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Reproducibility of hemodynamic responses during simulated occupational tasks performed by uncomplicated coronary artery disease patients

BY

MARCIA BRAZ

A THESIS

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The undersigned certify that they have read and recommend to the Faculty of Graduate Studies and Research for acceptance a thesis entitled "Reproducibility of Hemodynamic Responses during Simulated Occupational Tasks performed by Uncomplicated Coronary Artery Disease Patients", submitted by Marcia Braz in partial fulfillment of the requirements for the degree of Masters of Science in Physical Therapy.

(Supervisor)

Sharon Warren

Date: Feb 25, 1992

DEDICATION

To all my family, and especially to my parents,
who gave us education as their best gift.

ABSTRACT

The return to work recommendations for CAD patients with "blue-collar" jobs is an object of controversy in the cardiology field. The standard dynamic exercise test (GXT) has been widely used to guide these recommendations, despite the fact that it does not involve the static components of those jobs. The goal of this study was to evaluate the reproducibility of the simulated work test, which consists of weight carrying and weight lifting tasks.

Uncomplicated CAD patients were assigned to perform the weight carrying (n=12) or weight lifting tasks (n=11). They were tested on these tasks on two occasions spaced one week apart. Outcome variables were oxygen uptake, rate-pressure product and respiratory exchange ratio. Separate two-way ANOVA analysis showed no significant differences between days ($p>.05$) for any of the outcome variables of either tasks. However, during the weight carrying task the oxygen uptake variable was borderline for significance ($p=0.055$). For all the variables tested, the standard error of measurements were clinically insignificant, representing about 10% of the measurement value. The intraclass correlation coefficients were generally low, demonstrating poor test-retest reliability. It is concluded that the simulated work test needs additional research addressing the issue of reliability. The investigation of the concurrent and predictive validity of the simulated work test is also strongly recommended.

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LIST OF ABBREVIATIONS

CAD. Coronary Artery Disease
GXT. Graded Exercise Stress Test
WCT. Weight Carrying Test
WLT. Weight Lifting Test
AT. Anaerobic Threshold
CABS. Coronary Artery Bypass Surgery
MI. Myocardial Infarction
PTCA. Percutaneous Transluminal Coronary Angiography
HR. Heart Rate
SBP. Systolic Blood Pressure
$\dot{V}O_2$. Oxygen Uptake
R. Respiratory Exchange Ratio

CHAPTER I
INTRODUCTION

A. PROBLEM STATEMENT

Coronary artery disease (CAD) is prevalent in western cultures and also a major cause of death and disability (Health Reports, 1990). Part of this disability is the individual's inability to return to work or radically change his/her life style after a cardiac event.

Coronary artery disease has an economic impact on individuals and on health care funding agencies. A rough estimation of the medical care cost for each patient surviving a myocardial infarction is roughly $6,000 a year (DeBusk *et al*, 1988). Therefore, CAD should be managed in a way that keeps the patient productive after the onset of the disease. By promoting a higher rate of return to work after the cardiac event a decrease in morbidity and medical costs was observed (Dennis *et al*, 1988).

Many authors (Haskell *et al*; 1989; Giullette *et al*, 1989 and Picard *et al*, 1989) recommend that cardiac patients have appropriate assessment, treatment and placement in the work force. For many people, an unproductive life is not compatible with reasonable living conditions. However, return to work after a cardiac event may be difficult, especially for patients with physically demanding occupations (Sheldahl *et al*, 1985). It appears that there is a direct relationship between physically demanding jobs and economic status in heart patients (Dennis *et al*, 1988). Indeed, Crosby (1984) showed an inverse relationship between the economic status and the resumption of work of "blue-collar" workers, who represent 16% of the manual labour force.

The decision to return to work is usually influenced by many factors like: social and economic status (46.6%), psychological factors (40%) and age and medical reasons

(13.4%) (Monpere *et al*, 1988). According to Wenger *et al* (1982), about 50% of the cardiac patients who were manual labour workers feel that their jobs contributed to their illness. As a consequence, after the cardiac event they survive with a nonwork income from disability or retirement benefits. Attitudes of the employer, physician and family also appear to affect the decision of return to work (Walter, 1988). These attitudes seem to be influenced by ignorance about the true physical status of the patient, and a fear that working could precipitate another cardiac event.

When "blue-collar" workers are assessed for return to work, it is common practice to suggest that their jobs should be changed to less demanding ones. However, changing one's job after a certain age can be a very stressful process socially, economically and psychologically. It is clear that these workers need a scientifically based assessment to guide their employment recommendations. Vocational testing and counselling in the framework of the cardiac rehabilitation program seem to be an appropriate approach (Dennis *et al*, 1988).

The standard graded exercise stress test (GXT) has been traditionally used to guide the return to work recommendations for CAD patients. However, it seems inadequate to evaluate patients returning to manual labour work (Wilke *et al*, 1989; Dafoe *et al*, 1990). The GXT involves only lower limb exertion, and does not include the upper limb static components (such as lifting and carrying weights) present in the most demanding occupations. Even though general guidelines can be derived from the functional capacity observed on the GXT, a valid test simulating the "blue-collar" tasks is urgently needed (Foster, 1988).

In an attempt to better assess CAD patients for return to "blue-collar" work, researchers (Wilke and Sheldahl, 1985; Rod *et al*, 1989) have devised a work simulation test that involves carrying and lifting tasks. The test consists of a model which could be adapted to many work situations required in an industrial society. The test itself elicited fewer electrocardiographic (ECG) ST segment changes than the GXT, but also showed an important arrhythmia (bigeminy) not evident on the dynamic stress test (Sheldahl *et al*, 1985; Dafoe *et al*, 1990). The simulated work test was then considered a safe and practical way of clearing CAD patients for manual labour (Dafoe *et al*, 1990; Rod *et al*, 1989). However, the reliability and validity of these protocols have not been addressed.

B. OBJECTIVES OF THE STUDY

The main objective of this study was to determine the reproducibility (test-retest reliability) of the hemodynamic variables: rate-pressure product, oxygen uptake and respiratory exchange ratio obtained during an occupational work evaluation performed by patients who suffered an uncomplicated myocardial infarction, or underwent coronary artery bypass surgery or percutaneous transluminal coronary angioplasty.

C. RESEARCH HYPOTHESIS

The research hypothesis was as follows: Occupational work evaluation, performed by patients with uncomplicated CAD, will provide reproducible data on the following variables:

a. Mean oxygen uptake in the last minute of each stage;

b. Mean respiratory exchange ratio in the last minute of each stage;

c. Maximal rate-pressure product in each stage.

D. DEFINITIONS

The following words, abbreviations and terms are defined as they were utilized in this study:

Subjects- Patients who fulfilled the inclusion and exclusion criteria to participate in this study. All of them were being followed up by the University of Alberta Hospital Cardiology team.

"Blue-collar" workers- Consists of all skilled or unskilled manual labourers. For example: persons working in carpentry, building construction, plumbing, farming, etc.

"White-Collar" workers- Composed of managerial, middle, and lower status clerical office occupations. Also includes self-employed businessmen and professionals.

STPD- Stands for Standard Temperature Pressure Dry. The STPD is equivalent to 0^0 C, 760mm Hg (101.3 kPa), dry of water vapour.

ATPD- Ambient Temperature and Pressure Dry.

ATPS- Ambient Temperature and Pressure Saturated with water vapour.

BTPS- Body Temperature and Pressure Saturated with water vapour.

$\dot{V}E$- Ventilation per unit time or expiratory gas volume per minute.

FEO_2- Fraction of oxygen in the expired air.

Oxygen uptake (VO_2)- Volume of oxygen (at 0°C, 760 mmHg (101.3 kPa), dry-STPD) extracted from the inspired air, and usually expressed as litres per minute. In a specific period during exercise, the amount of oxygen uptake calculated equals the volume of oxygen utilized by the oxidative phosphorylation of foodstuffs in the cells of the exercising skeletal muscles. One litre of oxygen corresponds to 19.7 to 21.1 kJ (4.7 to 5.05 kcal) of energy liberation. One litre of oxygen at STPD = 44.6 mmol (one mol = 22.414 litres). It may be expressed as an absolute or relative value.

* **ABSOLUTE VALUE-** Oxygen consumption per unit of time (expressed in litres/min).

$$\dot{V}O_{2(STPD)} = \frac{VO_{2(STPD)}}{\text{collection time}}$$

* **RELATIVE VALUE-** Oxygen consumption (absolute value) per unit of body weight (expressed in ml/Kg/min). (Extracted from Astrand, 1986).

Carbon dioxide production (VCO_2)- Amount of carbon dioxide produced during an activity per unit time.

Coronary artery disease (CAD)- Considered to be a progressive disease of the coronary arteries, usually correlated with the early onset of atherosclerosis, hyperlipidaemia, high blood pressure, genetic history and other factors. Coronary insufficiency, i.e., a blood flow through the coronary arteries which is inadequate to meet the myocardial oxygen demands, occurs. This process is usually called ischaemia and is commonly manifested by chest pain (angina). When severe, it results in total cessation in blood flow, causing coronary thrombosis.

Myocardial Infarction (MI)- Ischemic damage of the myocardium which occurs when blood flow to the heart muscle is slowed or stopped at least for 15 to 30 minutes. The inadequate blood flow can occur if any of the coronary artery branches develop atherosclerosis, a lesion with a blood clot (thrombus) or spasm (uncommon). Whichever happens, the result is the same. Not enough blood and oxygen reaching the heart muscle causes its death in the affected area.

Percutaneous Transluminal Coronary Angioplasty (PTCA) - Non-surgical treatment designed to open a clogged coronary artery. In a catheterization laboratory, a catheter with a balloon on the tip is inserted usually through the femoral artery to be placed at the occluded coronary artery. Catheter in place, the balloon is inflated, flattening and fracturing the atherosclerotic plaque against the vessel wall and increasing the size of the lumen. An X-ray fluoroscope monitor is used to show the progress of the catheter as it moves through the arteries to the heart.

Coronary Artery Bypass Surgery (CABS)- Surgical intervention used to promote an increased circulation to the myocardium when there is a major coronary artery occlusion. Grafts from the saphenous vein (or internal mammary artery) are anastomosed to the ascending aorta and the distal portion of the occluded coronary artery. The bypass reestablishes the blood flow to the diseased segments. Relief of angina and improvement of functional status are frequently reported after the surgery is performed (Barnes *et al*, 1977).

Anaerobic Threshold (AT)- Point when metabolic acidosis and associated changes in gas exchange in the lungs occur during any prolonged continuous exercise. The early occurrence of the anaerobic threshold is dependent on the intensity of the exercise. At the AT point, the carbon dioxide production is greater than the amount of oxygen uptake (respiratory exchange ratio exceeds 1) due to an accumulation of lactate in the blood (Wasserman *et al*, 1973).

Cardiac Output- Rate at which each ventricle of the heart pumps blood into the aorta and pulmonary artery. It is usually represented by the product of heart rate and stroke volume and expressed as litres per minute. With small fluctuations, the cardiac outputs of the right and left ventricles are identical. When divided by the body surface area, cardiac output is used to calculate the "cardiac index", which relates the volume of blood pumped by the heart per minute to the body size (Astrand and Rodahl, 1986).

Valsalva Manoeuvre- Making an expiratory effort with the glottis closed, and causing an increase in intrathoracic pressure. A consequent increase in the afterload causes reflex cardiac slowing, which in turn causes a decrease in the cardiac output.

E. LIMITATIONS OF THE STUDY

The following limitations apply to this study:

1. Expectation bias

To decrease the possibility of expectation bias, the protocols were standardized and the testers were blinded to the test results from the first session.

2. Changes in patient's motivation and/or complications

Even though the patient motivation is a variable not easily controlled, the clinical status of the patients was not likely to change during the study time. Their conditions were very stable, and testing/retesting sessions were performed in the same manner about 7-10 days apart.

3. Validity of the simulated work test

Although this study examined the reliability of the simulated work test, its validity has not been addressed yet. This test can not be clinically accepted unless it is found to be valid.

4. Timing for blood pressure measurements

The blood pressure was measured on the last 20 seconds of each stage of the weight carrying protocol. Because the same procedure was not technically feasible for the weight lifting task, measurements were done immediately after the weights were lifted. Therefore, blood pressure values may have been underestimated. According to Barker *et al* (1983) 10 seconds are enough to cause a drop in blood pressure.

5. Learning effect

Even though the patients had a familiarization session prior to testing, the learning effect may have influenced the test results. Indeed, the second test appeared to provide consistently lower results than the first.

F. DELIMITATIONS OF THE STUDY

1. The study dealt only with males within the age-range of 35-65 years old. Females were not included because it would be practically impossible to find women attaining the inclusion criteria.

2. The simulated work test refers only to weight carrying and weight lifting tasks and does not involve other specific stresses (eg. psychological, heat) which may be found in many "blue-collar" jobs.

3. The loads used were standardized to a maximum of 40 pounds and did not take into account the patient's maximal voluntary muscle contraction.

4. This study only examined reliability of the simulated work test and did not consider whether or not the test is valid as a predictor of work-capacity or work-related cardiac events.

CHAPTER II
LITERATURE REVIEW

This chapter includes the discussion of three major topics. The first part deals with the reality of coronary artery disease (CAD) in the western world, its incidence and the traditional clinical approach to the problem of work resumption after a cardiac event. Secondly, a review of the newly created simulated work test composed of weight carrying and weight lifting is presented. The hemodynamic parameters clinically used to evaluate the CAD patient are reviewed here. Finally, the psychological and social benefits of returning to work after the cardiac event are briefly discussed.

A. THE INCIDENCE OF HEART DISEASE

Coronary artery disease remains the leading cause of death and hospitalization in most industrialized western countries (Health Reports, 1990). According to these statistics (Health Reports, 1990), CAD is responsible for 2.4 million of the 11 million deaths occurring annually. Even though the number of deaths is almost evenly divided between males and females, men usually die at a younger age than females.

From 1970 to 1980, 5.4 million Americans were diagnosed with CAD. Each year over one million individuals experience myocardial infarction and 670,000 survive in that country. Approximately 25% of these survivors are aged 35 to 65 years old. An estimated 65,000 coronary artery bypass surgeries (CABS) are performed annually, at an approximate cost of at least $10,000 per procedure. Overall, the average cost of follow-up for each patient in the first year after the cardiac event is about $6,000 (DeBusk and Davidson, 1980).

In Canada also CAD is the main cause of death, accounting for 77,000 deaths or 42% of all deaths in the period of 1981-1987. Only in 1988, the total number of deaths due to CAD was almost 50,000. In that year, 5.4% of males and 4.3% of females were disabled due to CAD. The rate of CABS increased 45.7% from 6,477 in 1981-1982 to 9,349 in 1986-1987. In the same period there was a 22.6% increase in the occurrence of MI and a 43.2% increase in the hospitalization for CAD (Health Reports, 1990).

The incidence of CAD and its associated disability are alarming. It appears that additional interventions are necessary to assure that the CAD patient will still be productive and have a good quality of life after the cardiac event.

B. PREDICTORS OF RETURN TO WORK AFTER HEART DISEASE

In general, 10% of CAD patients do not return to work after a cardiac event. However, manual labourers, as opposed to clerk workers, and surgically instead of medically treated patients seem to be less likely to resume work. Overall, reasons for not returning to work are related more to non-medical than medical factors (Kavanagh and Matosevick, 1988).

