	13.0%
Abnormal Resting ECG	3	16.7%	14	14.0%
Exercise B.P.				
SBP>220mmHg	2	11.1%	7	7.0%
Abnormal	0	0.0%	1	1.0%
PVC	2	11.1%	11	11.0%
PAC	2	11.1%	7	7.0%
R Wave Amplitude				
No Change	7	38.9%	24	24.0%
Increase	4	22.2%	36	36.0%
Decrease	2	11.1%	14	14.0%
"U" Shape	0	0%	2	2.0%
Inverted "U" Shape	5	27.8%	23	23.0%
Low Exercise Tolerance	1	5.6%	5	5.0%
Activity Rating				
Sedentary	7	38.9%	21	21.0%
Active 2x/wk	2	11.1%	19	19.0%
Active 3x/wk	8	44.4%	40	40.0%
Active 4x/wk	1	5.6%	20	20.0%

* $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$
PVC=Premature Ventricular Contractions (Multiform or Consecutive);
PAC=Premature Atrial Contractions

Table 9

Categorized Variables and ST-Segment Response For Female Clients

Risk Factor	Group			
	ST-Segment Depression no.	%	No ST Depression no.	%
N	12	25.5%	35	74.5%
Resting B.P. (>145/>90mmHg)	0	0.0%	3	8.6%
Abnormal Resting ECG	0	0.0%	2	5.7%
Exercise B.P.				
SBP>220mmHg	0	0.0%	0	0.0%
Abnormal	1	8.3%	0	0.0%
PVC	1	8.3%	4	11.4%
PAC	1	8.3%	1	2.9%
R Wave Amplitude				
No Change	4	33.3%	17	48.6%
Increase	0	0.0%	6	17.1%
Decrease	6	50.0%	9	25.7%
"U" Shape	0	0%	1	2.9%
Inverted "U" Shape	2	16.7%	2	5.7%
Low Exercise Tolerance	0	0.0%	5	14.3%
Activity Rating				
Sedentary	1	8.3%	6	17.1%
Active 2x/wk	3	25.0%	9	25.7%
Active 3x/wk	7	58.3%	17	48.6%
Active 4x/wk	1	8.3%	3	8.6%

* $p < 0.05$
** $p < 0.01$
*** $p < 0.001$
PVC=Premature Ventricular Contractions (Multiform or Consecutive); PAC=Premature Atrial Contractions

Correlations Among Variables

Male Clients

Pearson product moment correlations were calculated on a large number of the variables in this study. The male and female clients were anlalyzed separately. With the large sample size a low correlation could be found to be significant. Variables were selected on an *a priori* basis and will be presented in this section.

The correlation matrix for the male clients can be found in Table 10. For the male clients age was positively correlated with body fat ($r=0.69$) and negatively correlated with the predicted VO_2max on the Astrand test ($r= -0.63$) and the Bruce test ($r= -0.65$), maximum heart rate ($r= -0.67$) and total exercise time on the Bruce test ($r= -0.70$). Body weight and percent body fat were positively correlated ($r=0.53$). Percent body fat was negatively correlated with the predicted VO_2max on the Astrand ($r= -0.73$) and Bruce test ($r= -0.67$), fitness percentile on the Astrand test ($r= -0.58$), maximum heart rate on the Bruce test ($r= -0.50$) and total exercise time on the treadmill ($r= -0.69$). The predicted VO_2max on the Astrand test was positively correlated to the predicted VO_2max score on the Bruce test ($r=0.72$), physical activity rating ($r=0.53$) and total exercise time on the treadmill ($r=0.74$). Predicted VO_2max on the Bruce test was positively correlated with the fitness percentile on the Astrand test ($r=0.63$), and physical activity rating ($r=0.56$). The fitness percentile on the Astrand test was positively related to the physical activity rating of the male clients ($r=0.57$) and total exercise time on the treadmill ($r=0.63$). The clients reported activity status was positively correlated with total exercise time on the treadmill ($r=0.51$). Resting systolic blood pressure was related to the resting diastolic blood pressure ($r=0.54$).

Table 10

Correlation Between Variables for Male Clients

	Age	Ht	Wt	BF	VO2FU	VO2TM	Fit	Act	RtSBP	RtDBP	RtHR	HRmax	PmaxHR	TexerT	FxSBP
Age	1.0000 p =														
Ht	.1609 p = 0.082	1.0000 p =													
Wt	.2288 p = 0.013	.4461 p = 0.000	1.0000 p =												
BF	.6909 p = 0.000	.0531 p = 0.574	.5258 p = 0.000	1.0000 p =											
VO2FU	.6342 p = 0.000	.0723 p = 0.437	.4300 p = 0.000	.7297 p = 0.000	1.0000 p =										
VO2TM	.6506 p = 0.000	.0737 p = 0.428	.3539 p = 0.000	.6718 p = 0.000	.7217 p = 0.000	1.0000 p =									
Fit	.3918 p = 0.000	.0702 p = 0.450	.4059 p = 0.000	.5778 p = 0.000	.9089 p = 0.000	.6294 p = 0.000	1.0000 p =								
Act	.2280 p = 0.013	.0727 p = 0.434	.2167 p = 0.018	.4416 p = 0.000	.5341 p = 0.000	.5557 p = 0.000	.5693 p = 0.000	1.0000 p =							
RtSBP	.0373 p = 0.686	.0406 p = 0.662	.1229 p = 0.185	.0270 p = 0.776	-.0537 p = 0.564	-.0759 p = 0.414	.0404 p = 0.664	.0409 p = 0.660	1.0000 p =						
RtDBP	.1581 p = 0.087	.1069 p = 0.249	.2545 p = 0.005	.1766 p = 0.060	.1091 p = 0.240	.0809 p = 0.384	.0453 p = 0.626	.0096 p = 0.918	.5427 p = 0.000	1.0000 p =					
RtHR	.1517 p = 0.101	-.1956 p = 0.034	.1127 p = 0.224	.2527 p = 0.007	-.4335 p = 0.000	.3939 p = 0.000	.4644 p = 0.000	-.4338 p = 0.000	.0664 p = 0.475	.0987 p = 0.287	1.0000 p =				
HRmax	.6670 p = 0.000	.0357 p = 0.701	-.2194 p = 0.017	.5039 p = 0.000	.3131 p = 0.001	.4877 p = 0.000	.1633 p = 0.077	.1029 p = 0.267	.0633 p = 0.496	.0323 p = 0.729	.1135 p = 0.221	1.0000 p =			
PmaxHR	.1886 p = 0.041	.1557 p = 0.092	-.0099 p = 0.916	.0777 p = 0.411	-.2449 p = 0.008	-.0565 p = 0.543	.1880 p = 0.042	.0992 p = 0.285	.1296 p = 0.162	.0945 p = 0.309	.3243 p = 0.000	.5526 p = 0.000	1.0000 p =		
TexerT	.6953 p = 0.000	.0709 p = 0.445	.3593 p = 0.000	-.6884 p = 0.000	.7390 p = 0.000	.9368 p = 0.000	.6300 p = 0.000	.5116 p = 0.000	.0892 p = 0.337	.1498 p = 0.105	.4104 p = 0.000	.4895 p = 0.000	.0845 p = 0.363	1.0000 p =	
FxSBP	.0865 p = 0.352	.0486 p = 0.602	.1287 p = 0.165	-.0203 p = 0.830	.0538 p = 0.563	.1119 p = 0.228	.1389 p = 0.134	.1804 p = 0.051	.4257 p = 0.000	.2649 p = 0.004	.1989 p = 0.031	.0834 p = 0.369	.0434 p = 0.640	.0762 p = 0.412	1.0000 p =

Ht = Height; Wt = Weight; BF = Body Fat; VO2FU = Astrand Predicted VO2max; VO2TM = Bruce Predicted VO2max; FitTile = Astrand Fitness Percentile; Act = Activity Status; RtSBP = Resting Systolic Blood Pressure; RtDBP = Resting Diastolic Blood Pressure; RtHR = Resting Heart Rate; HRmax = Maximum Heart Rate; PmaxHR = Percentage of Maximum Heart Rate; TexerT = Total Exercise Time on Bruce Protocol; Exercise SBP = Exercise Systolic Blood Pressure.