The surgical objectives of the CABS are to relieve angina and to improve the functional capacity of the CAD patient (DeBusk and Davidson, 1980; Klonoff *et al*, 1989). As a consequence of this intervention, the patient should experience an improved quality of life, including resumption of work (Almeida *et al*, 1983; Walter, 1988). However, the rate of patients returning to work after surgery is shown to be 53% for patients with age 49 or less, 49% for age 50-54, 36% for age 55-59 and 37% for age 60-64 (Anderson *et al*, 1985). The reemployment rates after surgery have not been as high as expected (Walter, 1988).

Niles *et al* (1980) followed up 105 patients after CABS to estimate the rate of return to work. Fifty percent of the cohort had been working before the surgery and only an additional 10% were working about 20 months post surgery. The preoperative work status was found to be the most significant predictor of return to work ($p < 0.0001$). The group of patients who were labourers, were often worried that their jobs were too demanding for their condition. They were the least likely to resume work after CABS.

Smith & O'Rourke (1988) reported results similar to those of Niles *et al* (1980). By following up a group of 151 patients for a period of 16 months after the first MI, the former identified the physical activity associated with the job as the second most important predictor of return to work ($p< 0.003$). This time, the most important factor was the educational level ($p < 0.001$). In fact, Fioretti *et al* (1988) and Tempte (1988) reported that an average of 52% of the so-called "blue-collar" workers resumed work after a MI, compared to 68% of the "white-collar" workers. This difference was attributed to the uncertainties regarding the patient's fitness to perform the job.

There is evidence that the CAD patient should resume work as soon as possible after the cardiac event. Wenger *et al* (1982) noticed that about 15% of MI and CABS patients did not return to work after the event, even though they seemed physically capable of doing so. Hammermeister *et al* (1979) found that patients not working within the initial 6 months after a MI were less likely to resume employment. That fact suggested that returning to the workplace should be done as soon and as safely as possible.

It was also found by Wenger *et al* (1982) that patients' and physicians' concerns that physical work could elicit another heart attack were also major reasons for not resuming work. This finding was later confirmed by Dennis *et al* (1988) and Kavanagh and Matosevic (1988). The latter reported that 35% of CABS patients gave medical excuses for their inability to resume work. Specifically, those patients referred to "physician's concerns about the presence of effort angina, post surgery depression and type of job" as excuses. About 10% of the patients did not return to work due to employers' attitudes, which related to concerns about the employee's fitness to resume the work.

Post-operative predischarge GXT and the number of vessels bypassed were also reported as important predictors of return to work after CABS (Crosby, 1984). The more negative the GXT and higher number of vessels bypassed were linked to the lower return to work rates after CAD. On the other hand, severity of the disease, pre-operative left ventricular function (LVF) and pre- and post- operative MI rate did not appear to be of any major influence on this decision.

Monpere *et al* (1988) compared the return to work rate of CAD patients who underwent rehabilitation with those who did not. The return to work rate was 78% for the rehabilitation group compared to 51% for the other group. The program consisted of exercise training, secondary prevention and individual vocational counselling. They noted these were useful ways of improving the vocational rehabilitation of CAD patients.

C. CURRENT FORMAT FOR RETURN TO WORK RECOMMENDATIONS

Return to work after a cardiac event seems to be widely considered a criterion of good outcome (Wenger *et al*, 1982). There are indications that the level of physical activity required at work is an important factor influencing the employability of CAD patients. For many sedentary jobs the adequacy of the employee's fitness to resume work after CAD can be assessed by a medical history, physical examination and symptom limited GXT. However, as the physical demands of the job tasks increase, assessment of the physical working capacity seems to become more complex.

The GXT is widely used in the cardiology field. It is known as a reproducible test which provides an objective measure of the cardiovascular capacity for many patients, specially for those with CAD (Bruce *et al*, 1973). Specifically, its major role is to determine whether the coronary circulation is capable of increasing the O_2 supply to the myocardium in response to an increased demand. In many cases, however, the objective of the GXT is to determine if a patient can safely return to work (Fioretti *et al*, 1988).

Schlant and colleagues (1986) reported that if a significant exercise induced-ischemic ST segment depression or angina pectoris are absent during the test, it is assumed that they are also likely to be absent during activities of daily living. Since the GXT is a dynamic lower limb exertion test, its adequacy for clearing patients to return to manual labour jobs is questioned. The reason is because this test does not take into account the static effect of arm work, heavy lifting and weight carrying that occur in many jobs (Sheldahl *et al*, 1985; Kavanagh and Matosevick, 1988). Therefore, the GXT data may need to be supplemented with hemodynamic measurements observed during static tasks.

Many times the possibility that patients may be working in jobs that may be both physically and emotionally too demanding is overlooked (Cay and Walter, 1988). In other cases, however, patients who are potentially fit to resume work remain in a disabled position due to the lack of guidelines for their job recommendations (Haskell *et al*, 1989). There is presently no standardized method to evaluate the work capacity for CAD patients with physically demanding jobs.

Work recommendations for "blue-collar" CAD patients have been based on both GXT and on the subjective assessment by the attending physician (Sheldahl *et al*, 1985; Dennis *et al*, 1988; Dafoe *et al*, 1990). Such recommendations are often influenced by the concern that static physical work might precipitate a subsequent cardiac event (Dennis *et al*, 1988;

Barnes *et al*, 1977; Wenger *et al*, 1973). However, it is reported (Sheldahl *et al*, 1985; Nitter *et al*, 1977; Stern *et al*, 1976) that these recommendations are not usually correlated with physical parameters like aerobic capacity and vocational status. A patient may be reported as unable to resume work based on the GXT data due to the appearance of arrhythmias at high workloads of dynamic exercise. Since these high workloads elicit a high myocardial oxygen demand, represented by the rate-pressure product, sometimes angina and/or arrhythmias are reported. Conversely, the occupational tasks, most of the time, involve short and intermittent bouts of intensive isometric load that might not elicit the same responses (Sheldahl *et al*, 1985).

From an occupational viewpoint the information obtained from the GXT appears inadequate to estimate one's ability to return to "blue-collar" jobs. Wenger *et al* (1982) reported that three out of four patients undergoing GXT soon after a MI fall into a low-risk category. However, many of these patients do not resume work, particularly if their occupations involve static activities. This fact was explained by the general uncertainties about the validity of the GXT in evaluating one's ability to return to a demanding job after CAD.

D. ENERGY REQUIREMENTS OF OCCUPATIONS

Life expectancy has increased in most developed countries during the last decades. In the period of 1920 to 1922, just 10% of the Canadians could expect to reach their 85th birthday. By the period of 1985 to 1987, this rate had been increased to more than 30% (Health Reports, 1990). Renzulli *et al* (1988) report an average mortality rate for the general population of 6-7% for the period of 1950-1965, as opposed to a 2-3% rate in the 90's. The same trend occurred for the CAD population, whose increased life expectancy seems to be connected to the progress in intervention, such as drug and surgical therapy, prevention and rehabilitation (Renzulli *et al*, 1988).

People not only tend to live longer. They also want to keep themselves productive as long as possible. The nature of the work itself has changed in a way that favours return to work after CAD (Renzulli *et al*, 1988). For example, mechanization and automation have significantly reduced the energy expenditure of many jobs. Occupations which were labelled as heavy 20 years ago are now considered light. Therefore, it is suggested that CAD patients can now safely tolerate many "blue-collar jobs (Kavanagh and Matosevick, 1988).

Metabolic and cardiovascular demands of occupational tasks have been quantified primarily by measurements of oxygen uptake (expressed as METs [1]) during work and immediate recovery. Classifying the physical work according to its intensity facilitates the description of the fit between the worker and the job (Astrand, 1967; Brouha, 1967). Unfortunately, the major studies evaluating the energy requirements of different jobs were conducted at least 25 years ago, while the energy demands of contemporary jobs are radically changed. Astrand (1967) and Brouha (1967) evaluated the energy requirements (in METs) of occupational tasks for individuals free from CAD. In the absence of modern studies addressing the same issue, their findings are still used today to estimate the energy requirements of many jobs (Kavanagh and Matosevic, 1988).

Tasks such as carrying bricks of 16-40 lbs upstairs are reported to represent an energy expenditure up to 8 METs. Pushing objects of at least 75 lbs may require up to 9 METs. Walking and carrying objects of about 25-49 lbs require about 5 METs, while standing and lifting about 50 lbs takes

[1] 1 MET = 3.5 ml O_2 Uptake/Kg body wt/min.
(From Astrand & Rodahl, 1986)

4 METS (Passmore and Durnin, 1955; Brouha, 1967). However, Astrand (1967) found most occupational tasks do not exceed 5 METs. Researchers (Muir, 1977; Walter *et al*, 1988; Wenger *et al*, 1973) have reported that patients three months post MI typically have an aerobic capacity of 8-9 METs, yet only 50-75% of them return to work. Therefore, it would appear that the majority of CAD patients have the aerobic capacity greater than that required for most job situations. Yet, the return to work rate after cardiac disease does not seem to be satisfactory.

Physical exertion increases metabolic and cardiac demands roughly in proportion to the absolute intensity of the exertion. A given task may represent a different percentage of the maximal capacity for different individuals, depending on each one's maximal aerobic capacity when performing the task. The physical demands of a task are related to the task itself, but also to its intensity, the type of muscle contraction required, the size of the muscle mass involved (upper versus lower limbs), the work-rest cycle and environmental conditions such as heat and stress (Astrand and Rodahl, 1986; Haskell *et al*, 1989).

The static (isometric) component of a task seems to result in a greater tension on the exercising muscle than the dynamic exercise (Astrand and Rodahl, 1986). This tension is usually followed by a rapid and continuous rise in both systolic, and to a lesser extent, diastolic blood pressure. A moderate rise in oxygen uptake and heart rate are also observed (Astrand and Rodahl, 1986; Haskell *et al*, 1989). The magnitude of the increase in blood pressure seems to be proportional to the percentage of the maximal voluntary contraction maintained and the size of the muscle mass involved (Astrand and Rodahl, 1986). However, as found by Quarry *et al* (1974), total oxygen uptake during a short static activity seemed to be relatively small (2 to 4 METs) compared with a dynamic exercise producing a similar degree of fatigue.

Patients with stable CAD and preserved left ventricular function (LVF) usually respond to static exercise with increases in blood pressure and heart rate similar to those of healthy people (Helfant *et al*, 1971). Submaximal static exercise maintained for 3 minutes was generally well tolerated by CAD patients with good LVF (ejection fraction greater than 40 %) and dynamic functional capacity greater than 7 METs. Conversely, patients with poor LVF responded poorly to these activities. They showed a rapid decline in ejection fraction, caused by a depressed cardiac function (due to inadequate coronary blood flow) and increased rate of myocardial ischemia (Kivowitz *et al*, 1971). In 1980, Niles *et al* reported the relation of these symptoms with a greater prevalence of congestive heart failure.

E. THE SIMULATED WORK TEST

For many years the pressor response to heavy static effort was believed to impose excessive myocardial oxygen demands on CAD patients. However, the need for a complete rehabilitation after CAD stimulated the creation of a job-specific evaluation to guide return to work recommendations for "blue-collar" workers. The concept that physically demanding activities are necessarily dangerous for those patients has lately changed. It is now emphasized (Sheldahl *et al*, 1985, Haskell *et al*, 1989) that a test of combined isometric and dynamic functions is an adequate way to assess the patients's ability to return to work.

Test protoccls involving graduated weight carrying and weight lifting were developed by Sheldahl *et al* (1983). Cardiovascular responses suggestive of strain on the heart (such as rate-pressure product, angina pectoris and ST segment changes) were not elicited by these activities. However, the activities used seemed to be strenuous enough to detect inadequate cardiovascular responses to the exercise. Indeed, during an assessment of occupational limits and disability, Dafoe *et al* (1990) reported that a patient developed ventricular bigeminy while he was performing a weight lifting task (at a load as low as 20 lbs). This arrhythmia was not detected by the GXT. Thus, that assessment was used to identify safety limits for the patient's job.

Real occupational tasks require different types of exertion with combined static-dynamic components. Lower and upper limbs work together or separately, and varied number and size of muscles are involved (Astrand and Rodahl, 1986). This combination of exercise may elicit cardiovascular responses and ECG changes not observed during a GXT (Haskell *et al*, 1989).

Sheldahl *et al* (1983) and Haskell *et al* (1989) reported that most of the modern "blue-collar" jobs involve carrying and lifting loads at least up to 50 lbs. They suggested that moderate physically demanding jobs can be safely resumed earlier if the patient successfully performs a test that closely simulates the energy requirements of his job. Satisfactory performance on this test could increase the general confidence about his/her ability to return to work safely. Studies were conducted by Wilke and Sheldahl (1985) and by Smith & O'Rourke (1988) to test the safety of applying this load to CAD patients. The safety criteria was based on comparisons of weight carrying and lifting tasks with GXT data. Parameters observed were: occurrence of angina pectoris, ST segment changes, premature ventricular contractions (PVC) in a rate greater than 6/min, systolic blood pressure (SBP) greater than 220 mm Hg, and attainment of the maximal heart rate predicted for age and sex. More ischemic changes were observed during the GXT than during the weight lifting and weight carrying test. The fact that a higher rate-pressure product (systolic blood pressure x heart rate) was achieved during the dynamic GXT explains these findings.

There are suggestions that the uncomplicated CAD patient could safely perform the simulated work test soon after the cardiac event, if the maximum load does not exceed 50 lbs. Haskell *et al* (1989) and Wilke *et al* (1985) suggested that these static-dynamic tasks could be performed safely about 6 weeks after an uncomplicated MI, 7 weeks after CABS and 1 week after successful PTCA.

Recently, Rod and colleagues (1989) focused on testing a simulated work evaluation for selected CAD patients. Fifteen uncomplicated male CAD patients whose functional capacity was at least 7 METs participated in the study. The simulated work test was again reported as a feasible tool for assessing uncomplicated CAD patients who wished to resume work. The observed physiological responses to the tests showed that the test did not represent unsafe strains to those patients. In fact, the GXT and the weight lifting task elicited a higher heart rate than the weight carrying task. The former task, itself, elicited a higher SBP than the other two. Overall, most of the patients tested perceived the simulated work test as being very helpful in restoring their confidence to return to manual labour. They reported that fear was reduced and the anxiety alleviated.

E1. Validity of the simulated work test

It appears that both the weight carrying and weight lifting tasks are to some extent accurate representations of the real job, i.e., they have face validity. However, there are no validity studies published in this area.

It was shown (Astrand, 1967) that many "blue-collar" occupations used to require lifting and/or carrying of loads sometimes higher than 100 lbs. However, this overload in the workplace has been decreased recently due to automation and mechanization (Haskell *et al*, 1989). Concurrent validity studies for the simulated work test should be accomplished to clarify how well it can simulate the workplace job's requirements.

This test's predictive validity investigation is also strongly recommended. It is extremely important to know if any clinical test can be used to predict future complications during work situations, especially for the cardiac patients. Even though Wilke *et al* (1989) and Rod *et al* (1989) have stated that the simulated work test is a feasible tool for clinical settings, no studies so far have addressed the issue of its predictive validity. The closest study addressing this issue is reported by Manfre *et al* (1990). They showed that cardiovascular responses during arm cranking test (combined dynamic-isometric upper body work) are predictive of a safe return to work for CAD patients. The tension used represents loads in the range of 20-40 lbs, which may not closely simulate the occupational tasks encountered in the workplace.