Female Clients

The correlation matrix for the female clients can be found in Table 11. In the female clients, age was positively correlated with percent body fat (r = 0.63) and resting systolic blood pressure (r = 0.51). Age was negatively correlated with the predicted VO_2max values on the Astrand (r = -0.65) and Bruce test (r = -0.63), maximum heart rate (r = -0.71) and total exercise time on the treadmill (r = -0.66). Body weight was positively correlated to the percent body fat (r = 0.71) and negatively correlated with predicted VO_2max on the Astrand (r = -0.54) and the Bruce test (r = -0.51), fitness percentile on the Astrand test (r = -0.55) and the total exercise time (r = -0.53). Percent body fat was negatively correlated with the predicted VO_2max on the Astrand (r = -0.72) and the Bruce test (r = -0.70), fitness percentile on the Astrand test (r = -0.57), activity status (r = -0.54) and total exercise time on the treadmill (r = -0.72). The predicted VO_2max on the Astrand test was positively correlated with the predicted VO_2max score on the Bruce test (r = 0.79), physical activity status (r = 0.66) and total exercise time on the treadmill (r = 0.78). Predicted VO_2max of the Astrand test was negatively correlated with resting systolic blood pressure (r = -0.59) and resting heart rate (r = -0.51). The predicted VO_2max on the Bruce test was positively correlated with fitness percentile on the Astrand test (r = 0.69), and physical activity status (r = 0.57). There was a negative correlation between predicted VO_2max on the Bruce test and resting heart rate (r = -0.50). Fitness percentile as determined by the Astrand test was positively related to the physical activity status of the client (r = 0.63), total exercise time (r = 0.70) and negatively correlated with resting systolic blood pressure (r = -0.54). Physical activity status of the female clients was positively correlated to total exercise time on the treadmill (r = 0.54). Resting systolic blood pressure was positively correlated with resting diastolic blood pressure (r = 0.72).

Table 11

Correlation Between Variables for Female Clients

	Age	Ht	Wt	BF	VO2FU	VO2TM	Fit	Act	RtSBP	RtDBP	RtHR	HRmax	PmaxHR	TexerT	ExSBP
Age	1.0000														
	p =														
Ht	.1789	1.0000													
	p = 0.229	p =													
Wt	.2959	.0880	1.0000												
	p = 0.043	p = 0.556	p =												
BF	.6284	.1121	.7101	1.0000											
	p = 0.000	p = 0.469	p = 0.000	p =											
VO2FU	-.6544	.1531	-.5435	-.7194	1.0000										
	p = 0.000	p = 0.304	p = 0.000	p = 0.000	p =										
VO2TM	.6292	.1353	-.5120	.6986	.7930	1.0000									
	p = 0.000	p = 0.365	p = 0.000	p = 0.000	p = 0.000	p =									
Fit	.4559	.0031	-.5503	.5709	.8425	.6901	1.0000								
	p = 0.001	p = 0.984	p = 0.000	p = 0.000	p = 0.000	p = 0.000	p =								
Act	.3726	.0394	-.3573	.5419	.6604	.5706	.6279	1.0000							
	p = 0.010	p = 0.793	p = 0.014	p = 0.000	p = 0.000	p = 0.000	p = 0.000	p =							
RtSBP	.5133	.0709	.4046	.4640	-.5927	-.4878	-.5362	-.3467	1.0000						
	p = 0.000	p = 0.636	p = 0.005	p = 0.002	p = 0.000	p = 0.001	p = 0.000	p = 0.017	p =						
RtDBP	.3665	.1811	.2434	.3242	-.4377	-.3805	-.4004	.2471	.7216	1.0000					
	p = 0.011	p = 0.223	p = 0.099	p = 0.032	p = 0.002	p = 0.008	p = 0.005	p = 0.094	p = 0.000	p =					
RtHR	.3959	-.3236	.0101	.3802	.5077	-.5018	-.4054	.3574	.3055	.2402	1.0000				
	p = 0.006	p = 0.026	p = 0.946	p = 0.016	p = 0.000	p = 0.000	p = 0.005	p = 0.014	p = 0.037	p = 0.104	p =				
HRmax	-.7121	.0027	.2639	-.3803	.2765	.4236	.1926	.1145	-.3135	-.1235	.0015	1.0000			
	p = 0.000	p = 0.986	p = 0.073	p = 0.011	p = 0.057	p = 0.003	p = 0.195	p = 0.443	p = 0.032	p = 0.408	p = 0.992	p =			
PmaxHR	.0738	-.2209	-.1895	.0894	-.2581	-.0751	-.1859	.1414	.0664	.1881	.3775	.5600	1.0000		
	p = 0.622	p = 0.136	p = 0.202	p = 0.564	p = 0.080	p = 0.616	p = 0.211	p = 0.343	p = 0.657	p = 0.205	p = 0.009	p = 0.000	p =		
TexerT	.6589	.1497	.5286	.7185	.7828	.9709	.7048	.5392	.4660	-.4191	.4831	.4472	-.1122	1.0000	
	p = 0.000	p = 0.315	p = 0.000	p = 0.000	p = 0.000	p = 0.000	p = 0.000	p = 0.000	p = 0.001	p = 0.003	p = 0.001	p = 0.002	p = 0.453	p =	
ExSBP	.2133	.1405	.1997	.1912	-.1438	.0913	.1173	.0223	.2360	.0999	.0231	.1768	.0351	-.0648	1.0000
	p = 0.150	0.346	p = 0.178	p = 0.214	p = 0.335	p = 0.541	p = 0.432	p = 0.881	p = 0.110	p = 0.504	p = 0.878	p = 0.234	p = 0.815	p = 0.665	p =

Ht = Height; Wt = Weight; BF = Body Fat; VO_2FU = Astrand Predicted VO_2max; VO_2TM = Bruce Predicted VO_2max; Fit%tile = Astrand Fitness Percentile; Act = Activity Status; RtSBP = Resting Systolic Blood Pressure; RtDBP = Resting Diastolic Blood Pressure; RtHR = Resting Heart Rate; HRmax = Maximum Heart Rate; PmaxHR = Percentage of Maximum Heart Rate; TexerT = Total Exercise Time on Bruce Protocol; Exercise SBP = Exercise Systolic Blood Pressure.

Discriminant Function Analysis

Male Clients

A discriminant function analysis was used to determine which group of variables would best predict group membership for ST-segment depression and no ST-segment depression (Table 12). The variables selected by this analysis were age, percent body fat, predicted VO_2max on the Astrand (ml/kg/min) and on the Bruce protocol (ml/kg/min), fitness percentile on the Astrand test, fitness group, resting diastolic blood pressure, physical activity status, exercise duration of less than 6 minutes, and PVC's ($p=0.0004$). These variables could correctly predict 77.2 percent of the clients into a group with or without ST-segment depression. The canonical discriminant function histogram (figure 3) indicates that all of the clients with ST-segment depression had positive discriminant function scores. The more positive the discriminant function score the greater the chance that the client would be classified into the ST-segment depression group.

Variables that are measured in the Fitness Unit (age, weight, percent body fat, VO_2max of the Astrand test, fitness percentile, resting systolic, diastolic blood pressure and physciai activity status) were also assessed using the discriminant function analysis (Table 13). Age, percent body fat, VO_2max on the Astrand test, fitness percentile, resting diastolic blood pressure, and physical activity status correctly grouped 71.1 percent of the clients ($p=0.0013$). The canonical discriminant function analysis for the fitness unit variables can be found in figure 4. There is only one client with ST-segment depression with a negative discriminant function score. The number of clients with a discriminant function score greater than one is very similar to figure 3.

Table 12

Classification Function Coefficients for Male Clients on All Variables

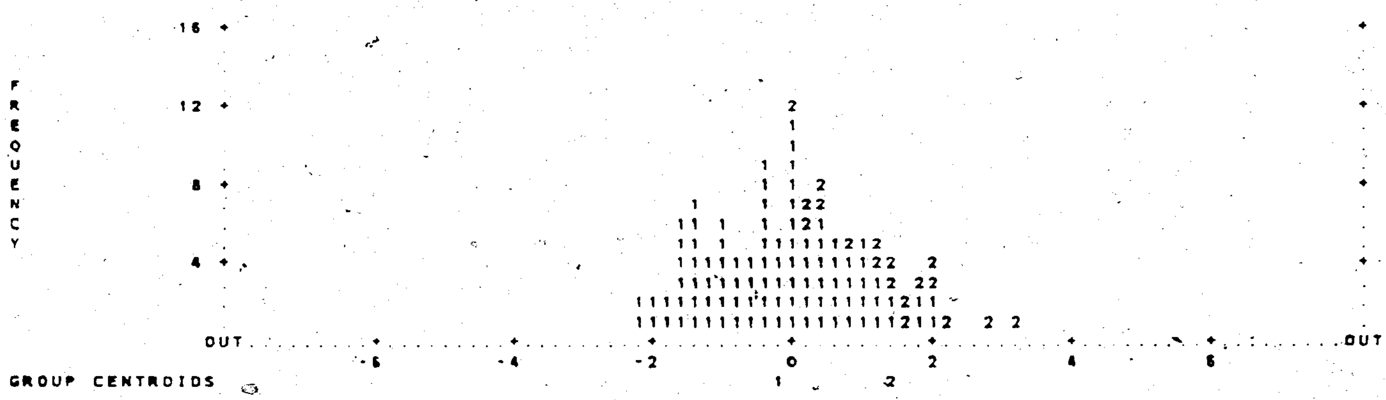
Variable	ST-Segment Depression		
	NO	YES	Standardized Canonical Discriminant Function Coefficients
Age	2.208	2.363	1.011
BF	2.912	3.011	0.397
VO2FU	5.304	5.610	2.725
VO2TM	1.759	1.648	-0.744
FIT%ile	-3.458	-3.556	-2.315
FitCls	156.840	160.570	1.167
RtDBP	1.146	1.214	0.375
Act	-2.221	-2.769	-0.351
ExDur	52.488	50.355	-0.298
PVC	-1.836	-3.462	-0.324
Constant	-328.246	-345.660	

BF = Body Fat; VO2FU = Predicted VO_2max on the Astrand Protocol; VO2TM = Predicted VO_2max on the Bruce Protocol; FIT%ile = Fitness Percentile on the Astrand Protocol; FitCls = Fitness Group; RtDBP = Resting Diastolic Blood Pressure; Act = Activity Rating; ExDur = Treadmill Exercise Time Rating; PVC = Preventricular Contractions.