It is known that different types of validity, i.e., concurrent, construct, content and predictive, of the simulated work test should be addressed in future studies. Testing patients in a laboratory atmosphere may not reflect the real stress present in the everyday situations in the workplace. In addition, environmental factors like heat, schedule and psychological stress may also play an important role in creating additional tensions.

E2. Weight carrying task

The weight carrying task, as defined by Rod *et al* (1989) is composed of three stages which require walking and carrying loads on a treadmill. A constant speed of 2 miles per hour and grade of 0% are set. There is a load free three minute warm up period before one starts the carrying activity. Each stage lasts three minutes, with a three-minute rest interval placed between each of them. In stage I, two dumbbells, of 10 lbs each, are carried during walking on the treadmill. Thirty pounds are carried in stage II (15 lbs in each hand), and 40 lbs (two 20 lbs dumbbells) in stage III. The electrocardiogram (ECG) and oxygen uptake are recorded continuously, and the blood pressure is taken in the last 20 seconds of each stage. This procedure is done to avoid underestimating the blood pressure reading. According to Sheldahl *et al* (1985) and Barker *et al* (1984), a significant drop in blood pressure usually occurs within 10 seconds of weight release.

E3. Weight lifting task

The protocol for the weight lifting task is very similar to the weight carrying task (Rod *et al*, 1989). It consists of three weight lifting periods of 4 minutes each, with a 3-minute rest interval between the stages. The loads used for each stage are the same as for the weight carrying task, i.e., one pair of 10, 15 and 20 lbs. The weights are lifted at a fixed rate of 4 lifts per minute from the floor to a height of 84 centimetres above the floor. To keep an adequate biomechanical balance, the load should be kept close to the gravitational centre of the body during lifting. All the physiological parameters are measured in the same manner for both the weight carrying and weight lifting tasks.

F. DETERMINING THE PATIENT'S ABILITY TO RESUME WORK AFTER A CARDIAC EVENT

Exercise stresses the primary function of the cardiovascular system, which is the supply of oxygen uptake and removal of carbon dioxide from the cells of the body. The simulated work test, a new approach proposed to evaluate the CAD patient's fitness to work, is still experimental. However, previous researchers (Sheldahl *et al*, 1985; Rod *et al*, 1989) investigated this test by using clinically accepted measurements of cardiovascular responses. These measurements are represented by oxygen uptake, blood pressure, heart rate, ischemia and arrhythmias (from ECG). They provide an estimation of the strain caused by the activity on the cardio-respiratory system. The respiratory exchange ratio (R) is indicated to assess the onset of the anaerobic threshold and the degree of cardiac impairment during exercise (Wasserman and Sietsema, 1988, Opasich *et al*, 1988).

F1. Oxygen uptake

Measurements of the dynamics of oxygen uptake in response to exercise has been shown to reflect cardiovascular function (Wasserman and Sietsema, 1988). All forms of muscular exercise do increase the metabolic rate, and thus involve the oxygen transport system. The energy required for the performance of occupational tasks has been assessed primarily by measuring the amount of oxygen taken up by the cardio-respiratory system during exercise and immediate recovery. Inability of the circulatory responses to meet an increased oxygen uptake requirement may be reflected by abnormalities in oxygen uptake dynamics, and an early increase in carbon dioxide output relative to oxygen uptake consequent to bicarbonate buffering of lactic acid (Wasserman and Sietsema, 1988).

The maximal oxygen uptake, highly related to the cardiac output, is, under standardized conditions, a highly reproducible and accurate measure of the individual's aerobic fitness. However, it does vary with sex, age, body weight, muscle mass, level of fitness and general health. For non-trained individuals, the average level of maximal oxygen uptake is shown to be about 2 l/min, or about 35 ml O_2/Kg/min (Astrand and Rodahl, 1986). The increase in oxygen uptake during exercise is caused by a combination of three respiratory processes:

1. Increased respiratory rate.

2. Increased tidal volume.
3. Increased oxygen diffusion at the alveolar level.

The cardiovascular system normally adapts to exercise so that greater amounts of oxygen may be delivered to the working tissues. These adaptations result in:

1. Increased heart rate.
2. Increased stroke volume.
3. Increased oxygen extraction at the capillary level (Wasserman and Sietsema, 1988, Astrand and Rodahl, 1986).

Continuous delivery of oxygen by the circulation is required for the generation of adenosine triphosphate (ATP) through the oxidative phosphorylation, which supplies energy for prolonged muscular contraction. One litre of oxygen corresponds to about 5 Kcal of useful energy. When oxygen transport is adequate, muscular contraction is maintained by aerobic metabolism of carbohydrates, fatty acids, pyruvate, lactate and other substracts to form ATP, carbon dioxide and water. In this aerobic process, little or no formation of lactic acid happens (Astrand and Rodahl, 1986). The oxygen uptake response to progressively increasing work rates is usually used to assess disability. Wasserman and Sietsema (1988) reported that 65% of the patients with ischemic heart disease had a reduced rate of increase in oxygen uptake, compared to healthy subjects.

Anaerobic processes are activated when oxygen delivery or utilization is insufficient to meet the total demands of the muscular contraction. Some of the ATP is produced by intense metabolism of muscle glycogen and blood glucose. This process results in the formation and accumulation of lactic acid (or lactate) from the oxidation of the pyruvate in the skeletal muscle. The blood or muscle lactate concentration is dependent on the intensity and duration of the activity. The intensity of exercise at which oxygen uptake does not increase in relation to the increased ventilation and lactate accumulation begins is called anaerobic threshold (AT: see [2]) (Astrand and Rodahl, 1986). Astrand (1967) reported that healthy individuals allowed to exercise at their own preferred rate, performed occupational tasks at an intensity of about 40% of their maximal oxygen uptake, never attaining their anaerobic threshold.

It is reported (Le Jemtel *et al*, 1985; Foster, 1988) that gas exchange measurements are essential means to quantify the functional capacity and overall physiological stress imposed by exercise on healthy subjects and cardiac patients. Peak oxygen uptake and respiratory exchange ratio allow a reliable judgement of the cardiopulmonary reserve for CAD patients. The traditional open circuit method of measuring gas exchange is described in Appendix III.

F2. Rate-pressure product

The rate-pressure product (RPP) is the product of systolic blood pressure and heart rate occurring at the same moment. This index was reported as a valid, reliable and non-invasive predictor of myocardial oxygen consumption for healthy and cardiac patients (Gobel *et al*, 1978). Because of its convenience, this indirect estimation of myocardial work has been widely used in programs of cardiac rehabilitation, exercise stress testing and occupational evaluation of cardiac patients (Rod *et al*, 1989; Dafoe *et al*, 1990).

During exercise, the increasing rate-pressure product in response to incremental exercise is assumed to represent the myocardial oxygen consumption and left ventricular impairment. This response is believed to be caused by an increased heart rate, left ventricular wall tension and

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[2]Anaerobic Threshold was defined by Wasserman (1973), as the level of exercise VO_2 above which aerobic energy production is supplemented by the anaerobic mechanism. In patients with heart failure, the AT level may be reduced because of an inadequate cardiac output.

myocardial contractility (Irwin and Tecklin, 1990). During the simulated work test, Sheldahl *et al* (1985) found a mean rate-pressure product ($x10^2$) of about 193 ± 46, 210 ± 51 and 220 ± 55 for patients lifting 20 lbs, 40 lbs and 50 lbs, respectively.

F3. Respiratory exchange ratio

The oxygen uptake alone provides the physiological cost of performing a given task. The respiratory exchange ratio ($R = \dot{V}CO_2/\dot{V}O_2$) provides an estimation of the energy demands and supply in the body during exertion. This ratio usually ranges from .7 to 1 and increases to levels above 1.0 at exhaustion, caused by the onset of the anaerobic metabolism. At this point, named anaerobic threshold (Wasserman and Sietsema, 1988), there is a net increase in the carbon dioxide output in relative to the amount of oxygen uptake. Buffering of lactic acid by sodium bicarbonate with secondary release of carbon dioxide indicate that the oxygen supply is inadequate as an energy source (Astrand and Rodahl, 1986).

It is reported (Opasich *et al*; 1988) that the onset of the anaerobic threshold reflects the severity of exercise-induced cardiac impairment in asymptomatic patients after MI. Wasserman and Sietsema (1988) also found that the magnitude of the reduction in the exercise anaerobic threshold was correlated with the degree of impairment. This relationship was based on the fact that the increased blood lactate concentration allowed estimation of the effectiveness of the oxygen transport system (Opasich *et al*, 1988). However, the assessment of the anaerobic threshold in many CAD patients is not easy. Symptoms such as shortness of breath and cough, indicative of left ventricular dysfunction, usually occur before that index is reached (Opasich *et al*, 1988).

It is indicated that the measurement of the respiratory exchange ratio during exercise is a useful test of cardiovascular function. It answers the question of how much work the subject can do before the heart fails to meet the tissue oxygen requirements.

G. PSYCHOLOGICAL AND SOCIAL BENEFITS OF RETURNING TO WORK AFTER A CARDIAC EVENT

Heart disease affects several aspects of a person's life. The issue of returning to work after a cardiac event seems to be specially critical. Some psychological factors, in particular, seems to considerably affect the CAD patient. These factors include the attitudes of the patient and his/her family, their understanding of the illness, their expectations and attitudes towards disability. In addition, the physical requirements of the job and the work environment will further influenced the decision to return to work after a cardiac event (Cay and Walker, 1988).

The adjustments usually needed after a cardiac event seem to involve a variety of aspects, ranging from the financial and psychological to the physiological. It has been observed (DeBusk and Davidson, 1980) that patients leaving the hospital after a cardiac event usually limit their activities due to fear that physical activity could precipitate another cardiac event. Thus, many times the CAD patient is not recommended to resume a productive life after the onset of the disease (Fioretti *et al*, 1988).

However, according to Smith and O'Rourke (1988), patients who did return to work after a first MI reported better health status perceptions, stronger socialization and a perception of a greater personal control over important events than did those patients who did not return to work. A better quality of life and feeling of well-being towards life were also observed by Schleifer *et al* (1989) and Cay and Walter (1988) for those patients who did return to work.

In the rehabilitation of the CAD patient, the importance of the issue of returning to work is strongly linked to the sociologic aspect of life. Social and economic impairment can result from prolonged unemployment after a "disabling" disease. Patients express concerns about their economical status, and a delayed return to work seems to mean major financial and psychological problems (Schleifer *et al*, 1989). Changing the patient's job to a less demanding one is not a solution, because change in job can itself lead to psychological problems. There may be added stress if the patient has to learn new skills in a different environment (Cay and Walter, 1988).

There are indications that the economic impact of CAD on some "blue-collar" patients can be reduced by appropriate application of work evaluation techniques (Picard *et al*, 1989; Dennis *et al*, 1988). The techniques suggested involve the use of a clinical test simulating the main tasks which are normally encountered in the workplace. In this way, suitable patients would return to work earlier, perhaps preventing further complications (Picard *et al*, 1989).

H. SUMMARY

A review of the literature points out the serious lack of standardization in the evaluation of work resumption for CAD patients with physically demanding jobs. The standard GXT, currently used to guide these recommendations, lacks most of the components usually encountered in these jobs. Changing one's job to guarantee a productive life is not easily accomplished, and seems to result in additional stress. These facts make the validation of the simulated occupational techniques an urgent task. The simulated work test seems to be a convenient test, allowing great flexibility of design to suit particular clinical questions. It also seems to be an adequate way of achieving a standard rehabilitative assessment for CAD patients (Foster, 1988). However, there is little published literature regarding the issue of the standardization of the simulated work test, and no studies examining its validity and reliability for cardiac patients.

CHAPTER III
METHODOLOGY

A. INTRODUCTION

This chapter will first describe the two pilot studies performed prior to the actual study protocol. The objective of the first pilot study was to check the test-retest reliability of the blood pressure measurements. The objective of the second one was to assess the feasibility of the simulated work test performed by a healthy subject. Then, procedures, equipment and methods of data analysis involved in the main study will be discussed in detail.

B. PILOT STUDIES

The first pilot study, entitled "The intra-rater reliability of blood pressure measurements", was undertaken to guarantee reliable blood pressure readings during the course of the main study. The American Heart Association recommendations for blood pressure measurements were followed (refer to appendix II). Thirteen healthy subjects (age 23-54) had two blood pressure readings on the same day, by the same person, with a maximum of 30-minute interval between the two sessions. Efforts were made to avoid diurnal variations, and the same instrument, which was the calibrated aneroid sphygmomanometer, was used throughout the study.

An intra-class correlation (ICC) analysis was run to examine the reliability of the repeated means. Systolic and diastolic blood pressure were analyzed separately. The unadjusted correlation coefficient, which includes both systematic and random errors, was used. A correlation coefficient of 0.99 was found for both systolic and diastolic measurements.

The second pilot study examined the feasibility of performing the weight carrying and the weight lifting tasks in the clinical setting. One single healthy subject was invited to accomplish the two tasks. This pilot study was extremely useful because it allowed the observation of potential problems. The following changes were suggested from the pilot study:

Weight carrying task

-need to establish an eye reference point. This would allow a better balance when the patients were on the treadmill;

-the weights should be handed in from the sides instead of from the front. Grabbing the weights from the front would compromise the balance and safety of the patient.

Weight lifting task

-need for an eye reference to show the height limit that the weight should be lifted;

-the blood pressure should be measured right after the weights were released, instead of during lifting. The elbow, bent for the lifting, did not allow an accurate reading.

These problems were corrected before the commencement of the study.

C. MAIN STUDY

C1. Subjects

Subjects were nineteen coronary artery disease male patients with a history of MI, CABS and/or PTCA. They were recruited to participate in this study through chart review and recommendations of the attending doctors and rehabilitation nurses. Female participants were not included because it was practically impossible to find women attaining the inclusion criteria concerning occupational status. Eight patients participated in the weight carrying task only, seven in the weight lifting task only, and four in both tasks. All the patients were being followed up by the Cardiology Staff of the University of Alberta Hospitals, Edmonton, Alberta. Patients who attained the following inclusion criteria were invited to participate in the study:

1) Male, age 35-60 years old;
2) History of MI, PTCA and/or CABS with a minimum of 6 weeks since the last cardiac event;
3) A previous occupation requiring moderate to heavy physical effort (eg. farmer, carpenter, bricklayer, welder, etc);
4) Uncomplicated clinical presentation;
5) Normal resting left ventricular function (ejection fraction >40%), measured by radionuclide ventriculography or cardiac catheterization;
6) Attainment of at least 70% of the maximal heart rate predicted for sex and age, as measured during the GXT. At least 60% of that value was required by patients taking ß-blockers.

* A brief explanation of the radionuclide ventriculography and GXT protocols, which were used to select patients for this study, are described in Appendix V.

The exclusion criteria were:

1) Unstable angina;
2) Claudication;
3) Neurological or orthopaedic conditions that may precede angina (like stroke or musculo-skeletal diseases), or preclude exercise testing.