Figure 3

Canonical Discriminant Function Histogram

of All Variables for Male Clients



1 = No ST-Segment Depression

2 = ST-Segment Depression

Table 13

Classification Function Coefficients of Fitness Unit Variables for Male Clients

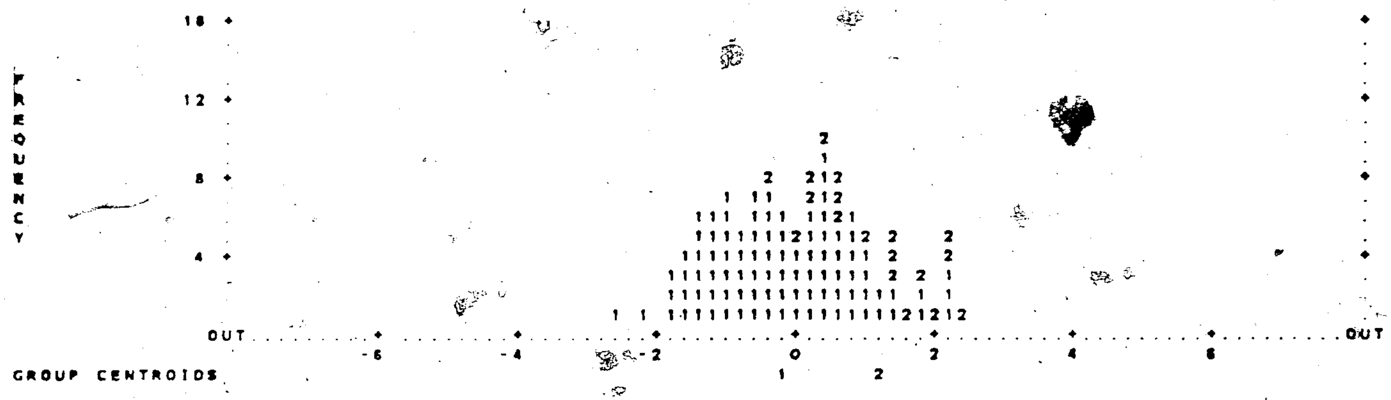
Variable	ST-Segment Depression		
	NO	YES	Standardized Canonical Discriminant Function Coefficients
Age	1.	1.550	1.014
BF	1.563	1.679	0.588
VO2FU	3.480	3.688	2.330
Fit%ile	-0.846	-0.880	-1.012
RtDBP	1.096	1.150	0.378
Act	1.031	0.305	-0.585
Constant	-143.061	-160.617	

BF = Body Fat; VO2FU = Predicted VO_2max on the Astrand Protocol; FIT%ile = Fitness Percentile on the Astrand Protocol; RtDBP = Resting Diastolic Blood Pressure; Act = Activity Rating.

Figure 4

Canonical Discriminant Function Histogram

of Fitness Unit Variables for Male Clients



1 = No ST-Segment Depression

2 = ST-Segment Depression

Female Clients

The combination of variables that had the best predictive value for group membership were height, percent body fat, final exercise heart rate, and exercise blood pressure rating (Table 14). These variables could correctly group 81.8 percent of the female clients into a group with and without ST-segment depression. The canonical discriminant function histogram for these variables is presented in figure 5. The majority of female clients with ST-segment depression had negative discriminant function scores. Six female clients with ST-segment depression and only two clients with no ST-segment depression had discriminant scores greater than negative one.

The only variable that was selected from the list of variables that could be measured in a fitness unit was percent body fat ($p=0.0261$; Table 15). Percent body fat could correctly classify group membership in 63.6 percent of the cases. The canonical discriminant function histogram (figure 6) indicated a diverse spread of discriminant function scores when percent body fat was the only discriminating variable.

Table 14

Classification Function Coefficients of All Variables for Female Clients

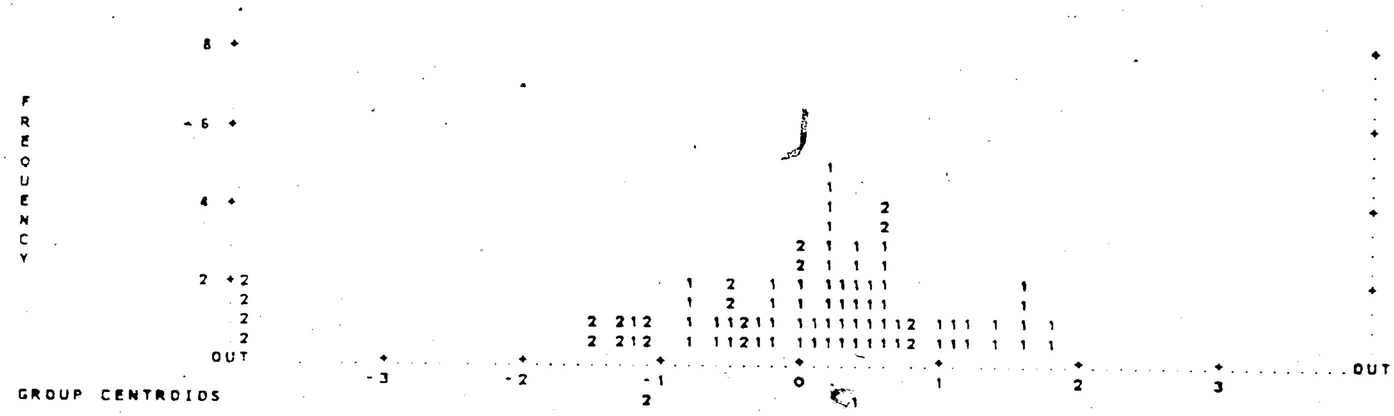
Variable	ST-Segment Depression		
	NO	YES	Standardized Canonical Discriminant Function Coefficients
Ht	0.730	0.789	-0.580
BF	2.139	1.956	0.746
HRmax	1.468	1.425	0.379
ExBP	15.069	17.463	-0.475
Constant	-224.710	-224.712	

Ht = Height; BF = Body Fat; HRmax = Maximum Heart Rate on the Bruce Protocol; ExBP = Exercise Blood Pressure Rating.

Figure 5

Canonical Discriminant Function Histogram

of All Variables for Female Clients



1 = No ST-Segment Depression

2 = ST-Segment Depression

Table 15

Classification Function Coefficients of Fitness Unit for Female Clients

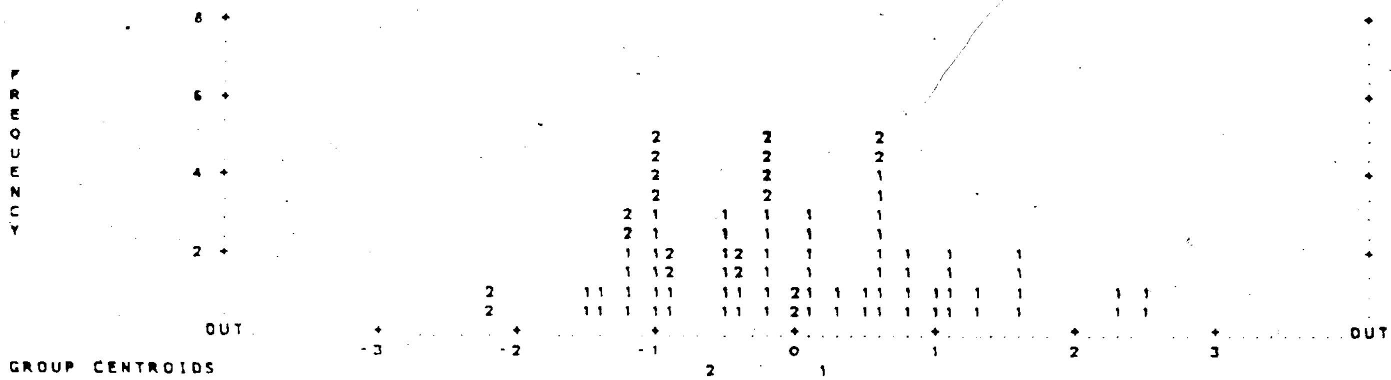
Variable	ST-Segment Depression		
	NO	YES	Standardized Canonical Discriminant Function Coefficients
BF	0.845	0.706	1.000
Constant	-13.476	-9.626	

BF = Body Fat.