The eligibility of CAD patients for the study was assured by review of the hospital records. Myocardial infarction was diagnosed by the presence of two or more of the following:

i) Typical history of retrosternal chest pain;
ii) ECG change of Q-wave (transmural) acute myocardial infarction;

iii) Elevated serum cardiac enzymes. The CPK-MB, myocardial-specific isoenzyme of CK (creatine-kinase) should be elevated greater than 8% of the baseline values (normal values CPK= 5-35 mU/mL).

Patients with poor left ventricular function may develop wall-motion abnormalities or significant arrhythmias during isometric or isodynamic exertion (Sagiv *et al*, 1985). Therefore, subjects were required to have moderate to good ejection fraction (minimum EF ≥ 40%), and an adequate cardiorespiratory fitness. The former was confirmed by attainment of at least 70% of the maximal age-predicted heart rate during the GXT.

Informed consent was obtained from the patient after the procedures had been fully explained (see appendix I). Permission was also obtained from the attending cardiologist.

C2. Design

This test-retest study examined the reliability of the simulated work test which consists of weight carrying and weight lifting tasks. Subjects performed two test evaluations separated by a 7-12 day interval. Both test sessions were conducted at the same time of day. When all the weight carrying task sessions were finished, the weight lifting task investigation got started. The following variables were measured:

1) Oxygen uptake
2) Rate-pressure product
3) Respiratory exchange ratio

C3. Equipment

For the completion of the study tests and measurement of the proposed variables, the following equipment was used:

C3a. Quinton 2000 treadmill

A Quinton Q2000-motor-driven treadmill, model 55/1983 from the Quinton Medical Company (figure III.1) was used to simulate walking in the weight carrying test. This computerized treadmill, which is commonly interfaced with the electrocardiograph and oxygen analyzer, is routinely used in exercise stress test laboratories.

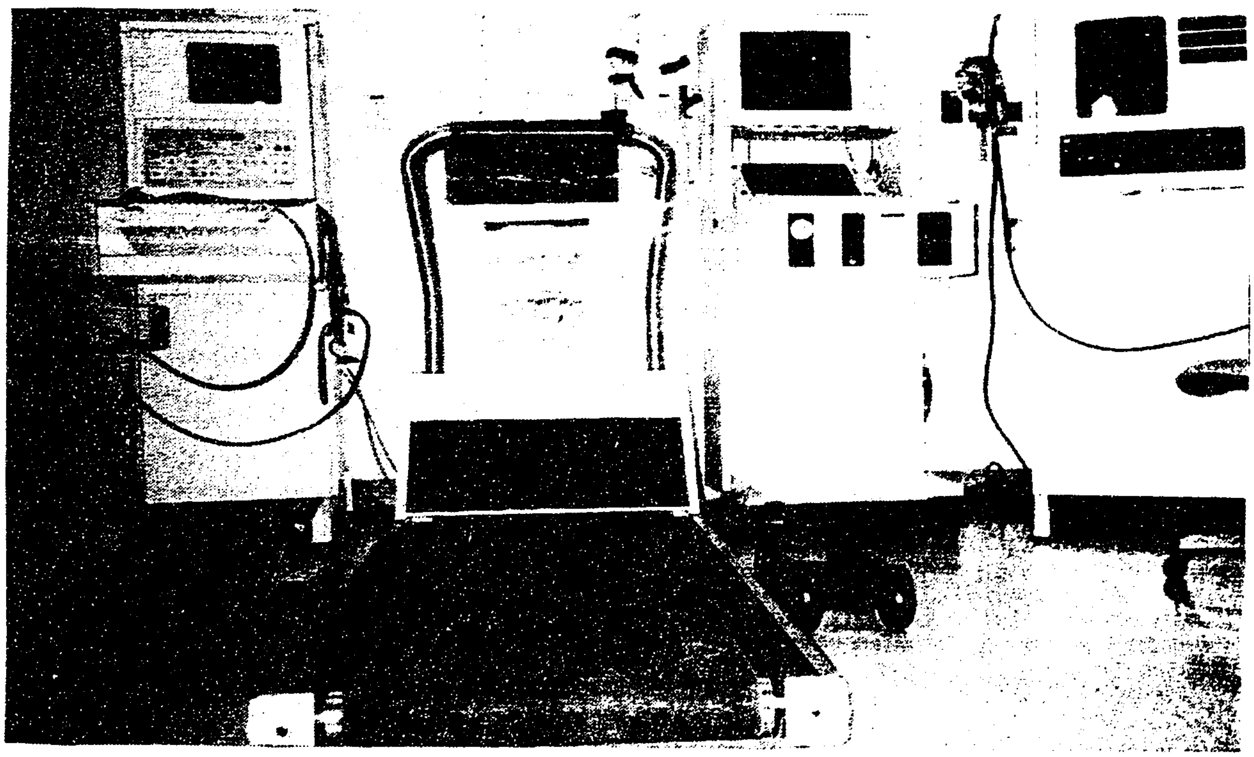

Figure III.1- Illustration of the Quinton 2000 treadmill (Model 55/1983), and set up of loads to be used during the weight carrying task.

C3b. Quinton Q-Plex cardio-pulmonary exercise system

The cardio-pulmonary exercise system, model 1/1989 from the Quinton Instrument Company, is a medical computerized oxygen analyzer. Interfaced with the treadmill and electrocardiograph (figure III.2), it provides a constant measurement of oxygen uptake, carbon dioxide production, tidal volume, respiratory frequency and ventilation, and calculates the respiratory exchange ratio.

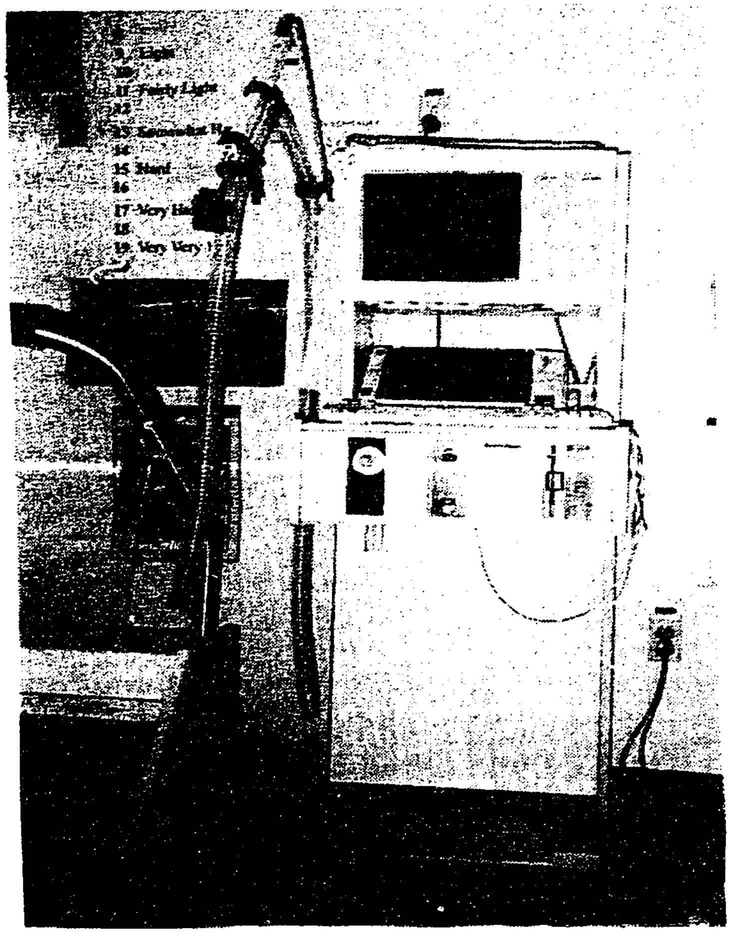

Figure III.2- Quinton Q-Plex cardio-pulmonary exercise system (Model 1/1989).

C3c. Baumanometer mercury sphygmomanometer

A calibrated Baumanometer-mercury sphygmomanometer was used to measure the blood pressure. It is usually recommended as the gold standard instrument for indirect blood pressure measurements (Barker *et al*, 1984).

C3d. Dumbbells and electrodes

Three sets of dumbbells (2 x 10 lbs, 2 x 15 lbs and 2 x

20 lbs) were used during this study to simulate the type of load and exertion usually encountered in the workplace.

The electrodes used to record the ECG were the light weight silver-silver chloride gel types (3M Ltd.), in which skin contact occurs by means of a gel conductor. They measure about 3 cm in diameter, and are known to be the best way to enhance the signal-to-noise ratio in physiological electrical tracings. Also, these electrode cables are designed to reduce motion artifacts.

C4. Tasks

The patients attended at least two identical occupational work evaluations, which were the weight carrying or the weight lifting tasks. Prior to testing all the subjects were provided with individual written information and familiarization instructions. Advice was that they should refrain from ingesting a heavy meal or engaging in vigorous physical activity for at least 3 hours prior to the tests. Specifically for the weight lifting task the patients had orientations, provided on an individual basis, regarding the following factors:

1) Prevention of the Valsalva Manoeuvre. They were instructed to "keep breathing regularly and to avoid straining against a closed glottis", since it would cause a sudden significant rise in blood pressure. The occurrence of the Manoeuvre was confirmed by constant monitoring of the continuous ventilation through the Q-Plex monitor.

2) A proper body mechanics with a free-style to lift the loads was encouraged. They could "lift the loads any way they found more comfortable, since the weights were kept close to the gravitational centre of the body". The optimal range of motion (height to be lifted) was shown, i.e., 84 cm from the floor.

The patient preparation and electrodes placement, using the 12-lead Mason and Likar method (Figure III.6) were similar to the standard GXT patient preparation. The 12-lead ECG, blood pressure measurements and cardiopulmonary changes (**oxygen uptake** and **respiratory exchange ratio**) were recorded continuously throughout the tests. A cardiologist was present at all the test sessions, and any one or all of the following criteria were used as test end-points:

a) Patient request or judgement that he couldn't handle the load;
b) Attainment of maximum age-predicted heart rate;
c) Anginal pain or ECG changes suggestive of ischemia (ST segment depression greater than 2 mm or T wave alterations or appearance of Q wave);
d) Vertigo, pallor, cyanosis, serious arrhythmias, dyspnea, drop in systolic blood pressure.

C4a. Weight carrying task

The loads were set up on the floor, beside the treadmill (see figure III.1). A two dumbbell set of 10, 15 and 20 lbs was placed at a convenient position at each side of the treadmill. The patients performed three stages of walking and carrying weights. Stages were three minutes each and separated from each other by three-minute rest intervals. The treadmill speed was set at 2 mph, with an inclination constantly set at zero percent. Two people were necessary to hand the loads to the patient from the sides at the right time, and to take them as soon as the treadmill had stopped. The patient was then allowed to rest in a sitting position right after completion of each stage. The mouthpiece, reported to be very uncomfortable, was removed as soon as the last task stage was completed.

Figure III.3 shows the schematic representation of the weight carrying task.

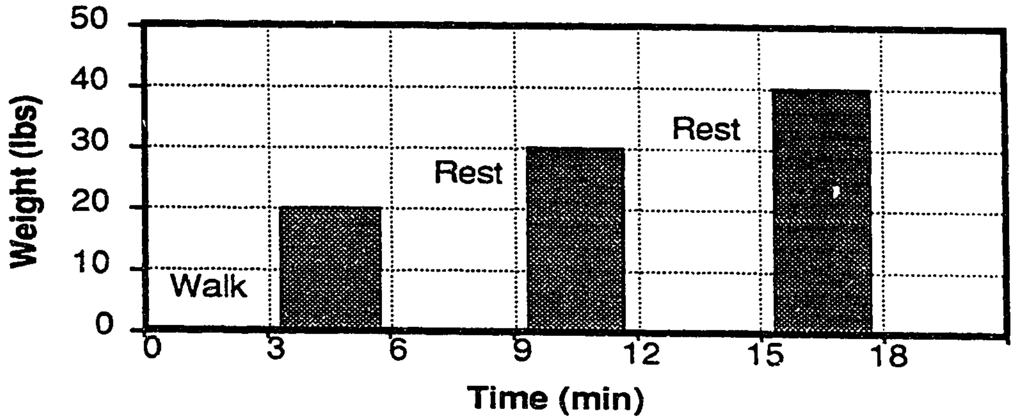

Figure III.3- Schematic representation of the weight carrying task

C4b. Weight lifting task

Two identical sets of dumbbells were arranged on the floor in front of the patient (figure III.5). A visual indication of the height to lift the load was placed at 84 cm from the floor. Patients lifted dumbbells for three four-minute stages separated by a three-minute rest interval. Please refer to Figure III.4 for a schematic representation of the weight lifting task. Patients were instructed to lift the loads in a free style, always preventing the Valsalva Manoeuvre, in a rate of four per minute. The lifting rate was timed from the computer clock.

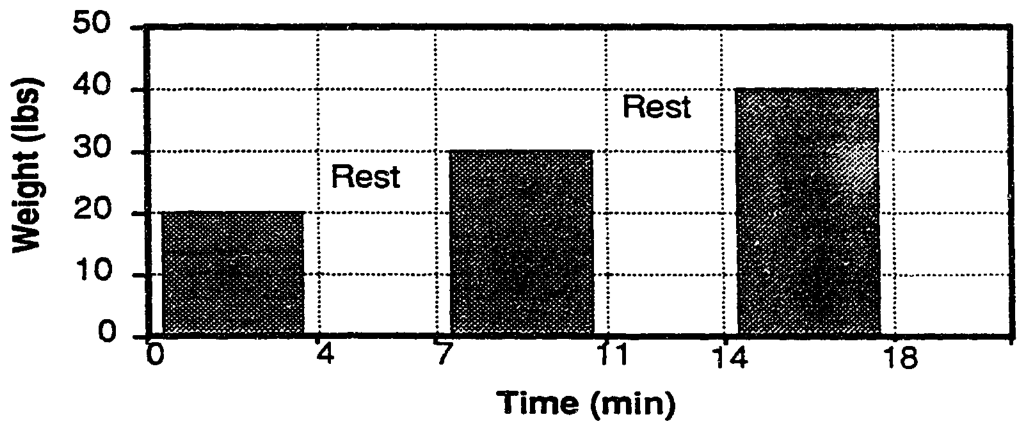

Figure III.4- Schematic representation of the weight lifting task

Figure III.5- Weight lifting task set up.

C5. Physiological measures

C5a. Blood pressure

The blood pressure was measured during the last 20 seconds of each stage of the weight carrying task. For the weight lifting task, however, this same procedure was not technically possible because the elbow was flexed during the lifting. Thus, the blood pressure was measured immediately after the weights were released. The same person performed all the measurements, and the technique was standardized according to the American Heart Association Recommendations for Blood Pressure Determination by Sphygmomanometers/1981 (Appendix II).

C5b. Heart rate

The standard 12-lead ECG was used, with electrode placement consistently based on the Mason and Likar diagram (Figure III.6). The areas used for electrode placement were shaved and the superficial layer of skin was gently abraded with a fine-grained sandpaper and cleansed. After an adequate skin preparation, the electrodes were applied.

The heart rate was then obtained from the ECG tracing, a method widely used in clinical and research settings. It is known to be the most reliable way to monitor heart rate and other changes suggestive of arrhythmias or ischemia (such as level of ST depression, slope, aberrant beats). The reading obtained from the continuous printout was confirmed by manual reading through the ECG ruler.