Figure 6

Canonical Discriminant Function Histogram of

Fitness Unit Variables for Female Clients



1 = No ST-Segment Depression

2 = ST-Segment Depression

B. Discussion

Comparison of Fitness Groups

Male Clients

The primary benefit that occurs with increased physical activity is an increased maximal oxygen uptake. There are secondary benefits such as a lower total body weight, decreased percent body fat, and a lower heart rate at rest and at submaximal work intensities. Comparison of the male clients in the low and high fitness groups in this study confirms the beneficial factors associated with a higher level of physical fitness. Cooper and colleagues (1976) found that age, weight, percent body fat, resting heart rate, and resting systolic and diastolic blood pressures were significantly different ($p<0.01$) when comparing males rated as having a very poor and an excellent level of cardiovascular fitness. Cooper and colleagues (1976) used an age-adjusted treadmill time during a modified Balke treadmill test to determine the physical fitness level rather than a submaximal fitness test as used in this study.

It is possible that the age difference between the two groups of male clients could account for some of the differences in body weight, percent body fat, predicted maximal oxygen uptake on the Astrand and Bruce tests, total exercise time on the Bruce protocol, and final exercise heart rate on the treadmill. There was a positive correlation between age and percent body fat and a negative correlation between age and predicted VO_2max on the Astrand and Bruce test and total exercise time on the treadmill that would support that age is a contributing factor in the results. The development of fitness as an integral part of an improved lifestyle is a recent phenomena. The older clients in this study are less likely to perceive fitness as an important lifestyle goal. Even if the older clients maintained an active lifestyle there is still a decrease in: maximal oxygen uptake; stroke volume; maximal heart rate; and there is increased lay down of body fat (Astrand and Rodahl, 1977; McArdle, Katch and Katch, 1981).

The male clients in the two fitness groups had very similar resting systolic and diastolic blood pressures. Scheur and Tipton (1977) found that physical activity may not lower resting blood pressure in normotensive subjects as those examined in this study. The higher incidence of male clients in the high fitness group rated as having a hypertensive exercise blood pressure response may be related to a longer exercise time on the treadmill and a greater work output. There is evidence to suggest that the occurence of a hypertensive blood pressure response during exercise may predict the development of resting hypertension (Wilson and Meyers, 1981). However, the beneficial effects of a lower body weight and lower percent body fat may prevent the clients in the high fitness group from developing resting hypertension. Wilson and Meyers (1981) were using patients, had slightly lower values for resting hypertension and slightly higher values for exercise hypertension than the values used in this study which makes a direct comparison difficult.

The prevalence of low exercise tolerance was higher for the low fitness group of the male clients. Low exercise tolerance may be an indicator of underlying problems and has been found to be related to the development of CAD. Exercise duration on the treadmill was negatively related to body weight and percent body fat which are all related to greater risk of developing CAD.

The use of R wave amplitude to predict presence of CAD is a controversial issue. A five category classification system was used in this study to classify R wave amplitude response to exercise. This classification system has not been used by other researchers. A wide variety of R wave amplitude responses occurred with exercise and there was no relationship between the R wave response and the fitness group or ST segment depression for the male clients.

Fitness as determined by the Astrand test was not related to the prevalence of ST-segment depression for the male clients in this study. An active lifestyle has been a commonly identified procedure by health professionals for reducing the risk of CAD.

This increased activity should be measured as an enhanced maximal oxygen uptake during a submaximal exercise test. If a submaximal exercise test is not discriminating enough to identify differences between individuals then the relationship between fitness and CAD will be low. To suspect that CAD or even ST-segment depression in normotensive asymptomatic clients would be related to a single variable, such as fitness, may be too simple of an approach. There is a multiple of risk factors (family history, hypertension, diabetes, elevated blood lipids, obesity, inactivity, and ECG abnormalities) and the interaction of these risk factors over three or four decades of life may be responsible for the development of CAD.

Female Clients

There was a disproportionate number of female clients in the low fitness group which makes interpretation of the results risky. The reason for a lower number of females in the low fitness group is unclear. There are two possible explanations: a) the females that are interested in fitness test information are quite fit, while females who are unfit avoid confirming what they already know; b) or the Astrand test overpredicts maximal oxygen uptake in females and thus there are fewer female clients rated as having a low fitness level. A correlation coefficient of 0.79 was found between the predicted maximal oxygen uptake for the Astrand and the Bruce test which may indicate that the first suggestion is more plausible.

The beneficial effects that would be expected to occur with a high level of physical fitness were also evident for the female clients in this study. The mean age difference of 11.4 years and the difference in the sample size between the two fitness groups could have substantially influenced the results. One difference in the results of the female clients is that the high fitness group had significantly lower resting systolic and diastolic blood pressures. It should be noted that the low fitness group's mean systolic and diastolic blood pressure are still within the normal range. Age, body mass, percent body fat and physical fitness level may all affect the blood pressure of the clients in the low fitness group. There was no relationship between the fitness group and the number of female clients rated as having a resting or exercise hypertensive blood pressure response. Whether the higher resting blood pressure of the low fitness group is clinically significant will be difficult to determine unless these clients are followed longitudinally.

The prevalence of low exercise tolerance was related to low fitness for the female clients. Fifty percent of the female clients in the low fitness group could not complete six minutes of exercise on the Bruce protocol. This would indicate that these clients are extremely unfit or may have underlying disease. Allen and colleagues (1980) found that for female subjects an exercise duration of less than three minutes on the treadmill was related to the development of CAD. The six minute exercise duration used in this study was identical to that of Bruce and colleagues (1980). Differences between client populatons and test protocols makes direct comparison to other investigations difficult.

ST-segment depression was not related to the fitness group for the female clients. ST-segment depression has poor predictive power for detecting CAD in female clients and this decreases the chance that there would be a significant relationship between fitness and ST-segment depression (Sketch et al., 1975; Allen et al., 1980).

ST-Segment Response

Male Clients

The overall prevalence of ST-segment depression for the male clients in this study was 15.3 percent. This prevalence rate is greater than the findings of some researchers (Froelicher et al., 1974; Erikssen et al., 1976; McHenry et al., 1980; Giagnoni et al., 1983) and is similar to the findings of other researchers (Bruce et al., 1974; Cumming et al., 1976; Allen et al., 1980; Bruce et al., 1980). Only 118 male clients were examined in this study compared to the 510 to 9438 apparently healthy male subjects in other investigations. The sample in this study were fitness centre clientele and may not be a true representation of the general population in the Edmonton area. Other investigations (Bruce et al.1974, Froelicher et al.1974, Giagnoni et al.,1983) have used employees of large corporations to collect subjects. A low prevalence rate for ST-segment depression would have been expected in a fitness testing centre due to the screening procedures (Par-Q). The exact reason for the higher prevalence of ST-segment depression in this study is unclear. The age of the clients in this study was similar to the age of the clients in other studies. The direct comparison to many ST-segment response studies of asymptomatic populations is complicated by the following differences: incidence of CAD between countries; sample studied; ECG lead system; mode of exercise; and intensity of exercise. Cumming and colleagues (1975) is the only study on other canadian asymptomatic males and comparison to this study is difficult because the exercise mode is different (bicycle verus treadmill).

Family history and elevated blood lipids were not included in this study but it is possible that the clients with ST-segment depression were at higher risk due to these variables. A selection process, introduced by the clients, may have influenced the prevalence of ST-segment depression. For example, individuals who are concerned about their health may seek advice from a fitness appraisal centre. It is less disturbing to be told that your fitness level is low rather than suffering underlying disease.

The clients with ST-segment depression were older and had a greater percent body fat. With increased age an increased prevalence of ST-segment depression would be expected. The predicted maximal oxygen uptake on the Bruce protocol, stages completed, total exercise time and final exercise heart rate were lower for the clients with ST-segment depression. None of the male clients experienced any symptoms during the exercise tests, but in some instances the exercise test was terminated prior to the attainment of the 90 percent age predicted maximum heart rate. This would explain some of the differences in the exercise variables on the Bruce test.

The use of a prediction equation using variables that are collected in a fitness centre (age, percent body fat; predicted VO_2max on the Astrand test, fitness percentile, resting diastolic blood pressure and physical activity status) can be used to predict group membership for ST-segment response in 71.1 percent of all cases. If the clients with a canonical discriminant score greater than one can be identified then a subgroup of male clients with an increased chance for ST-segment depression can be screened with out a clinical stress test. This information would allow fitness appriasal centres to identify clients that may be at greater risk of CAD and allow for lifestyle modifications to reduce the risk.

Female Clients

The overall prevalence rate for ST-segment depression for female clients in this study was 25.5 percent. This prevalence rate is almost identical to the 25 percent rate found by Cumming and colleagues (1973) for 357 healthy women and only slightly less than the 30 percent found be Bruce and colleagues (1971) and the 33 percent found by Profant and colleagues (1973). The later two researchers included an upsloping ST-segment in the criteria for an abnormal exercise ECG which would explain the higher prevalence rate in these investigations. However, the use of an abnormal exercise ECG to predict the development of CAD is of limited value in female subjects (Sketch et al., 1975; Allen et al., 1980). The exact reason for the higher prevalence rate of ST-segment depression in female subjects is beyond the scope of this paper. Barolsky and colleagues (1979) have suggested that either anatomical or physiological characteristics of subjects is responsible for the higher prevalence.

The female clients with ST-segment depression had characteristics that would be associated with an increased level of physical fitness (ie. weighed less, lower percent body fat, lower resting heart rate). The discriminant function analysis identified body fat as as the only variable measured in a fitness appraisal centre that would predict group membership for ST-segment response. Figure 6 indicates that the spread of canonical discriminant function scores is quite large. If ST-segment depression has poor predictive value in female clients then the use of a variable such as body fat to predict ST-segment depression is of little value.

Comparison of Exercise Tests

Correlation coefficients of 0.72 ($p<0.001$) and 0.79 ($p<0.001$) were found for male and female clients respectively for the Astrand and Bruce predicted maximal oxygen uptakes. A high correlation would have been expected due to the diverse nature of the low and high fitness groups for predicted VO_2max. Since both exercise tests are predictors of VO_2max the chances of an extremely high correlation is reduced. Another consideration is that during the Astrand test the client's body weight is supported and during the Bruce test the client's energy cost is weight dependent. Older people in North Amercia are more familar with walking than with cycling and thus familarity with an exercise mode may also affect the correlation between the two tests. The determination of heart rate from a 10 second count of the radial pulse during the Astrand submaximal test could also account for a lower correlation. The use a heart rate monitor is a necessity for accurate heart rate determination and it would be ideal to have an ECG tracing for the measurement of heart rate. The measurement of heart rate must be accurate and of a great enough intensity to ensure an accurate prediction of maximal oxygen uptake.

Future Directions

Currently few fitness appraisal centres use an ECG to determine heart rate during an exercise test. The use of either a CM_5 or a CC_5 lead for monitoring the heart rate is appropriate fo fitness testing. The mean age of the clients with ST-segment depression was 42.8 ± 9.1 years and the mean heart rate at the occurence of ST-segment depression was 152.2 ± 11.4 beats per minute. During the submaximal exercise test the heart rate zone for a client age 43 years is between 157 to 127 beats per minute. It cannot be said with 100 percent certainty that a single lead ECG, such as the CM_5, would detect all of the ECG abnormalities found at the Cardiac

Stress Laboratory. The exercise modes were different and the final heart rate achieved during the two exercise tests were also different which makes a direct comparison difficult. Another consideration is that the sensitivity and the specificity of the CM_5 and CC_5 in comparison to V_5 have only been examined in patient populations and not in asymptomatic clients as in this study (Lam and Chaitman, 1984; Chaitman and Hansen, 1981). It may be safe to say that some of the abnormal ST-segment responses could be identified during the fitness test. However, without other clinical symptoms (angina or dyspnea) being present during exercise the occurence of ST-segment depression makes clinical evaluation of the test difficult. The test result could be given to a physician to decide whether there would be a need for further clinical evaluation.

At present, Certified Fitness Appraisers are only allowed to determine heart rate from the ECG during a fitness test (C.A.S.S., 1983). Shephard (1980) reported that there is a need for individuals conducting exercise tests to be trained in the interpretation of exercise ECG's. With this knowledge an exercise tester could not ethically ignore an abnormal exercise ECG but to send all abnormal ECG responses to a physician or cardiologist for further evaluation or follow-up would be impractical and costly (Shephard, 1980). The exercise tester must be aware that ST-segment depression is not 100 percent sensitive for detecting CAD in an asymptomatic population. For example, it would be unduly stressful for a client of a fitness appraisal centre to be told that they have an abnormal ECG, when in reality there may be no unde[illegible]ing disease. However, asymptomatic individuals who have an abnormal ECG response to exercise have been shown to be at greater risk of developing CAD. The cost of not following-up an abnormal ECG response may be far greater than the price of a medical evaluation. Identification of high risk individuals may allow fo: further assessment and proper risk factor intervention. A fitness appraisal centre with trained personnel and the information that can gained at such a centre could screen asymptom[illegible]iduals at greater risk of developing CAD that would not normally be identified.

Chapter V

Summary, Conclusion and Recommendations

A. Summary

The purpose of this study was to determine if ST-segment depression during a treadmill stress test was related to cardiovascular fitness on a submaximal exercise test. The secondary aim was to determine if these abnormalities could potentially be detected in a fitness centre using a single lead ECG (CM_5). One hundred and eight (108) male clients (0-30 percentile n=62; 70-100 percentile n=56) and 47 female clients (0-30 percentile n=10; 70-100 percentile n=37) from two diverse fitness levels volunteered for further assessment. The male clients in the low fitness group were older, weighed more, had a greater percent body fat, lower predicted VO_2max on the Astrand and Bruce test, lower fitness percentile, higher resting heart rate, lower total exercise time on the treadmill, and completed fewer 3 minute exercise stages on the Bruce protocol. There were more male clients in the high fitness group rated as having a hypertensive exercise blood pressure and more clients in the low fitness group rated as having a low exercise tolerance on the Bruce protocol. The female clients showed similar results with the low fitness group having a higher resting systolic and diastolic blood pressure. No female clients had a hypertensive exercise blood pressure and there were more female clients in the low fitness group rated as having a low exercise tolerance. ST-segment depression was not related to the fitness group for either the male or the female clients. The prevalence of ST-segment depression was 15.3 percent for the male clients and 25.5 percent for the female clients. A discriminant function analysis correctly classified 71.1 percent of the male clients into a group, with or without ST-segment depression, using age, percent body fat, VO_2max on the Astrand test, fitness percentile, resting diastolic blood pressure, and physical activity status. There were no useful variables that would predict group membership for the female clients.

B. Conclusion

1. Cardiovascular fitness was not related to ST-segment depression during the treadmill stress test for male or female clients.

2. It cannot be determined with certainty the number of ECG abnormalities that could be detected with a single lead ECG in a fitness centre but it is safe to say that some of the ECG abnormalities could have been detected.

3. Fitness unit information may be able to identify a group of male clients with a higher prevalence of ST-segment depression.

C. Recommendations

1. The clients from this study should be followed-up over a 3 to 5 year period to determine to incidence of cardiac events. A complete risk factor analysis for CAD should be included to identify the important risk factors for this sample.

2. To determine the prevalence of ECG abnormalities during a fitness test a single lead ECG (CM_5 or CC_5) should be recorded. Only male clients should be studied and they should be from all fitness levels. Individuals with abnormal responses could have a 12 lead treadmill stress test to determine if serial abnormal responses will occur.

3. Error in the submaximal fitness test must be reduced to a minimum. An ECG tracing is the most accurate method of determining heart rate. Standardized test conditions are necessary and the fitness tester must have a good knowledge of test procedures. For example, the subject must be in a post-absorptive state,

rested, free of any known illness, should not have smoked a cigarette or consumed a caeffinated beverage for two hours prior to the test, and the clients fear or anxiety must be controlled as well as possible (Astrand and Rodahl, 1977). The work load during the second exercise stage must be of a great enough intensity to achieve a heart rate of approximately 200 minus the client's age and 170 minus the client's age. Care should be used when interpreting the submaximal exercise test results and limitations of the test should be indicated to the clients.

Chapter VI

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Appendix A: Physical Activity Readiness Questionnaire (PAR-Qand Consent Form)

THE UNIVERSITY OF ALBERTA
FITNESS APPRAISAL SCREENING QUESTIONNAIRE

The questionnaire and consent form is designed to assist in identifying the small number of adults from whom this submaximal fitness test might be inappropriate. Please complete all parts of the questionnaire and sign it.

NAME: ______________________ ADDRESS: ______________________

____

Physical Activity Readiness Questionnaire* (PAR-Q) YES NO

Has your doctor ever said you have heart trouble?

Do you frequently suffer from pains in your heart or chest?

Do you often feel faint or have spells of severe dizziness?

Has a doctor ever said your blood pressure was too high?

Has your doctor ever told you that you have a bone or joint problem such as arthritis that has been aggravated by exercise, or might be made worse with exercise?

Is there a good physical reason not mentioned here why you should not follow an activity program even if you wanted to?

Are you over age 69 and not accustomed to vigorous exercise?

Consent for the Standardized Test of Fitness

I, ______________________, authorize the University of Alberta to administer and conduct an exercise fitness test designed to determine my physical work capacity. I understand that I will perform tests of grip strength, [illegible] and trunk flexion.

[illegible] my sex and age group. During the [illegible] my heart rate will be monitored and my blood pressure will [illegible] at the completion of the test. [illegible] predetermined heart rate [illegible] distress [illegible] with other types of fitness tests [illegible] and nausea.

[illegible] that I can discontinue the test at any time [illegible]. The test has been fully described to me [illegible] opportunity to satisfy my questions about the test.

[illegible] such an examination, I waive any legal [illegible] the University of Alberta from any and all claims [illegible] personal injuries sustained or death resulting from these tests. This waiver shall be binding upon my heirs and my personal representatives.

DATE: ______________ SIGNATURE: ______________________

Appendix B: Calculation of VO_2max From the Modified Astrand Test

Calculations:

1. To obtain the final heart rate value, average the [illegible] and 8 minute heart rate values. With this average heart rate value and the final work load value on the bicycle ergometer (Kpm), obtain a prediction of the maximal oxygen consumption (l/min) using Table A for males and Table B for females.