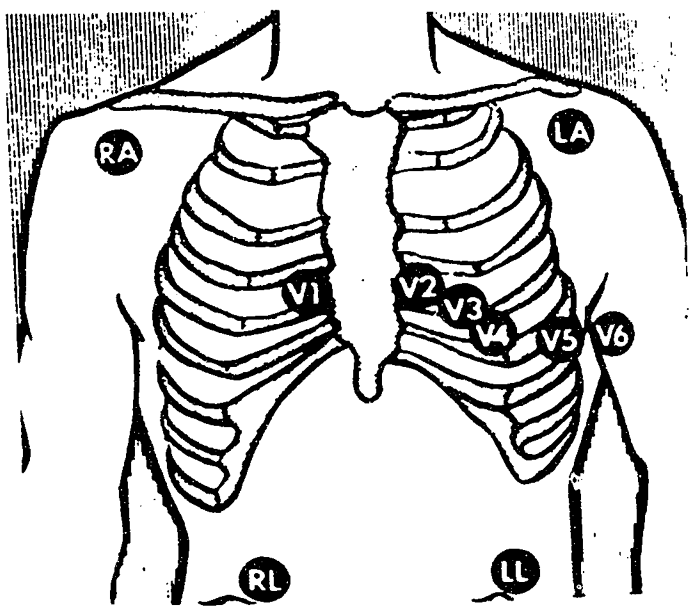

Figure III.6- Twelve-lead positions commonly used in exercise testing as modified by Mason and Likar, 1956.

C5c. Oxygen uptake ($\dot{V}O_2$) and carbon dioxide ($\dot{V}CO_2$)

Oxygen uptake and $\dot{V}CO_2$ were recorded simultaneously by the Quinton Q-Plex Cardio-Pulmonary Exercise System during the tests. Through continuous breath-by-breath measurements, the system provided a constant analysis of the metabolic demands and overall exercise performance. The data output was obtained every 20 seconds during the test.

To measure $\dot{V}O_2$ and $\dot{V}CO_2$ from pulmonary gas exchange, the patients exercised with a head apparatus, breathing through a mouthpiece and a low resistance, non-rebreathing three-way valve (figure III.7). The nose was clamped to avoid breathing or losing air through it. The $\dot{V}O_2$ was automatically calculated after determination of expired gas volume ($\dot{V}E$, ml/min), FEO_2, $FECO_2$, expired gas temperature and barometric pressure (Appendix III).

C6. OUTCOME MEASURES

C6a. Rate-pressure product

The rate-pressure product was calculated manually. It was the product of systolic blood pressure and heart rate, recorded at the same time at the end of each stage. The rate-pressure product is an indirect estimation of myocardial oxygen consumption during the simulated work test.

C6b. Oxygen uptake

The oxygen uptake recordings for the last minute were averaged for each subject, and the values were registered for data analysis.

C6c. Respiratory exchange ratio

The respiratory exchange ratio values from the last minute were also averaged for each subject. It is calculated automatically from the ratio of carbon dioxide production ($\dot{V}CO_2$) and oxygen uptake ($\dot{V}O_2$), i.e., $R= \dot{V}CO_2/\dot{V}O_2$). The value, in interval scale, usually ranges from 0.70 to 1.

Figure III.7- Head apparatus and mouthpiece with a three-way non- rebreathing valve for measurement of oxygen uptake.

D. DATA ANALYSES

The data were expressed as mean and standard deviation. A two-way ANOVA with repeated measures on both factors (session versus stage) was used to examine differences between sessions for the variables:

i) Oxygen Uptake

ii) Respiratory exchange ratio

iii) Rate-pressure product

The two-way ANOVA examined the hypothesis that:

1) Weight carrying and weight lifting simulated occupational

tests would provide reproducible data on these variables.

When the F-ratio from the two-way ANOVA analysis was statistically significant ($p < 0.05$), a Newman-Keuls post-hoc analysis was used to locate the pairwise mean differences. An ICC was also calculated for each variable, to provide a correlation coefficient indicative of the test-retest reliability (Winer *et al*, 1991). The simulated work test would be considered reliable if an ICC greater than 0.8 were obtained and if no significant differences between sessions were found. The standard error of the measurement (SEM) was also calculated to assess the variance of each measurement (Rothstein, 1985).

E. ETHICAL CONSIDERATIONS

The safety of the application of loads up to 50 lbs for cardiac patients has been established (Sheldahl *et al*, 1985; Butler *et al*, 1987; Rod *et al*, 1989). The patients were tested in the stress testing laboratory of the Department of Cardiology, where safety equipment and trained personnel are permanently available in case of an emergency. A cardiologist was in attendance at all tests.

The study participants were informed of the nature of the study and its potential risks. Informed consent was obtained after all the procedures had been fully explained. Patients at high risk for performing the tests were excluded based on the evaluation of resting left ventricular function and results of a standard GXT. Guidelines for stopping during the tests were standardized according to the American College of Sports Medicine (1986). Each testing session was conducted on one occasion for each patient for less than one hour. The patients were told that they could withdraw from the study at any time without prejudice or coercion (see Appendix I).

All records and data from this study were kept strictly confidential. The patients were told that they would be referred to only by subject number in any presentation of the study data. Ethics approval was obtained from "Ethics Review Committee For Human Experimentation", University of Alberta, Faculty of Medicine in October/1990.

CHAPTER IV
RESULTS

This study examined the reproducibility of the simulated occupational test, composed of weight carrying and weight lifting tasks, performed by CAD patients. This chapter was divided in different sessions to display the study results.

The first part reports the patient characteristics and clinical data. The second part describes the data and results obtained throughout the study, i.e., the two-way ANOVA results, means, standard deviations, intra-class correlation (ICC) coefficients and standard error of the measurements (SEM), for the three variables investigated. The weight carrying and the weight lifting tasks will be described separately.

A. PATIENTS' CHARACTERISTICS

Tables IV.1, IV.2 and IV.3 illustrate the characteristics of the nineteen male CAD patients participating in this study.

TABLE IV.1

Physical characteristics of the study subjects.

Patient Group		Age (years)	Height (cm)	Weight (Kg)
WCT n=12	mean ± S.D.	53 ± 8.33	175.3 ± 7.5	84.3 ± 16.18
WLT n=11	mean ± S.D.	50 ± 7.31	178.0 ± 7.3	86.9 ± 14.01

TABLE IV.2

Frequency of cardiac events in the study subjects

Cardiac event and MI location	WCT n=12	WLT n=11
MI (based on ECG)	12	9
Ant	5	2
Inf	4	5
Subend	3	2
MI only	5	3
PTCA only	0	2
MI + PTCA	3	3
MI + CABS	3	3
MI + PTCA + CABS	1	0

WCT= Weight Carrying Task   WLT= Weight Lifting Task

TABLE IV.3

Resting left ventricular ejection fraction (LVEF) and the % of the age-predicted maximal heart rate of subjects.

Patient Group	Resting LVEF (%)	Total B-blocker	% HR GXT B-Blocker	[illegible] GXT [illegible] B-Blocker
WCT	7[illegible].33 ± 7.57	8	71.00 ± 10.01	91.0 ± 7.4
WLT	63.00 ± 7.07	6	74.71 ± 13.77	90.5 ± 6.6

There were no drop-outs from this study, probably due to the support of the attending physician. The patients were attending regularly for follow-up anyway. As a matter of fact, many of them were very interested in knowing how well they would perform the simulated work test, since they were planning to return to their occupational activity.

Because 70% of the subjects had their resting left ventricular ejection fraction (LVEF) derived from cardiac catheterization methods, the LVEF value may be unusually high, as compared to what it would be if only radionuclide ventriculography methods had been used.

B. WEIGHT CARRYING TASK

The tests occurred smoothly and were well tolerated by the patients. No abnormalities, such as serious arrhythmias, drop in systolic blood pressure or anginal pain occurred. The Valsalva Manoeuvre, which would have caused a sudden increase in blood pressure due to increased intrathoracic pressure, did not occur. The non-occurrence of this manoeuvre was confirmed through constant monitoring of the ventilation by the Q-Plex system.

The ANOVA results for the three outcome measures for the weight carrying task are presented in **tables IV.4 to IV.6**. For both the oxygen uptake and rate-pressure product, there were significant differences among stages and no significant differences between days. However, the difference between days approached significance for both variables. There was a significant day/stage interaction for the respiratory exchange ratio variable only.

TABLE IV.4

Summary of two-way ANOVA of <u>oxygen uptake</u> for the weight carrying task.

SOURCE	MS	F-RATIO	PROB
DAY Error	8.84 1.93	4.57	0.055
STAGE Error	7.10 0.10	71.94	0.001
DAY X STAGE Error	0.38 0.17	2.29	0.125

Significance level= $p < 0.05$

TABLE IV.5

Summary of two-way ANOVA of <u>rate-pressure product</u> for the weight carrying task.

SOURCE	MS	F-RATIO	PROB
DAY Error	11809000 3625500	3.26	0.098
STAGE Error	35785000 372886	95.97	0.0003
DAY X STAGE Error	564989 403652	1.40	0.268

* Significance level= $p < 0.05$

TABLE IV.6

Summary of two-way ANOVA of <u>respiratory exchange ratio</u> for the weight carrying task.

SOURCE	MS	F-RATIO	PROB
DAY Error	0.00142 0.00051	2.80	0.122
STAGE Error	0.00200 0.00068	2.95	0.106
DAY X STAGE Error	0.00170 0.00020	7.64	0.0048*

* Significance level= $p < 0.05$

The interaction is plotted and shown in **figure IV.1.** The post-hoc comparisons are shown in **table IV.7** along with the mean and standard deviation for each variable.

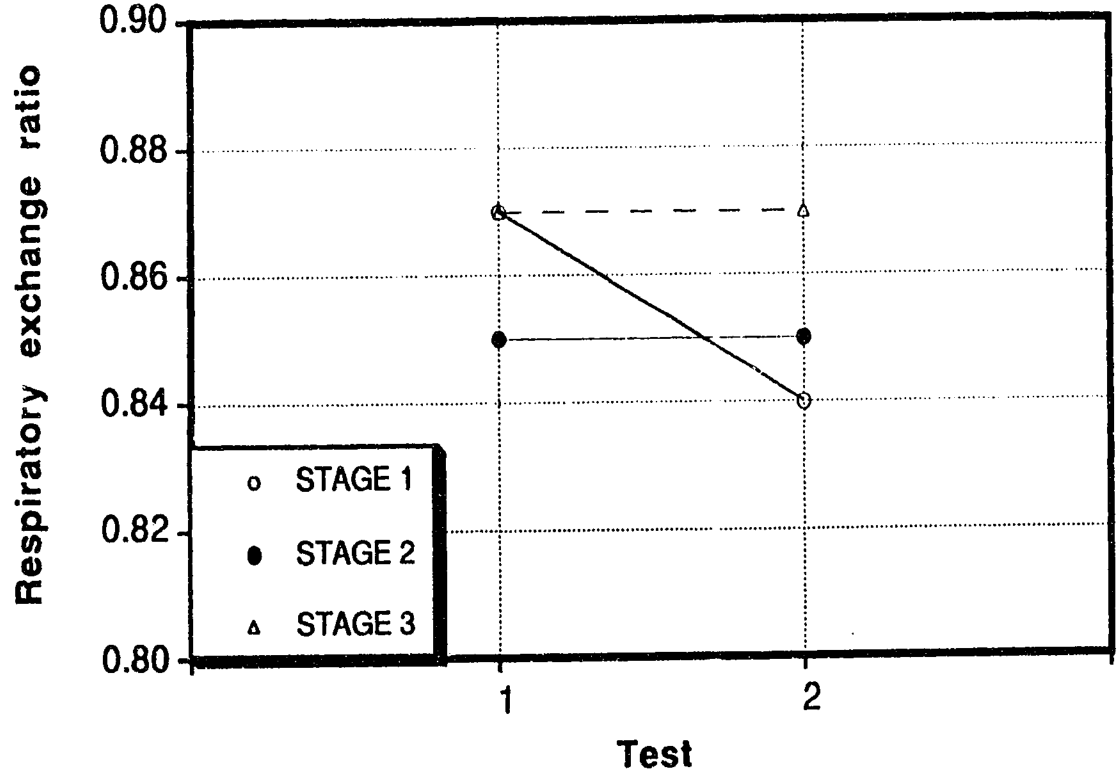

Figure IV.1.- Respiratory exchange ratio on 3 stages of the weight carrying task in 2 occasions

TABLE IV.7

Physiological measurements for weight carrying task for days one and two, and resultant ICC and SEM values.

Variable Stage		Mean ± Standard Deviation T1	T2	ICC unadj	adj	SEM
SBP	Stage 1	148.17 ± 16.28	144.17 ± 19.64	0.70	0.71	4.70
(mmHg)	Stage 2	158.33 ± 15.90	154.83 ± 19.02	0.91	0.92	4.59
	Stage 3	168.33 ± 18.39	161.83 ± 20.84	0.76	0.86	5.31
HR	Stage 1	90.33 ± 14.18	86.33 ± 11.83	0.88	0.92	4.09
(bpm)	Stage 2	92.00 ± 12.74	90.83 ± 12.10	0.97	0.91	3.68
	Stage 3	94.75 ± 12.52	92.33 ± 12.92	0.79	0.85	3.61
$\dot{V}O2$	Stage 1	12.54 ± 1.91	1[illegible]55 ± 1.55	0.20	0.17	1.62
(ml/Kg	Stage 2	12.74 ± 1.74*	12.19 ± 1.74*	0.17	0.17	1.82
/min)	Stage 3	13.41 ± 1.66*■	12.85 ± 1.65*■	0.28	0.25	1.38
	Stage 1	13489 ± 3068	12521 ± 2687	0.33	0.30	2433
RPP	Stage 2	14581 ± 2468*	14125 ± 2869*	0.27	0.24	2545
	Stage 3	15946 ± 2522*■	[illegible]40 ± 2716*■	0.56	0.54	1900
	Stage 1	0.87 ± .05	0.84 ± .04	0.20	0.16	0.03
R	Stage 2	0.85 ± .03	0.85 ± .04	0.38	0.35	0.05
	Stage 3	0.87 ± .04	0.87 ± .05	0.35	0.32	0.05

* Significantly greater than stage 1
■ Significantly greater than stage 2

Both the adjusted and unadjusted reliability correlation coefficients are presented in **table IV.7**. These analyses showed a very low correlation for all the outcome measures.

C. WEIGHT LIFTING TASK

The test-retest sessions for the weight lifting task occurred in conditions which were similar to the weight carrying task. A limited sample of 11 patients attaining the same inclusion criteria participated in this task. However, for two of these patients the conditions of the second test was slightly changed from the first. One subject had a decreased ß-blocker dosage on the second test, and the other patient was first tested in the morning and then retested in the afternoon. The data was analyzed with and without these subjects. Overall, no angina, serious arrhythmias or other significant problems occurred for any of the study participants during the testing sessions.

The results of the two-way ANOVAs are presented in **tables IV.8, IV.9** and **IV.10**. There were no statistically significant differences between days for all the variables. However, as displayed in **table IV.11**, both the adjusted and unadjusted ICC coefficient are quite low. The SEMs shown in **table IV.11** were low.