2. Correct the VO_2max value (l/min) for age by multiplying the value by the appropiate age correction score (Table C).

3. To calculate the VO_2max value in ml/kg/min, take the absolute value (l/min) and the clients weight (lbs/kg) and go to Table D and E.

4. The norms in [illegible] used to give the client a rating score.

Table A
Prediction of Maximal Oxygen Consumption for Males

Heart rate	Maximal Oxygen Uptake litres/min. 300 kpm/min	600 kpm/min	900 kpm/min	1200 kpm/min	1500 kpm/min	Heart rate	Maximal Oxygen Uptake litres/min. 300 kpm/min	600 kpm/min	900 kpm/min	1200 kpm/min	1500 kpm/min
120	2.2	3.5	4.8			148		2.4	3.2	4.3	5.4
121	2.2	3.4	4.7			149		2.3	3.2	4.3	5.4
122	2.2	3.4	4.6			150		2.3	3.2	4.2	5.3
123	2.1	3.4	4.6			151		2.3	3.1	4.2	5.2
124	2.1	3.3	4.5	6.0		152		2.3	3.1	4.1	5.2
125	2.0	3.2	4.4	5.9		153		2.2	3.0	4.1	5.1
126	2.0	3.2	4.4	5.8		154		2.2	3.0	4.0	5.1
127	2.0	3.1	4.3	5.7		155		2.2	3.0	4.0	5.0
128	2.0	3.1	4.2	5.6		156		2.2	2.9	4.0	5.0
129	1.9	3.0	4.2	5.6		157		2.1	2.9	3.9	4.9
130	1.9	3.0	4.1	5.5		158		2.1	2.9	3.9	4.9
131	1.9	2.9	4.0	5.4		159		2.1	2.8	3.8	4.8
132	1.8	2.9	4.0	5.3		160		2.1	2.8	3.8	4.8
133	1.8	2.8	3.9	5.3		161		2.0	2.8	3.7	4.7
134	1.8	2.8	3.9	5.2		162		2.0	2.8	3.7	4.6
135	1.7	2.8	3.8	5.1		163		2.0	2.8	3.7	4.6
136	1.7	2.7	3.8	5.0		164		2.0	2.7	3.6	4.5
137	1.7	2.7	3.7	5.0		165		2.0	2.7	3.6	4.5
138	1.6	2.7	3.7	4.9		166		1.9	2.7	3.6	4.5
139	1.6	2.6	3.6	4.8		167		1.9	2.6	3.5	4.4
140	1.6	2.6	3.6	4.8	6.0	168		1.9	2.6	3.5	4.4
141		2.6	3.5	4.7	5.9	169		1.9	2.6	3.5	4.3
142		2.5	3.5	4.6	5.8	170		1.8	2.6	3.4	4.3
143		2.5	3.4	4.6	5.7						
144		2.5	3.4	4.5	5.7						
145		2.4	3.4	4.5	5.6						
146		2.4	3.3	4.4	5.6						
147		2.4	3.3	4.4	5.5						

(Source: P.O. Astrand. Work Test with the Bicycle Ergometer, pg. 24)

Table B
Prediction of Maximal Oxygen Consumption for Females

Heart rate	Maxial Oxygen Uptake litres/min. 300 kpm/min	450 kpm/min	600 kpm/min	750 kpm/min	900 kpm/min
120	2.6	3.4	4.1	4.8	
121	2.5	3.3	4.0	4.8	
122	2.5	3.2	3.9	4.7	
123	2.4	3.1	3.9	4.6	
124	2.4	3.1	3.8	4.5	
125	2.3	3.0	3.7	4.4	
126	2.3	3.0	3.6	4.3	
127	2.2	2.9	3.5	4.2	
128	2.2	2.8	3.5	4.2	4.8
129	2.2	2.8	3.4	4.1	4.8
130	2.1	2.7	3.4	4.0	4.7
131	2.1	2.7	3.4	4.0	4.6
132	2.0	2.7	3.3	3.9	4.5
133	2.0	2.6	3.2	3.8	4.4
134	2.0	2.6	3.2	3.8	4.4
135	2.0	2.6	3.1	3.7	4.3
136	1.9	2.5	3.1	3.6	4.2
137	1.9	2.5	3.0	3.6	4.2
138	1.8	2.4	3.0	3.5	4.1
139	1.8	2.4	2.9	3.5	4.0
140	1.8	2.4	2.8	3.4	4.0
141	1.8	2.3	2.5	3.4	3.9
142	1.7	2.3	2.8	3.3	3.9
143	1.7	2.2	2.7	3.3	3.8
144	1.7	2.2	2.7	3.2	3.8
145	1.6	2.2	2.7	3.2	3.7
146	1.6	2.2	2.6	3.2	3.7
147	1.6	2.1	2.6	3.1	3.6

Heart rate	Maxial Oxygen Uptake litres/min. 300 kpm/min	450 kpm/min	600 kpm/min	750 kpm/min	900 kpm/min
148	1.6	2.1	2.6	3.1	3.6
149		2.1	2.6	3.0	3.5
150		2.0	2.5	3.0	3.5
151		2.0	2.5	3.0	3.4
152		2.0	2.5	2.9	3.4
153		2.0	2.4	2.9	3.3
154		2.0	2.4	2.8	3.3
155		1.9	2.4	2.8	3.2
156		1.9	2.3	2.8	3.2
157		1.9	2.3	2.7	3.2
158		1.8	2.3	2.7	3.1
159		1.8	2.2	2.7	3.1
160		1.8	2.2	2.6	3.0
161		1.8	2.2	2.6	3.0
162		1.8	2.2	2.6	3.0
163		1.7	2.2	2.6	2.9
164		1.7	2.1	2.5	2.9
165		1.7	2.1	2.5	2.9
166		1.7	2.1	2.5	2.8
167		1.6	2.1	2.4	2.8
168		1.6	2.0	2.4	2.8
169		1.6	2.0	2.4	2.8
170		1.6	2.0	2.4	2.7

(Source: P.O. Astrand. Work Test with the Bicycle Ergometer, pg. 25)

Table C
Age Correction Factor

Age	Factor	Max. heart rate	Factor
15	1.10	210	1.12
25	1.00	200	1.00
35	0.87	190	0.93
40	0.83	180	0.83
45	0.78	170	0.75
50	0.75	160	0.69
55	0.71	150	0.64
60	0.68		
65	0.65		

(Source: P.O. Astrand. Work Test with the Bicycle Ergometer, pg. 28)

Table D
Maximal Oxygen Consumption

Body weight		Maximum Oxygen Uptake litres/min																								
[illegible]	[illegible]	1.5	1.6	1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3.0	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9
[illegible]	[illegible]	[illegible]	[illegible]	34	36	38	40	42	44	[illegible]	46	[illegible]	[illegible]	54	56	58	60	62	64	66	68	70	72	74	76	78
[illegible]	[illegible]	29	[illegible]	33	35	37	39	41	[illegible]	45	47	[illegible]	[illegible]	53	55	57	59	61	63	65	67	69	71	73	75	[illegible]
[illegible]	[illegible]	29	[illegible]	33	35	37	38	41	42	44	[illegible]	[illegible]	50	[illegible]	54	56	58	60	62	63	65	67	69	71	73	75
[illegible]	[illegible]	28	30	32	34	36	38	40	42	[illegible]	45	47	49	51	[illegible]	55	57	59	60	62	64	66	68	70	72	74
[illegible]	54	28	[illegible]	31	33	35	37	39	41	43	44	46	48	50	52	54	[illegible]	57	[illegible]	[illegible]	63	65	67	69	[illegible]	[illegible]
[illegible]	[illegible]	27	29	31	[illegible]	[illegible]	[illegible]	38	40	42	44	45	47	49	51	53	55	[illegible]	58	60	62	64	[illegible]	67	69	[illegible]
[illegible]	[illegible]	27	29	30	[illegible]	34	[illegible]	38	39	[illegible]	43	45	[illegible]	48	50	52	54	[illegible]	57	59	61	63	64	66	68	70
[illegible]	[illegible]	[illegible]	28	30	31	33	35	37	39	40	42	44	45	[illegible]	49	51	[illegible]	54	[illegible]	58	[illegible]	61	63	65	67	68
[illegible]	58	26	28	[illegible]	31	33	34	[illegible]	38	40	[illegible]	43	45	47	48	50	[illegible]	[illegible]	[illegible]	57	59	[illegible]	62	[illegible]	[illegible]	67
[illegible]	59	25	27	29	31	32	34	[illegible]	37	39	41	42	44	45	47	49	51	53	54	54	58	[illegible]	[illegible]	[illegible]	64	65
[illegible]	60	25	27	28	30	32	33	35	37	38	40	42	[illegible]	45	47	48	50	52	53	55	57	58	60	62	63	65
[illegible]	[illegible]	25	[illegible]	28	30	31	33	34	36	38	39	41	43	44	46	48	49	51	52	54	56	57	59	61	62	64
137	62	24	26	27	[illegible]	31	32	34	35	37	39	40	42	44	45	47	48	50	52	53	55	55	58	60	61	63
139	63	24	25	27	29	30	32	33	35	[illegible]	38	40	41	43	44	46	48	49	51	52	54	56	57	59	60	62
141	64	23	25	27	28	30	[illegible]	[illegible]	34	[illegible]	38	39	41	42	44	45	47	48	50	52	53	55	56	58	59	[illegible]
143	65	23	25	[illegible]	28	29	[illegible]	32	34	[illegible]	[illegible]	38	40	42	43	45	46	48	49	51	52	54	55	57	58	60
[illegible]	66	23	24	26	27	29	30	32	33	35	[illegible]	38	39	[illegible]	42	44	45	47	48	50	52	53	55	[illegible]	58	59
148	67	22	24	25	27	28	30	31	33	34	[illegible]	37	39	40	42	43	45	46	48	49	51	52	54	55	57	58
150	68	22	24	25	26	28	29	31	32	34	35	37	38	40	41	43	44	46	47	49	50	51	53	54	[illegible]	57
152	69	22	23	25	26	28	29	30	[illegible]	[illegible]	35	36	38	39	41	42	43	45	41	48	49	51	52	54	55	57
154	70	21	23	24	26	27	29	30	[illegible]	33	34	35	37	39	40	41	43	44	46	47	49	50	51	53	54	56
157	71	21	23	24	25	27	28	30	31	32	34	35	37	38	39	41	42	44	45	46	48	49	51	52	54	55
159	72	21	22	24	25	26	28	29	31	32	33	35	36	38	39	40	42	43	44	46	47	49	50	51	53	54
161	73	21	22	23	25	26	27	29	30	31	33	34	36	37	38	40	41	42	44	45	47	48	49	51	52	53
[illegible]	74	20	22	22	24	26	27	28	30	[illegible]	32	34	35	36	38	39	41	42	43	45	46	47	49	50	51	53
165	75	20	[illegible]	23	24	25	27	[illegible]	[illegible]	[illegible]	32	33	35	36	37	39	41	[illegible]	43	44	45	47	48	49	51	52
[illegible]	76	20	21	22	24	25	[illegible]	28	[illegible]	30	32	33	34	[illegible]	37	[illegible]	39	[illegible]	42	[illegible]	45	46	47	49	50	51
170	77	[illegible]	21	22	23	25	26	27	[illegible]	[illegible]	[illegible]	32	34	[illegible]	36	38	39	40	41	43	44	45	47	48	49	51
172	78	19	21	22	23	24	[illegible]	27	28	29	[illegible]	32	[illegible]	35	36	37	38	40	[illegible]	42	44	45	46	47	49	50
174	[illegible]	[illegible]	[illegible]	22	[illegible]	24	25	27	[illegible]	29	[illegible]	[illegible]	[illegible]	34	[illegible]	37	38	39	41	42	43	44	[illegible]	47	48	49
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	24	[illegible]	[illegible]	[illegible]	29	[illegible]	[illegible]	33	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	40	41	43	44	45	[illegible]	48	[illegible]
[illegible]	[illegible]	[illegible]	20	[illegible]	22	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	35	36	37	38	[illegible]	41	42	[illegible]	44	45	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	23	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	30	[illegible]	[illegible]	34	35	[illegible]	[illegible]	39	40	[illegible]	[illegible]	44	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	22	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	30	[illegible]	[illegible]	[illegible]	35	[illegible]	[illegible]	[illegible]	41	[illegible]	42	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	40	42	42	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	38	[illegible]	40	41	42	44	45	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	24	[illegible]	[illegible]	28	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	38	40	41	[illegible]	43	44	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	24	[illegible]	[illegible]	[illegible]	[illegible]	30	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	38	39	[illegible]	[illegible]	43	44	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	41	42	[illegible]	44	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	21	22	[illegible]	[illegible]	[illegible]	[illegible]	28	29	[illegible]	31	33	[illegible]	[illegible]	[illegible]	[illegible]	38	39	40	[illegible]	[illegible]	44
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	24	[illegible]	[illegible]	[illegible]	29	30	31	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	38	[illegible]	40	41	42	[illegible]
[illegible]	[illegible]	[illegible]	18	19	20	21	22	23	24	25	26	27	29	30	[illegible]	32	33	34	35	36	37	38	40	41	42	[illegible]
203	[illegible]	[illegible]	[illegible]	18	[illegible]	[illegible]	22	[illegible]	24	[illegible]	[illegible]	[illegible]	28	[illegible]	30	32	33	34	[illegible]	[illegible]	37	38	39	40	41	[illegible]
205	[illegible]	[illegible]	[illegible]	18	19	20	[illegible]	23	24	[illegible]	26	[illegible]	28	29	30	31	[illegible]	[illegible]	34	35	37	38	39	40	41	42
[illegible]	94	[illegible]	[illegible]	16	19	[illegible]	[illegible]	22	23	24	25	27	[illegible]	[illegible]	30	31	32	33	34	35	36	37	38	39	40	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	18	19	20	[illegible]	22	[illegible]	24	25	[illegible]	27	28	29	31	[illegible]	33	34	35	36	37	38	39	40	[illegible]
212	96	[illegible]	17	18	19	20	[illegible]	22	23	24	[illegible]	26	27	28	[illegible]	30	[illegible]	32	33	34	35	36	38	39	40	[illegible]
214	97	[illegible]	16	16	19	20	21	22	23	24	25	26	27	28	29	30	[illegible]	32	33	34	35	36	37	38	39	40
216	98	[illegible]	[illegible]	17	18	19	[illegible]	21	22	23	24	25	27	28	29	30	[illegible]	32	33	34	35	36	37	38	39	40
[illegible]	99	[illegible]	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
[illegible]	[illegible]	[illegible]	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39

(Source: P.O. Astrand. Work Test with the Bicycle Ergometer, pg. 26)

Table E
Maximal Oxygen Consumption

Body Weight pound	kg	4.0	4.1	4.2	4.3	4.4	4.5	4.6	4.7	4.8	4.9	5.0	5.1	5.2	5.3	5.4	5.5	5.6	5.7	5.8	5.9	6.0
		Maximum Oxygen Uptake - litres/min																				
110	50	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110	112	114	116	118	120
112	51	78	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110	112	114	116	118
115	52	77	79	81	83	85	87	88	90	92	94	96	98	100	102	104	106	108	110	112	113	115
117	53	75	77	79	81	83	85	87	89	91	92	94	96	98	100	102	104	106	108	109	111	113
119	54	74	76	78	80	81	83	85	87	89	91	93	94	96	98	100	102	104	106	107	109	111
121	55	73	75	76	78	80	82	84	85	87	89	91	93	95	96	98	100	102	104	105	107	109
123	56	71	73	75	77	79	80	82	84	86	88	89	91	93	95	96	98	100	102	104	105	107
126	57	70	72	74	75	77	79	81	82	84	86	88	89	91	93	95	96	98	100	102	104	105
128	58	69	71	72	74	76	78	79	81	83	84	86	88	90	91	93	95	97	98	100	102	103
130	59	68	69	71	73	75	76	78	80	81	83	85	86	88	90	92	93	95	97	98	100	102
132	60	67	68	70	72	73	75	77	78	80	82	83	85	87	88	90	92	93	95	97	98	100
134	61	66	67	69	70	72	74	75	77	79	80	82	84	85	87	89	90	92	93	95	97	98
137	62	65	66	68	69	71	73	74	[illegible]	77	79	81	82	84	85	87	89	90	92	94	95	97
139	63	63	65	67	68	70	71	73	75	76	78	79	81	83	84	86	87	89	90	92	94	95
141	64	63	64	66	67	69	70	72	73	75	77	78	80	81	83	84	86	88	89	91	92	94
143	65	62	63	65	66	68	69	71	72	74	75	77	78	80	82	83	85	86	88	89	91	92
146	66	61	62	64	65	67	68	70	71	73	74	76	77	79	80	82	83	85	86	88	89	91
148	67	60	61	63	64	66	67	69	70	72	73	75	76	78	79	81	82	84	85	87	88	90
150	68	59	60	62	63	65	66	68	69	71	72	74	75	76	78	79	81	82	84	85	87	88
152	69	58	59	61	62	64	65	67	68	70	71	72	74	75	77	78	80	81	83	84	86	87
154	70	57	59	60	61	63	64	66	67	69	70	71	73	74	76	77	79	80	81	83	84	86
157	71	56	58	59	61	62	63	65	66	68	69	70	72	73	75	76	77	79	80	82	83	85
159	72	56	57	58	60	61	63	64	65	67	68	69	71	72	74	75	76	78	79	81	82	83
161	73	55	56	58	59	60	62	63	64	66	67	68	70	71	73	74	75	77	78	79	81	82
163	74	54	55	57	58	59	61	62	64	65	66	68	69	70	72	73	74	76	77	78	80	81
165	75	53	55	56	57	59	60	61	63	64	65	67	68	69	71	72	73	75	76	77	79	80
168	76	53	54	55	57	58	59	61	62	63	64	66	67	68	70	71	72	74	75	76	78	79
170	77	52	53	55	56	57	58	60	61	62	64	65	66	68	69	70	71	73	74	75	77	78
172	78	51	53	54	55	56	58	59	60	62	63	64	65	67	68	69	71	72	73	74	76	77
174	79	51	52	53	54	56	57	58	59	61	62	63	65	66	67	68	70	71	72	73	75	76
176	80	50	51	53	54	55	56	58	59	60	61	63	64	65	66	68	69	70	71	73	74	75
179	81	49	51	52	53	54	56	57	58	59	60	62	63	64	65	67	68	69	70	72	73	74
181	82	49	50	51	52	54	55	56	57	59	60	61	62	63	65	66	67	68	70	71	72	73
183	83	48	49	51	52	53	54	55	57	58	59	60	61	63	64	65	66	67	69	70	71	72
185	84	48	49	50	51	52	54	55	56	57	58	60	61	62	63	64	65	67	68	69	70	71
187	85	47	48	49	51	52	53	54	55	56	58	59	60	61	62	64	65	66	67	68	69	71
190	86	47	48	49	50	51	52	53	55	56	57	58	59	60	62	63	64	65	66	67	69	70
192	87	46	47	48	49	51	52	53	54	55	56	57	59	60	61	62	63	64	66	67	68	69
194	88	45	47	48	49	50	51	52	53	55	56	57	58	59	60	61	63	64	65	66	67	68
196	89	45	46	47	48	49	51	52	53	54	55	56	57	58	60	61	62	63	64	65	66	67
198	90	44	46	47	48	49	50	51	52	53	54	56	57	58	59	60	61	62	63	64	66	67
201	91	44	45	46	47	48	49	51	52	53	54	55	56	57	58	59	60	62	63	64	65	66
203	92	43	45	46	47	48	49	50	51	52	53	54	55	57	58	59	60	61	62	63	64	65
205	93	43	44	45	46	47	48	49	51	52	53	54	55	56	57	58	59	60	61	62	63	65
207	94	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	59	60	61	62	63	64
209	95	42	43	44	45	46	47	48	49	51	52	53	54	55	56	57	58	59	60	61	62	63
212	96	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	63
214	97	41	42	43	44	45	46	47	48	49	51	52	53	54	55	56	57	58	59	60	61	62
216	98	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61
218	99	40	41	42	43	44	45	46	47	48	49	51	52	53	54	55	56	57	58	59	60	61
220	100	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60