There were significant differences between stages for all variables. Post-hoc analysis and descriptive statistics are presented in **table IV.11**.

TABLE IV.8

Summary of two-way ANOVA of oxygen uptake for the weight lifting task.

SOURCE	MS	F-RATIO	PROB
DAY Error	8.09 6.60	1.23	0.293
STAGE Error	9.96 0.46	21.58	0.0001*
DAY X STAGE Error	0.58 0.44	1.32	0.287

* Significance level = 0.05

TABLE IV.9

Summary of two-way ANOVA of rate-pressure product for the weight lifting task.

SOURCE	MS	F-RATIO	PROB
DAY Error	193330 47441000	0.41	0.537
STAGE Error	22708000 615885	36.87	0.0001*
DAY X STAGE Error	38008 516590	0.07	0.883

* Significance level = 0.05

TABLE IV.10

Summary of two-way ANOVA of respiratory exchange ratio for the weight lifting task.

SOURCE	MS	F-RATIO	PROB
DAY Error	19.6 19.9	0.98	0.345
STAGE Error	48.1 532.2	9.04	0.007*
DAY X STAGE Error	3181.0 920.1	0.03	0.953

* Significance level = 0.05

TABLE IV.11

Physiological measurements for weight lifting task for days one and two and resultant ICC and SEM values.

Variable Stage	Means ± Standard Deviations T1	T2	ICC unadj	adj	SEM
SBP (mmHg) Stage 1	129.09 ± 15.03	131.27 ± 14.43	0.84	0.82	4.53
Stage 2	134.90 ± 13.57	136.00 ± 17.86	0.81	0.78	4.09
Stage 3	137.82 ± 15.14	137.09 ± 15.55	0.60	0.58	4.56
HR (bpm) Stage 1	98.27 ± 16.35	98.09 ± 13.26	0.93	0.90	3.99
Stage 2	104.45 ± 18.70	104.18 ± 15.93	0.92	0.91	4.80
Stage 3	108.63 ± 18.42	108.82 ± 19.57	0.93	0.91	5.90
$\dot{V}O_2$ (ml/Kg/min) Stage 1	13.21 ± 2.11	13.62 ± 2.59	0.07	0.03	1.95
Stage 2	13.59 ± 2.10*	14.23 ± 2.18*	0.57	0.64	1.65
Stage 3	14.22 ± 2.32*■	15.27 ± 1.80*■	0.27	0.24	1.90
RPP Stage 1	12661 ± 2416	12909 ± 2602	0.71	0.69	1647
Stage 2	14023 ± 2465*	14213 ± 3353*	0.07	0.09	9248
Stage 3	14596 ± 2681*■	15001 ± 3367■	0.23	0.19	2722
$\bar{R}$ Stage 1	0.82 ± .07	0.81 ± .07	0.80	0.79	0.04
Stage 2	0.84 ± .06	0.82 ± .06	0.51	0.48	0.05
Stage 3	0.85 ± .08	0.83 ± .05	0.27	0.28	0.06

* Significantly greater than stage 1
■ Significantly greater than stage 2

The next two **tables**, **IV.12** and **IV.13**, describe the findings encountered during the analysis of the weight lifting task data when the sample size was composed of only nine patients. This analysis excludes the two patients who had the retesting session performed in different conditions, as compared to the first test. The results did not differ from the analyses on all eleven subjects.

TABLE IV.12

Physiological measurements for weight lifting task for days one and two and resultant ICC and SEM values (n= 9).

Variable	Stage	Mean ± standard deviation T1	T2
$\dot{V}O_2$	Stage 1	13.23 ± 1.98	12.94 ± 2.18
(ml/Kg	Stage 2	13.80 ± 2.08*	13.79 ± 2.16*
/min)	Stage 3	14.26 ± 2.35*■	14.87 ± 1.75*■
	Stage 1	12413 ± 2207	12397 ± 1910
RPP	Stage 2	13836 ± 2493*	13640 ± 2208*
	Stage 3	14615 ± 2756*■	14526 ± 2403*■
	Stage 1	0.81 ± .06	0.81 ± .07
R	Stage 2	0.83 ± .06	0.82 ± .06
	Stage 3	0.85 ± .08	0.83 ± .05

* Significantly greater than stage 1
■ Significantly greater than stage 2

TABLE IV.13

Summary of two-way ANOVA for the weight lifting task (n=9).

Variable	Source	F-ratio	Prob
$\dot{V}O2$	Day	0.13	0.73
(ml/Kg	Stage	25.02	0.003*
/min)	D x S	2.67	0.108
RPP	Day	0.05	0.828
	Stage	38.23	0.0003*
	D x S	0.09	0.830
R	Day	0.72	0.421
	Stage	9.64	0.007*
	D x S	0.18	0.804

* Significance level = $p < 0.05$
D=Day - S=Stage

CHAPTER V
DISCUSSION

This study was undertaken to examine the reproducibility of the simulated work test, which consists of weight carrying and weight lifting tasks. The simulated test has the objective of determining the fitness of uncomplicated CAD patients to safely resume physically demanding jobs.

Results from this study were not conclusive in terms of establishing the simulated work test as a reproducible tool. Additional research is recommended to clarify this test's reliability and validity. A brief explanation of the meaning of the statistical methods used to analyze the data will be followed by a separate discussion of each outcome variable. Then, general observations from both tasks will be discussed.

A. STATISTICAL CONSIDERATIONS

To be assured of a good test-retest reliability of the simulated work test, the results for each of the variables evaluated should include:

1) No significant difference between days.
2) An ICC greater then 0.8.
3) A clinically insignificant SEM.

The **two-way ANOVA** analysis was used to determine the overall differences between days and stages. Different F-ratios, represented by the mean square between divided by the mean square within, were obtained for each source, i.e., day, stage and day versus stage. The mean square between is a reflection of the difference between subjects. The mean square within is affected by the differences between times. Thus, the greater the variance between each patient score, the higher the mean square between would be, and a higher F-ratio would result. The larger the sample size, the more powerful is the test in terms of detecting a significant difference between means. In the present study the sample sizes were small.

The **ICC** is commonly used for reliability assessments. It is derived from a one-way ANOVA with repeated measures and is representative of the ratio of the mean square between and mean square within, as shown by the formula:

$$ICC = \frac{MS_b - MS_w}{MS_b + (K-1)(MS_w)}$$

MS_b= Mean square between subjects
MS_w= Mean square within subjects
K= Number of repeated measures

Therefore, if there is little variance among the subjects' scores (i.e., MS_b is small), or if there is a large variance between repeated measures, the ICC values will tend to be low (Winer *et al*, 1991).

Theoretically, the **standard error of the measurement** (SEM) is calculated to estimate the possible variability in each individual reading. The true value for the measurement could be plus or minus the value of the SEM (Rothstein, 1985). Therefore, this value can be useful for clinical judgements.

B. OXYGEN UPTAKE

B1. Weight carrying task

Although there was no statistically significant difference in oxygen uptake between test sessions, the probability ($p=0.055$) **table IV.4** approached significance. The retest session provided mean scores which ranged between 4-8% lower than the first test (**table IV.7**) (refer to Appendix V to observe the raw data). The subjects may have been more anxious in test one than in test two, even though they were familiarized with the procedures prior to testing. In addition, it is quite likely that the probability would be less if a larger sample size had been used, since it would provide a more powerful test.

The way in which anxiety and learning effect might have affected the test results is explained as follows. Besides the known physiological factors affecting the amount of oxygen uptake, psychological factors like anxiety also are active in this process. Adrenergic stimuli are released during stress and increase the heart rate, breathing rate and the contractile force of the heart muscle fibres (Astrand and Rodahl, 1986). These observations occurred during this study, mainly in the first minutes of the first test session of the weight carrying task. Variations in the cardiac output, usually associated with an almost linear variation in the amount of oxygen uptake, may also have occurred. The cardiac output, which is the product of stroke volume and heart rate, directly influences the amount of oxygen uptake (VO_2=cardiac output x arteriovenous oxygen difference)(Irwin and Tecklin, 1990). It is also suggested that learning effect might have affected the consistency of the results obtained over time. It is assumed that a third test could perhaps provide results consistent with the results from the second test, showing a higher efficiency level during the performance of the task.

Although the tasks interstage differences were significant (**table IV.7**), their means were quite close. Surprisingly, sometimes the difference between stages is less than the difference between days. The small increases in the amount of oxygen uptake to progressively increasing work rates may reflect a limitation of the cardiac output. Wasserman and Sietsema (1988) observed this same response in 65% of the patients with ischemic heart disease studied, as compared to a healthy population.

The clinical characteristics of the sample evaluated were very similar (**tables IV.1 TO IV.3**). It is assumed that the low variability between the patients scores influenced the low ICC coefficient (**table IV.7**). Reports from Wermuth *et al* (1990), who studied a similar population, show that means and standard deviations for peak oxygen uptake during the weight carrying tasks were in the range of 18 ± 2 ml/Kg/min. The means obtained from this present study (**table IV.7**) were small in comparison to Wermuth *et al*'s findings, while the standard deviations are comparable.

The oxygen uptake analysis showed that the SEM values varied from 10.3 - 14.9% of the mean scores for both weight carrying test sessions (**table IV.7**). These values are representative of about 0.5 MET, or half of the metabolic requirements for one minute in resting conditions. According to Astrand and Rodahl's reports (1986), the limits of SEM for prediction of maximal oxygen uptake during submaximal exercise were 10% for well trained healthy individuals and 15% for non-trained ones. Considering that this study investigated only CAD patients, who usually attain a low maximal oxygen uptake, the SEMs reported by this present study should not represent a significant clinical value.

B2. Weight lifting task

The two-way ANOVA and the SEM results, which were less than 10% of the measured value, indicated that the weight lifting task is a reproducible tool. No significant differences between mean values of test-retest sessions were detected (p= 0.293), although the mean scores were lower on the second test (**table IV.8** and Appendix V). However, the ICC suggested the opposite idea (**table IV.11**). Overall low ICC coefficients showed a poor relationship between tests one and two. However, since two out of three statistical methods factors favour the reproducibility of the weight lifting task. Therefore, considering the limitations of the statistical method, it is concluded that it has the potential to be clinically evaluated as a reproducible tool.

Overall, test-retest raw data (Appendix V) indicates slightly higher oxygen uptake values on the weight lifting task retest session. However, these differences are not statistically significant. It is suggested that at least three test sessions would be required to observe trends in the consistency of the data. Probably the same factors interfering with the weight carrying task would seem to influence the weight lifting task as well. Less anxious and more efficient patients should determine more stable results in the following test sessions (Astrand, 1986). Also, part of the weight lifting task sample (37%) had already participated in the weight carrying task sessions. These patients were possibly relatively more efficient than their colleagues.

There are no reports of normal subjects performing the simulated work test. However, measures of maximal and submaximal oxygen uptake in healthy subjects are normally highly reproducible, as stated by Astrand and Rodahl (1986). The low ICC reported by this present study seems to result from the low patient variability (table IV.11). Patients participating in this study were all clinically stable, promptly attaining the inclusion criteria and volunteering to participate. They could be representative of a more cooperative, thus biased, part of the CAD population. Perhaps a wider portion of this population, randomly selected, would represent a higher between subject variance. In addition, more generalization of the study results could be allowed.

At the same time, if a study was being conducted on subjects similar to those in this study, statistically significant differences could occur just because of measurement variability. Then, it is suggested that at least two tests would need to be performed to guarantee a stable baseline measure before treatment.

C. RATE-PRESSURE PRODUCT

C1. Weight carrying task

Since this variable is a product, its factors will be discussed separately. Then, the rate-pressure product will be discussed as a whole.

According to the mean scores of test-retest sessions (**table IV.7**), the systolic blood pressure readings were consistently lower on the second test (Appendix V shows the raw data). The obtained SEM value was about 4.90 mmHg. Analyzed from a clinical viewpoint, this value does not seem to represent a significant variability in the systolic pressure measurement. As stated by Irwin and Tecklin (1990), the limitation in reliability of indirect blood pressure recordings is so much during exercise, that only major changes are considered significant, specially for the systolic blood pressure. For this study, the intra-tester reliability of blood pressure measurements at rest was checked primarily checked in a pilot study (r=0.99).

The interstage blood pressure variation was very low, even though the test was gradually incremented with heavier loads. Astrand and Rodahl (1986) explains this finding as follows. During exercise periods of short duration or intermittent exercise, the increase in the systolic blood pressure is initially minimal. This happens because the initial adaptations to exercise include a marked dilation of the arteries of the exercising muscles. Thus, there is a redistribution of the blood flow in the body and then a fall of the total peripheral resistance. Since initially the cardiac output is slightly increased to adapt to exercise, the blood pressure (as a product of the cardiac output and total peripheral resistance) is kept constant or slightly increased (Astrand and Rodahl, 1986). Blood pressure responses to the simulated occupational tasks, as evaluated by this study, agree with Astrand and Rodahl (1986) reports.

The heart rate response in different stages of the weight carrying task was also low. Since all the patients were somewhat "trained" for this activity (because their occupations involved the same tasks), the low heart rate observed should not be surprising. Possibly a raised sympathetic tone during the first test session, and anxiety due to inexperience, caused the small differences in test-retest values.

The rate-pressure product, as a product of the systolic blood pressure and heart rate, followed the same pattern as its factors, i.e., it was also lower on the second day. However, ANOVA results were approaching significance between the two sessions (p=0.098), **table IV.5**. Once again, the difference is assumed to be due to sympathetic activity and learning effect.

There was very little difference between adjusted and unadjusted ICC coefficients. This fact indicates that a major systematic error did not occur. It also means that different random factors such as anxiety and learning effect could have played a role in the low reliability values. Because the rate-pressure product variable is a product, possible errors occurring in each factor separately would be further magnified. Descriptive statistics (**table IV.7**) seem to indicate that a physiological confounding bias (learning effect, anxiety) was affecting the first test results, which were lower than the second test day for 67% of the patients. Therefore, as suggested earlier in this discussion, perhaps results from a third test would be more consistent with those results of the second test.

C3. Weight lifting task

As shown in **table IV.11**, the systolic blood pressure and heart rate readings were very similar in test-retest sessions of the weight lifting task. During the weight carrying task, the retest session consistently provided values lower than the first test. It is likely that one of the reasons for this increased stability on the weight lifting task occurred due to the fact that 37% of the patients participated in both tasks. Perhaps these patients were more familiarized with the protocols because the previous experience. It is also suggested that both tasks (weight carrying and weight lifting) demand different degrees of exertion. For example, the weight carrying task involves more isometric effort than the lifting task, which has a lift-rest cycle.

A similarity between means of the rate-pressure product in test-retest sessions was also observed (**table IV.9**). However, low ICC coefficients were obtained (**table IV.11**). From these findings it is suggested that the same factors affecting the weight carrying task (learning effect and efficiency level, and sample selection) may have affected the weight lifting task results.

According to the clinical records, many of the patients participating in this study had a history of angina occurring at a low rate-pressure product during the GXT. Nevertheless, no angina or significant arrhythmias occurred during the simulated work test, even though similar or higher rate-pressure products were observed. Findings from Rod *et al* (1989), during testing of the same category of patients with the same protocols, supported these results.

Explanations for the non-occurrence of angina or ischemic responses during static effort are speculated by Amsterdam *et al* (1974) and DeBusk *et al* (1978). Angina is the result of an imbalance between myocardial oxygen demand and supply that is typically related to a restricted coronary circulation consequent to arteriosclerosis (Amsterdam *et al*, 1974). These researchers argue that the onset of ischemic responses, shown by ECG ST segment changes and angina, is usually rare during those situations mainly because of the high diastolic pressure which occurs. They suggest that the elevated diastolic pressure, associated with an elevated left ventricle diastolic volume and elevated wall tension resultant from isometric effort would contribute to an increased subendocardial perfusion. Consequently there would be decreased myocardial blood flow requirements and thus a low rate-pressure product, which is assumed to represent the myocardial oxygen uptake. At the same time, a lower peak heart rate would also suggest that the myocardial oxygen uptake would be decreased by superimposing static on dynamic effort. Perhaps the increased time of myocardial tension during isometric effort would allow the heart to obtain more oxygen, thus improving the perfusion. This enhanced myocardial perfusion would perhaps prevent the ischemia from occurring.

D. RESPIRATORY EXCHANGE RATIO

D1. Weight carrying task

The reason behind the interaction occurring during the weight carrying task, shown in **table IV.6**, is probably explained by the fact that the respiratory exchange ratio variable was so stable that even slight variations were detected. Since the exercise was not demanding enough to trigger the anaerobic metabolism, it was expected that the respiratory exchange ratio values would not vary significantly. A variation of 0.05, as observed in the SEM, certainly did not represent physiological changes in the aerobic process of energy extraction. This interaction may have been caused probably due to anxiety, as it was shown by hyperventilation occurring mainly during test one of the weight carrying task. The magnitude of the physiological changes do not seem to indicate any clinical significance.

It is reported that some CAD patients can reach the anaerobic threshold at oxygen uptake values as low as 8.6 ± 0.7 ml O_2/Kg/min (Opasich *et al*, 1988). However, the same observation did not occur during this study. Perhaps this fact happened because the simulated work test involves mainly intermittent work, or because the patients were clinically very stable. The respiratory exchange ratio never exceeded 1, or indication of the onset of anaerobic metabolism was not observed during the study. For these reasons, the non-significance of the interstage difference for this variable **(table IV.7)** was not surprising. If each exercise stage had been longer and greatly stressful, the maximal oxygen uptake could eventually be achieved. The metabolic fuel could then be changed to generate energy through anaerobic sources, and the carbon dioxide production would perhaps exceed the amount of oxygen uptake.

Astrand and Rodahl (1986) support this argument. By simulating occupational tasks of intermittent bouts, such as brick laying and carpentry tasks, healthy individuals were allowed to exercise at their own preferred rate. It was observed that they worked consistently at an intensity of about 40% of their maximal oxygen uptake. These individuals rarely achieved the anaerobic threshold and the blood lactate concentration was kept relatively stable, indicating an almost balanced oxygen supply to the exercising muscles. The low oxygen uptake values and the general non-attainment of anaerobic threshold found during this present study are in agreement with Astrand and Rodahl (1986). It is then suggested that during labour work, an "economical" level of oxygen consumption is kept, from a physiological point of view.

This study did not evaluate the maximal aerobic capacity of the CAD patients. While the investigation of the maximal oxygen uptake is useful in the evaluation of athletes and healthy subjects, the same does not occur for the CAD population. Le Jemtel *et al* (1985) report that many of these patients usually have end-point symptoms suggestive of left ventricular impairment before they attain a point of maximal oxygen uptake.

One of the possible explanations for the low ICC observed for the respiratory exchange ratio (**table IV. 7**) can be the study sample, as explained earlier in this chapter. In a sample whose patients have similar clinical conditions, the variability between subject tends to be small. Besides considerations on the limitations of the ICC method, a small between subjects variance will tend to lower the correlation coefficient.

D2. Weight lifting task

During the weight lifting task, there were no significant differences in test-retest reliability of the respiratory exchange ratio (p=0.344) (**table IV.10**). No interaction was observed during the weight lifting task, as opposed to what was observed during the weight carrying task. It is concluded that overall the patients were more accustomed to the protocols, and the two tasks involve different degrees of exertion. Even though both tasks carry intermittent static-dynamic work, the weight carrying task requires a longer period of isometric effort. Subjects carried the loads during the 3 minutes of each exercise stage. The weight lifting task, on the other hand, had a rest-exercise cycle, with the weights being lifted at a rate of 4 per minute, and no exertion between lifting.

As it was explained for the weight carrying task, it is known that 37% of the subjects participated in both tasks. Thus, it is assumed that overall the weight carrying task sample was more relaxed, as compared to the weight carrying sample. This fact also explains the higher ICC coefficients obtained during the weight lifting task (**tables IV.11**). Possibly the greater variance between subjects favoured the ICC results. Also, less test-retest variability would occur for these patients participating in both tasks, even if anxiety affected the results of the first test.

The SEM observed during the weight lifting task, for the respiratory exchange ratio, are also not significant, from a clinical standpoint. The same reasons supposed to have affected the weight carrying task would apply for the weight lifting task. These SEM values ranged from 0.038 to 0.061, and do not represent significant physiological changes during exercise.

E. GENERAL COMMENTS

The data results for both tasks clearly show that the simulated work test's reproducibility over time is limited when evaluating uncomplicated CAD patients for returning to labour jobs. The test-retest correlation of the respiratory exchange ratio was satisfactory (r=0.8) during the first stage of the weight lifting task. However, the same did not happen for other stages of other variables. To satisfy the requirements of this study all the ANOVA, ICC and SEM results should have favoured the test-retest reliability of all the variables and stages evaluated.

Based on the two-way ANOVA results and on the relative clinical insignificance of the SEM in all the stages, there is a trend to believe that the simulated work test has a potential to be reliable. To confirm this hypothesis, further investigation should be done to examine its reproducibility, validity and sensitivity. Then, the factors addressed as confounding this study's results should be corrected.

The results from this present investigation suggest that some factors should be modified to improve the test-retest reliability of the work simulated test. It appears that a randomly selected sample would include a greater variability of the CAD population. For example, if CAD patients who did not pass the GXT had been evaluated, more generalization could be inferred from the data. This present study selected only clinically stable patients, and thus only a narrow portion of the CAD population was tested.

Because many measurement values decreased on the retest session, it is believed that at least three test repetitions would provide results more consistent over time. By testing the patients more sessions, the first test could be designed to completely familiarize them with the research procedures. This approach is suggested to decrease the learning effect and the anxiety during the tests. Perhaps a higher correlation between results of the second and third retest measures could be obtained.

As far as the results from this study could assess, significant left ventricular dysfunctions did not occur during either the weight carrying or lifting tasks. Because the systolic blood pressure is a result of the relationship between cardiac output and total peripheral resistance, a significant left ventricular dysfunction would be noticeably followed by a fall in systolic blood pressure (Irwin and Tecklin, 1990). A fall in heart rate, shortness of breath, ST segment changes (depression or elevation) and pallor could also occur as a result of fall in the cardiac output. These are indirect suggestions derived from the clinical observation, since ejection fraction, representative of the left ventricular function, was not evaluated during the study tests.

Sagiv *et al* (1985) found that global left ventricular function remained stable in trained CAD patients during isometric work performed at 30% of the maximal voluntary contraction. DeBusk *et al* (1978) had also reported that isometric exertion, regardless of the percentage of the maximal voluntary contraction used, failed to elicit angina pectoris, ischemic ST segment displacement, or worrisome ventricular arrhythmias among uncomplicated CAD patients.

The implementation of the simulated work test as a clinical tool has been a matter of controversy in the cardiology field. DeBusk *et al* (1978) objected to the use of any modes of static exercise to evaluate CAD patients to return to work. The simulated work test was referred to as "an expensive tool due to personnel use and time". However, this test would be performed only by CAD patients who would wish to return to manual labour. Also, Picard *et al* (1989) and Haskell *et al* (1989) reported economic benefits for patients evaluated by vocational counselling after a cardiac event.

Even though this study was not an intervention, it partially agrees with Wenger (1982). The former author supports the idea that the general impairment after CAD can be minimized with vocational counselling, which supposedly decreases the psychosocial complications. Some patients tested during the present study reported a feeling of more confidence to perform their work. Some of them were already working before the study commencement. However, for most of those patients, work resumption was not based on a test which estimated their ability to do so safely.

In summary, it appears that the acceptance of the simulated work test could mean a significant step for the rehabilitation sciences. It is stated by the Health Reports (1990) that the goal of these sciences is "to restore the total patient's capabilities to return to the same or better quality of life he/she had prior to the onset of the disease". Further investigation of the simulated work test should contribute to the achievement of this goal.

F. METHODOLOGICAL CONSIDERATIONS

The variations in the blood pressure in different situations of daily living are well documented in the literature (Astrand and Rodahl, 1986). Beside factors such as mood, climate, circadian rhythm and others, the measurer and instrument can interfere with the reliability of the blood pressure readings (Rothstein, 1985). For this study, the intra-tester reliability of blood pressure measurements was checked at rest conditions (r=0.99). However, this study still faces the limitation that reliable readings during exercise can be difficult due to noise and body motion.

Even though the results yielded data which were not reproducible based on the criteria for the study success, many factors were controlled to avoid this finding. The patients had an uncomplicated clinical status and their cardiovascular fitness was unlikely to change in one week interval. The test sessions were standardized and the circadian rhythm was controlled. Therefore, it is likely that the non-reproducibility of the measurements (oxygen uptake, blood pressure and heart rate) was more a reflection of the anxiety, low variance between individuals and learning effect, rather than intrinsic major "error". The occurrence of anxiety was confirmed by the observation of increased ventilation and respiratory rate, mainly during the first test session of the weight carrying task.

G. CLINICAL IMPLICATIONS AND SUGGESTIONS FOR FUTURE RESEARCH

Complete rehabilitation of the CAD patient requires an urgent standardization of the return to work recommendations and promotion of a productive life. The simulated work test seems to represent a key step in the process of rehabilitation of the CAD patients, since it has face and content validity. However, additional studies evaluating the predictive validity are strongly recommended for the safety of the patient who will perhaps resume work based on this evaluation.

On-job monitoring of the cardiovascular responses to physically demanding work tasks may be also valuable to guide the return to work recommendations. Since many jobs entail unusual physical, psychological or environmental stresses, further research should evaluate how the responses encountered in the lab would compare to the workplace evaluation. Portable ECG, oxygen analyzer and blood pressure devices could be helpful in addressing the concurrent validity of the simulated work test.

Cardiac rehabilitation should be a path from a temporary inability to work, due to illness, to a return to the previous life habits, including work. However, examining the relationship between a programmed rehabilitation and the return to work rates are necessary. In addition, the relationship between a standardized work follow-up program and the prognosis of the coronary patient require further investigation. Perhaps the implementation of static-dynamic training, instead of dynamic only will be beneficial to improve the return to work rates after the onset of CAD.

CHAPTER VI
CONCLUSIONS

The objective of the present study was to evaluate the reproducibility of the simulated work test. Cardiovascular responses were measured on 19 CAD patients performing repeated tasks of weight carrying and weight lifting. Two-way ANOVA, Intra-Class Correlation (ICC) and standard error of the measurement (SEM) were run to examine the test-retest reliability of these tasks.

The ANOVA showed no significant differences in test-retest analysis and the SEMs were always clinically insignificant. The ICC coefficients were lower than the expected reliability of .8. Even though the simulated work test tends to be reproducible, additional research is still needed to examine if it could be an instrument for specialized exercise testing in cardiac rehabilitation centres.

Therefore, the conclusions from the present study indicate that:

1. Data from this study are not conclusive in establishing the simulated work test as a reproducible tool. However, two out of the three methods used to analyze the data favoured its reproducibility. The study tests were performed by uncomplicated CAD patients who had been working in manual labour jobs.

2. As far as the limit load of 40 lbs was concerned, the simulated work test did not imply unsafe hemodynamic stress for uncomplicated CAD patients. This conclusion was derived from the parameters rate-pressure product, oxygen uptake and respiratory exchange ratio.

3. The test-retest reliability of the simulated work test should be reexamined. A randomly selected sample should be used to decrease the chance of biased subjects. In addition, for reliability studies, at least three test repetitions should be performed to determine whether consistency would improve after test two.

4. Future research is strongly recommended to evaluate the concurrent and predictive validity of the simulated work test. These are essential characteristics for any accepted clinical tool. Also, they are of relevance for the safety of the patient returning to work after a cardiac event.

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APPENDIX I

CONSENT FORM AND INFORMATION SHEET

REPRODUCIBILITY OF HEMODYNAMIC RESPONSES DURING SIMULATED OCCUPATIONAL TASKS

Investigators:- Dr. D. Humen (Phone # 492- 1576)
- Ms. M. Braz (Phone # 439- 5469)

CONSENT

I freely and voluntarily consent to participate in this research project, under the direction of Dr. Dennis Humen. I acknowledge that I have been informed of the objectives of the study and given a thorough description of the research protocol.

I am aware that I may withdraw from this research protocol at any time, without affecting my clinical care. I have been assured that personal records relating to this study are confidential. Although this evaluation may improve my confidence and feeling about being able to return to work, I am aware of the possible risks and discomforts. The information that has been obtained in this study and that bears my name will be seen only by the investigators. My name will not be published or presented in conferences. If the study reveals any information that could influence my decision to continue in this study, I will be promptly informed.

With my signature below, I indicate that I have read and understood the information sheet, and I acknowledge receipt of a copy of this consent form.

Witness's name signature
Date

Subject's name signature
Date

Investigator's name signature
Date

*Individuals to be contacted for any information:
- Dr. D. Humen (Phone # 492- 1576)
- Ms. M. Braz (Phone # 439- 5469)

REPRODUCIBILITY OF HEMODYNAMIC RESPONSES DURING SIMULATED OCCUPATIONAL TASKS

Investigators:- Dr. D. Humen (Phone #: 492- 1576)
- Ms. M. Braz (Phone #: 439- 5469)

INFORMATION SHEET

The principal objective of this study is to examine the reliability of repeated measures of exercise capacity and function of the heart and circulation associated with weight carrying and lifting tasks. I will be required to attend at least two research evaluations in the cardiology Department of U. of A., where I have been followed up since my cardiac event.

For screening and safety, a resting evaluation of the function of my heart has already been performed, as well as a standard exercise test walking on a treadmill. I will refrain from ingesting a heavy meal or engage in vigorous physical activity for at least 3 hours prior to the tests. The test sessions will be scheduled at my convenience, and each one will take about half an hour to be completed. Exercise responses: blood pressure, electrocardiogram and oxygen use during exercise will be monitored during each test. Electrocardiogram electrodes, a nose clamp and a mouthpiece with a breathing valve will be used during the tests. I may feel a little muscle soreness on the day following the tests, from this exertion.