(Source: P.O. Astrand. Work Test with the Bicycle Ergometer, pg. 27)

Table F
Swedish Norms for Maximal Oxygen Consumption for Males and Females Aged 20 to 69 Years

Age	Maximal oxygen uptake, Vo_2 l, ml/kg × min.				
	low	somewhat low	average	high	very high
20–29	≤1.69	1.70–1.99	2.00–2.49	2.50–2.79	≥2.80
	≤28	29–34	35–43	44–48	≥49
30–39	≤1.59	1.60–1.89	1.90–2.39	2.40–2.69	≥2.70
	≤27	28–33	34–41	42–47	≥48
40–49	≤1.49	1.50–1.79	1.80–2.29	2.30–2.59	≥2.60
	≤25	26–31	32–40	41–45	≥46
50–65	≤1.29	1.30–1.59	1.60–2.09	2.10–2.39	≥2.40
	≤21	22–28	29–36	37–41	≥42
20–29	≤2.79	2.80–3.09	3.10–3.69	3.70–3.99	≥4.00
	≤38	39–43	44–51	52–56	≥57
30–39	≤2.49	2.50–2.79	2.80–3.39	3.40–3.69	≥3.70
	≤34	35–39	40–47	48–51	≥52
40–49	≤2.19	2.20–2.49	2.50–3.09	3.10–3.39	≥3.40
	≤30	31–35	36–43	44–47	≥48
50–59	≤1.89	1.90–2.19	2.20–2.79	2.80–3.09	≥3.10
	≤25	26–31	32–39	40–43	≥44
60–69	≤1.59	1.60–1.89	1.90–2.49	2.50–2.79	≥2.80
	≤21	22–26	27–35	36–39	≥40

(Source: P.O. Astrand. Work Test with the Bicycle Ergometer, pg. 29)

Appendix C: Medical History Questionnaire

Name: ______________________ Age: ________ Sex: _____ DOB: _____

Address: ____

Phone: (home): ______________ (bus): ______________

Occupation: ______________________

Habitual Physical Activity: Sedentary (no regular exercise)

Takes regular exercise

Smoking: No. / day ____________

Smoked for ________ years

Quit ________ years ago

No. of packs x years ____________

Alcohol: Drinks/week ____________

Previous Medical History:

Family History of:

Hypertension

Strokes

Diabetes

Systematic enquiry: CNS

[illegible]

[illegible]

[illegible]

Examination: Pulse: ____________ [illegible]: ________

BP: ______________

CVS

[illegible]

AB[illegible] Check [illegible]

[illegible]

Comments:

Appendix D: Fitness Unit Data Sheet

UNIVERSITY OF ALBERTA
FITNESS TEST

NAME: ______________________ DATE OF TEST: __________

AGE: __________ SEX: __________

ANTHROPOMETRIC DATA

HEIGHT: ______ WEIGHT: ______

GIRTHS: Chest ______ Gluteal ______

Abdomen ______ Thigh ______

FINAL ______

SKINFOLDS:

TRICEPS ______ ______ ______ ______

SUBSCAPULAR ______ ______ ______ ______

BICEPS ______ ______ ______ ______

SUPRAILIAC ______ ______ ______ ______

TOTAL ______

BICYCLE ERGOMETER TEST

RESTING HR: ______ RESTING BP: ______

STAGE I: Workload ______ kpm
4 Min HR ______ BP: ______

STAGE II: Workload ______ kpm
7 Min HR ______ BP: ______
8 Min HR ______ BP: ______

POST EX HR (:30-1:00) ______ POST EX BP (:30-1:00) ______
POST EX HR (2:30-3:00) ______ POST EX BP (2:30-3:00) ______

MUSCULAR STRENGTH AND ENDURANCE, FLEXIBILITY TEST

GRIP STRENGTH RT. ______ LT. ______ TOTAL ______

TRUNK FLEXION ______ cm.

60 SEC. SIT-UPS ______

PUSH UPS ______

UNIVERSITY HOSPITALS
Division of Cardiology

REQUISITION FOR EXERCISE TEST

Name: **Age:** **Sex:** **Date:**
Physician: A.H.C.I.P. No
Preferred Exercise: Bicycle/Treadmill
Major Symptom:

If Chest Pain Specify: | Typical Angina | Atypical Angina | Non-Specific |

Clinical Diagnosis: | Cornary Artery Disease | Mitral Valve Disease | Aortic Valve Disease |
| Other |

Information sought:
Present Medication:

REPORT

Resting H.R. bts/min Resting B.P. mmHg Resting ST mm (lead)
Height cm Weight kg

EXERCISE TEST

Protocol Undertaken	Bruce	Modified Bruce	Bicycle	Other		
Terminated Due to	Pain	ST	Arryth	Fatigue	Target H.R.	S.B.P.
	S.B.P. > 220 mmHg	Other				

Total Time min	Total Work (W/kpm)	Highest load (kpm/W) stage
Highest H.R. bts/min	% for age & sex	Highest S.B.P. mmHg
Type of B.P. response	Normal / Hypertensive	Abnormal
Highest VO_2 l/min (Measured/Predicted)		Predicted C.O. l/min

RESTING ECG | SR | LBBB | RBBB | Other | Q | Ant | Lat | Inf | Other | ST-T | Ant | Lat | Inf | Other |

EX. E.C.G.

Maximum ST mm | Ant | Lat | Inf | Other |
ST slope — Change in R wave amplitude | Increased | Decreased | Unchanged |
E.C.G. Criteria for ischaemia discounting slope | Present | Absent |
P.V.C. | Multifocal/Unifocal | P.A.C. | Multifocal/Unifocal |

PROBABILITY FOR CAD based on | Age, Sex, B.P., Symptoms, ST, Cor Calc., Ex. Thallium Scan |

10 20 30 40 50 60 70 80 90 100

COMMENT:

Drug Code 1 2 3 4 5 6 7 8 9 10

3830-13646-17DEC81-CARDIO

EXERCISE TEST - BRUCE PROTOCOL

NAME: AGE: WEIGHT: HEIGHT:

DATE: DOCTOR: TEST NO.:

RESTING BP: RESTING HR: RESTING ST:

MEDICATIONS: ____________________

TIME (MIN)	GRADE	HR	BP	ST (MM)	PRODUCT	BORG	FAI.
1	1						
2							
3							
4	2						
5							
6							
7	3						
8							
9							
10	4						
11							
12							
13	5						
14							
15							
16	6						
RECOVERY	1 MIN						
	2 MIN						
	3 MIN						
	4 MIN						
	5 MIN						