For the study protocol, an assessment of my ability to perform activities present in most physically demanding jobs will be held. The preparation and monitoring is similar to the standard exercise test. I will be assigned to perform either the weight carrying or the weight lifting test, which are described below:

a. Weight carrying test:

I will be required to walk on a treadmill carrying weights at a comfortable speed (between 1.5-2 miles per hour), flat slope. This is an incremental test with 3 stages lasting 3 minutes each and loads up to 40 lbs (i.e., 20 lbs, 30 lbs and 40 lbs). There is a rest interval between the stages, and I can discontinue the test anytime.

b. Weight lifting test:

For this test, I will be required to lift loads up to 40 lbs (20 lbs, 30 lbs and 40 lbs) at a rate of about 4 lifts/minute. There are three stages during the test, each one lasting 4 minutes. There is a 3 minute rest interval between each stage. Blood pressure, electrocardiogram and oxygen use will be measured constantly in the same pattern throughout all tests.

* One week after the first work evaluation, I will be required to return to the laboratory to repeat the test.

APPENDIX II

AMERICAN HEART ASSOCIATION RECOMMENDATIONS FOR HUMAN BLOOD PRESSURE DETERMINATION BY SPHYGMOMANOMETERS

AMERICAN HEART ASSOCIATION RECOMMENDATIONS FOR HUMAN BLOOD PRESSURE DETERMINATION BY SPHYGMOMANOMETERS

The observer should be trained in taking the blood pressure, hear well and see well to read the manometer. When reading the manometer, the eyes should be at level with the meniscus column. The patient should be comfortably seated, arm slightly flexed and the whole forearm supported at heart level. The patient should be in a quiet room at a comfortable temperature, with the arm unconstricted by clothing. Exertion, exposure to cold and heavy eating or smoking should be avoided for a half hour before the measurement. Allow the patient to rest at least five minutes before recording.

Technique:

The deflated cuff should be applied with the lower margin about 2.5 cm above the antecubital space. Care should be taken to insure that the centre of the bladder is applied directly over the medial surface of the arm. A preliminary palpatory determination of systolic blood pressure should be done to give the examiner an estimate of the maximal pressure to which the system needs to be elevated in subsequent determinations.

The bell stethoscope should be applied to the antecubital space over the previously palpated brachial artery. It should be applied firmly, but with as little pressure as possible, and with no space between the bell and the skin. Heavy pressure will distort the artery and produce sounds heard below the diastolic pressure. The stethoscope should not touch clothing or the pressure cuff.

With the stethoscope in place, the pressure is raised approximately 30 mm Hg above the point at which the radial pulse disappears, and then released at a rate of 2 to 3 mm Hg/second. Faster or slower deflation will cause systematic errors.

As the pressure falls, The Korotkoff sounds became audible over the artery below the cuff and pass through the four phases as the pressure declines and sounds disappear.

PHASE I: Period marked by the first appearance of faint clear tapping sounds which gradually increase in intensity.

PHASE II: The period during which a murmur or swishing quality is heard.

PHASE III: The period during which sounds are crisper and increase in intensity.

PHASE IV: The period marked by the distinct, abrupt muffling of sound so that a soft, blowing quality is heard.

PHASE V: The point at which the sounds disappear.

The muffling and disappearance points are referred to as the fourth and fifth "points". When all the sounds have disappeared, the cuff should be deflated rapidly and completely. One or two minutes should elapse for the release of blood trapped in the veins before further determinations are made.

The systolic blood pressure is the point at which the initial tapping sound is heard. To make certain the sound is not extraneous, one should hear least two connective beats as the pressure falls. The diastolic blood pressure is the point at which the last so as heard. Both systolic and diastolic pressures should read to the nearest 2 mm Hg mark of the manometer scale or dial.

From: Subcommittee of American Heart Association Post Graduate Education Committee. Recommendations for human blood pressure determination by sphygmomanometers. Hypertens (1981) 3:510A-519A.

APPENDIX III

OPEN CIRCUIT METHOD OF MEASURING GAS EXCHANGE

OPEN CIRCUIT METHOD OF MEASURING GAS EXCHANGE

To measure pulmonary gas exchange the subject inhales air from the atmosphere, while the exhaled air is directed into a collection device. The collected air is analyzed for its oxygen (F_{EO2}) and carbon dioxide (F_{ECO2}) content and its volume is measured. The following steps and computations are made to obtain the oxygen consumption:

1. If oxygen consumption and energy expenditure are to be compared when measured at different times and places, it is necessary to account for the factors affecting gas volume. Thus, all volumes are corrected to conditions of **standard temperature, pressure, dry** (STPD), i.e., "O" degrees centigrade or 273 degrees absolute, one atmosphere of pressure, and free of water vapour.

a. The STPD factor is computed as follows:

$$STPD = \frac{273}{(273^0 + T_{GAS})} \times \frac{(P_{BAR} - P_{H20})}{760}$$

T_{GAS}: Gas temperature in degrees centigrade
P_{BAR}: Atmospheric pressure in mm Hg (from barometer)
P_{H2O}: Water vapour pressure in mm Hg values (standard)

b. The measured volume is corrected to STPD according to the equation:

$$V_{E(STPD)} = V_{E(ATPS)} \text{ X } STPD$$

$V_{E(ATPS)}$: Volume of expired air at atmospheric temperature, pressure and saturated with water vapour.
$V_{E(STPD)}$: Volume of expired air corrected to STPD conditions.

2. The amount of oxygen consumed is equal to the amount of oxygen inhaled minus the amount of oxygen exhaled. The calculation of the amount of oxygen expired is:

$$V_{EO2} = \frac{V_{E(STPD)} \text{ X } F_{EO2}}{100}$$

V_{EO2}: The percentage concentration of O_2 in expired air.

3. To find the amount of oxygen inhaled, knowledge of the volume of nitrogen (N_2) in inspired and expired air is used. Note that 79.04% is the accepted concentration of N_2 in atmospheric air, when corrected to STPD:

$$V_{I(STPD)} = V_{E(STPD)} \times \frac{F_{EN2} \text{ in expired air}}{79.04\%}$$

$$F_{EN2} = 100 - (F_{EO2} + F_{CO2})$$

4. After the volume of inspired air ($V_{I(STPD)}$) is known, the amount of oxygen inhaled is determined by multiplying the volume of inspired air at STPD by the concentration of oxygen in the inspired air. The atmospheric air has the following composition:

O_2= 20.93%; CO_2= 0.03% and N_2= 79.04%

Therefore:

$$V_{IO2} = V_{I(STPD)} \times \frac{20.93}{100}$$

5. The oxygen consumption of the collected period is:

$$V_{O2(STPD)} = V_{IO2} - V_{EO2}$$

6. Oxygen consumption per unit of time (VO_2), also called the "absolute value":

$$\dot{V}O_{2(STPD)} = \frac{VO_{2(STPD)}}{\text{collection time}}$$

$\dot{V}O_{2(STPD)}$: Expressed in litres/min
Collection time: Expressed in min

7. Oxygen consumption per unit of body weight, called the "relative value":

$$\text{Relative value} = \frac{\text{Absolute value x 100 ml/litre}}{\text{Weight of subject}}$$

$$\dot{V}O_2 = \frac{\dot{V}O_2 \times 1000 \text{ ml/litre}}{\text{Weight of subject}}$$

$\dot{V}O_2$ (Relative value): Expressed in ml/Kg/min
$\dot{V}O_2$ (Absolute value): Expressed in litres/min
Weight of the subject: Expressed in Kg.

APPENDIX IV

SCREENING METHODS

SCREENING METHODS

1. STANDARD GRADED EXERCISE TEST (GXT):

The treadmill has been the preferred approach for GXT in North America in the past decade, since walking or running on a grade makes it easy to estimate body work and compare it to other physiological methods. The Bruce protocol has become the most commonly accepted and used. When patients present no symptoms to limit the test, the predicted maximal heart rate is used as a guide to limit it, even though they are encouraged to exercise as long as they can.

The following diagram shows the levels of difficulty the Bruce protocol involves:

BRUCE PROTOCOL

STAGE	MINUTES	SPEED (mph)	GRADE (%)	METS
1	3	1.7	10	5
2	3	2.5	12	7
3	3	3.4	14	10
4	3	4.2	16	13
5	3	5.0	18	16
6	3	5.5	20	19
7	3	6.0	22	22

Blood pressure, and twelve-leads ECG are continuously monitored across the test. The ECG tracing for GXT is taken with the modified Mason-Likar 12-lead placement, to avoid interferences from contracting muscles (American College of Sports Medicine, 1986).

End-points regularly used for termination of the GXT are: patient request, attainment of maximum age-predicted HR, anginal pain, ECG changes suggestive of ischemia (like ST segment depression > 2mm), vertigo, pallor, cyanosis, serious arrhythmias, drop in SBP (American College of Sports Medicine, 1986).

2. Radionuclide Ventriculography:

The resting evaluation of the left ventricular function (LVF) and the ejection fraction value provide important information. This cardiac imaging technique shows the contractility and normality of the heart as a pump. This assessment helped in the evaluation of the patient suitability for participating in this study.

The procedures for radionuclide ventriculography (RV) requires the intravenous injection of a radiopacque substance (isotope) to facilitate the visualization of the cardiac chambers, the normality of the wall motion and cardiac output. From these observations, the LVF status is derived.

Miller *et al* (1988) reported that LVF can be reproducibly and accurately assessed with this technique. The LVF (represented by the ejection fraction) is calculated based on relative LV counts. This method may also be useful for the detection of high risk patients: acute MI, severe LV dysfunctions and aneurysms due to CAD (Miller *et al*, 1988).

APPENDIX V

RAW DATA

WEIGHT CARRYING TASK

		$\dot{V}O_2$ (ml/Kg/m)		$\dot{V}O_2$ (l/m)		RPP		RER	
SUBJ	STAGE	T1	T2	T1	T2	T1	T2	T1	T2
1	1	11.84	12.65	0.87	0.93	144	119	0.85	0.80
	2	[illegible]	[illegible]	0.94	1.00	150	134	0.86	0.85
	3	[illegible]	[illegible]	0.98	1.01	159	142	0.86	0.88
2	1	11.95	[illegible]	1.00	0.88	[illegible]	[illegible]	0.81	0.78
	2	11.70	11.66	0.98	0.96	[illegible]	[illegible]	0.79	0.77
	3	13.12	12.65	1.09	1.04	119	116	0.82	0.78
3	1	9.80	9.30	0.85	0.79	183	160	0.91	0.87
	2	11.20	9.40	0.97	0.86	179	192	0.89	0.89
	3	10.78	10.75	0.94	0.94	184	190	0.92	0.92
4	1	12.47	11.88	1.01	0.96	185	162	0.83	0.86
	2	13.10	12.17	1.06	0.98	180	172	0.88	0.90
	3	14.00	12.50	1.13	1.01	194	187	0.89	0.94
5	1	12.36	12.75	0.80	0.79	154	108	0.88	0.85
	2	11.55	13.60	0.71	0.79	154	120	0.85	0.86
	3	12.95	13.95	0.80	0.83	174	134	0.85	0.88
6	1	12.27	10.62	0.88	0.78	127	111	0.86	0.82
	2	11.88	11.33	0.85	0.83	151	122	0.86	0.85
	3	13.55	12.25	0.97	0.89	157	136	0.90	0.86
7	1	16.50	13.77	1.11	0.93	153	151	0.82	0.81
	2	16.45	14.95	1.11	1.01	163	168	0.82	0.83
	3	16.58	16.10	1.13	1.09	194	172	0.83	0.82
8	1	9.65	8.45	0.82	0.73	83	74	0.84	0.83
	2	10.00	8.95	0.85	0.77	103	91	0.84	0.87
	3	10.22	9.47	0.87	0.81	123	97	0.85	0.86
9	1	12.65	12.02	1.47	1.39	122	144	0.94	0.90
	2	13.20	12.55	1.53	1.45	134	156	0.89	0.91
	3	13.53	13.55	1.57	1.57	159	159	0.93	0.92
10	1	15.10	11.60	1.62	1.24	133	124	0.82	0.79
	2	15.00	11.70	1.61	1.25	160	144	0.85	0.81
	3	15.50	12.45	1.62	1.34	163	155	0.85	0.83
11	1	13.60	12.80	1.00	1.00	123	123	0.87	0.86
	2	13.70	13.27	1.02	1.00	133	136	0.88	0.86
	3	13.80	13.56	1.02	1.02	153	154	0.87	0.87
12	1	12.32	12.20	1.20	1.20	118	132	0.96	0.88
	2	12.67	13.27	1.24	1.30	134	149	0.84	0.86
	3	13.05	13.22	1.28	1.30	132	146	0.85	0.86

WEIGHT LIFTING TASK

		$\dot{V}O_2$ (ml/Kg/m)		$\dot{V}O_2$ (l/m)		RPP		RER	
SUBJ	STAGE	T1	T2	T1	T2	T1	T2	T1	T2
1	1	14.62	13.17	1.19	1.03	118	110	0.91	0.88
	2	15.90	14.90	1.25	1.16	128	124	0.90	0.83
	3	15.72	15.75	1.22	1.23	135	131	0.97	0.83
2	1	12.90	12.80	1.04	1.03	127	147	0.85	0.84
	2	12.25	14.05	0.99	1.13	139	148	0.87	0.83
	3	12.20	15.57	0.94	1.26	148	160	0.88	0.85
3	1	15.71	14.88	1.36	1.35	166	189	0.94	0.89
	2	14.62	15.55	1.26	1.41	170	221	0.88	0.90
	3	16.20	16.67	1.40	1.52	168	224	0.91	0.93
4	1	10.55	18.45	0.82	1.44	109	116	0.77	0.77
	2	10.72	16.87	0.83	1.32	107	114	0.79	0.76
	3	11.87	17.42	0.93	1.36	121	118	0.79	0.78
5	1	12.34	12.42	1.09	1.13	123	103	0.79	0.76
	2	12.87	12.77	1.12	1.16	140	119	0.78	0.79
	3	13.01	13.63	1.18	1.24	162	131	0.79	0.77
6	1	13.05	12.95	2.04	1.50	120	112	0.86	0.88
	2	13.97	13.17	1.96	1.60	132	120	0.85	0.87
	3	14.75	13.95	2.24	1.67	139	139	0.89	0.90
7	1	15.60	14.92	1.63	1.54	124	118	0.76	0.78
	2	14.75	15.81	1.47	1.50	145	128	0.88	0.80
	3	15.20	15.25	1.59	1.57	156	150	0.88	0.82
8	1	9.80	10.28	0.95	0.99	78	108	0.76	0.84
	2	10.62	11.30	1.03	1.10	87	112	0.81	0.86
	3	10.68	13.05	1.03	1.18	95	99	0.81	0.88
9	1	11.10	9.25	0.73	0.61	129	126	0.74	0.68
	2	11.80	10.62	0.78	0.71	139	142	0.73	0.73
	3	13.03	12.61	0.86	0.83	149	151	0.76	0.75
10	1	15.70	16.27	1.10	1.12	164	159	0.87	0.87
	2	17.05	17.57	1.19	1.20	183	181	0.89	0.92
	3	18.77	18.27	1.31	1.26	199	185	0.95	0.88
11	1	13.93	14.42	1.00	1.16	135	133	0.75	0.72
	2	14.95	13.95	1.21	1.30	150	153	0.79	0.75
	3	16.02	15.80	1.37	1.27	168	161	0.84	0.82

$\dot{V}O_2$(ml/Kg/min)= Relative value of oxygen uptake

$\dot{V}O_2$(l/min)= Absolute value of oxygen uptake

RPP= Rate-pressure product

RER= Respiratory exchange ratio