GRADED EXERCISE STRESS TESTING: TREADMILL PROTOCOLS
COMPARISON OF PEAK EXERCISE TIMES IN CARDIAC PATIENTS

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Master of Science

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ABSTRACT

Introduction and Purpose

Exercise is one of the frequent physiological stresses that can result in cardiovascular abnormalities that are not present at rest and it can help to establish a good idea on the sufficiency of cardiac function. The Optimal exercise stress test protocol should consider the reason of the test, the results that are expected from the test, and the individuality of the population that is being tested. The duration of the optimal test should be approximately 10 to 12 minutes. The purpose of this research was to compare a new protocol (ARP protocol) capability in categorizing patients into high or low functional capacity categories prior to exercise with Bruce and Modified Bruce protocols.

Materials and Methods

The study consisted of a sample of 73 Summa cardiac rehabilitation phase II patients from 1996 to date. Clinical and demographic data was abstracted from hard-copy and electronic cardiac rehab clinical files and were entered into a separate electronic Microsoft Access research database. Statistical analysis was conducted on SPSS version 16.0. Means, standard deviations and correlation matrices were generated. Multinomial Logistic Regression was incorporated to evaluate if there was a significant difference
between treatments while controlling for peak estimated work output in METs and age at test administration.

**Results**

The study consisted of 73 patients, 29 female and 44 male. The sample has mean age of 67.06 years ($SD = 10.37$; range = 43.39 years). The ARP is predicted most accurately (75.8%), while the other protocol, Bruce 53.8% and Modified Bruce 35.7%, are predicted with less accuracy.

**Conclusions**

The Accelerated Ramp Protocol (ARP) has higher accuracy in predicting the maximum work capacities in cardiac patients within the optimal time limit 8 – 12 minutes.
DEDICATION

To my father Ibrahim
To my mother Aisheh
To my husband Ala’
To my son Faris
To my daughter Ayah
ACKNOWLEDGEMENTS

My greatest thanks and appreciation goes to Dr. Ronald Otterstetter who fulfilled the role of my advisor and chair of the thesis committee. A great appreciation goes to Mr. James Rosneck, for his enormous encouragements and support during my research and fellowship at Akron City Hospital. I would like also to acknowledge the great support of Dr. Donna Waechter through this research and her valuable advices. I would like also to thank Ms. Laura Richardson for setting as a committee member and for her valuable comments.

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CHAPTER I
INTRODUCTION

Stress tests are an important diagnostic and prognostic tool for assessing patients with suspected or known ischemic heart disease\(^1\). Exercise is one of the frequent physiological stresses that can result in cardiovascular abnormalities that are not present at rest and it can help to establish a good idea on the sufficiency of cardiac function\(^2\). Thus, when using exercise as cardiovascular test, it is more suitable to call it exercise test rather than stress test since there are several non-exercise stress tests such as pharmacologic stress test (\emph{e.g.}, with dobutamine, dipyridamole, or adenosine) and atrial pacing stress test\(^{1,2}\).

Exercise stress test is routinely used in evaluating patients who present with chest pain, in patients who have chest pain on exertion, and in patients with known ischemic heart disease\(^3\). It was originally used combined with ECG to illustrate if there were any ST segment changes derived from myocardial ischemia\(^4\), which occurs when oxygen supply to myocardial is not adequate to its demand\(^5\). Nowadays, exercise stress testing is still used to monitor ST segment changes; nevertheless, it is also used to detect important information from exercise capacity such as blood pressure response, development of arrhythmias, and angina during exercise\(^4\). This information allows for evaluation of
presence and severity of ischemia, prognosis, overall function capacity, and effectiveness of therapeutic interference.

Searching for an “optimal” test for evaluating electrocardiographic and/or gas exchange responses to exercise is essential and it has spanned 7 decades in developing several protocols that are used frequently now. The graded exercise test is the most regular stress test applied using either the treadmill or cycle ergometer. Normally, the treadmill is used in the United States and its protocols advantages and disadvantages were discussed by several studies. Yet, an ideal protocol should take into consideration the purpose of the test and the subject whom are tested. Some protocols, like Bruce test, are used only because of the availabilities of the equipments or the traditions even though they might be unsuitable to many cardiovascular patients.

Commonly, an incremental symptom-limited maximum test is used because it is expected to provide the greatest information on factors that limit exercise performance and on possible critical effects that are induced by exercise. Patients with advanced disease, however, might find exercise on cycle ergometer very difficult because their VO2max is often equal to that necessary for pedaling at 0 watt. Additionally, doing exercise on treadmill is not easy because it requires many attempts to find the target speed, nevertheless, it is time consuming to get patients familiar with it. Estimate oxygen uptake and METs from work rate when using any protocol is important, yet, it is inaccurate. Thus, many laboratories directly measure expired gases to increase the information obtained concerning a patient’s cardiopulmonary function.
CHAPTER II
LITERATURE REVIEW

Exercise is one of the most common physiologic stresses which the human body deals with in regular bases. Maximal exercise defines the limits of performance in a healthy individual or the functional capabilities of the patient with heart disease\textsuperscript{10}. Nearly all body systems integrate and involve together in the homeostatic adjustments required for exercise which increases the oxygen consumption and metabolic rate up to 20 folds comparing to the resting rate\textsuperscript{9}. The major factor behind this increase is the augment in the cardiac output, especially the heart rate, as much as 6 folds\textsuperscript{9}. The limiting factors for these adjustments are an individual’s age, sex, body size, fitness, exercise type, and the presence or absence of heart, lung or blood disease\textsuperscript{10}. Exercise was manipulated and used as a test to evaluate the cardiovascular system. The results that were obtained from graded exercise test (GXT) showed positive correlation and significant relationship in diagnosing cardiac patients.

The following sections offer a synthesis of literature review on key topics related to exercise testing. Due to rapid changes in cardiovascular assessments, the discussion presented herein will be limited as possible to documents published during the last ten years. Special attention will be given to publications dealing with MET measurements, peak exercise time, and energy expenditure during stress test.
Cardiovascular Disease (CVD)

The cardiovascular system is the major transportation and distribution network in the human body; delivering essential substances (e.g. glucose and oxygen) to the working tissue and removing the by-products of metabolism (e.g. carbon dioxide, lactate, and heat). In its simplest formation, the system composed of three parts: the pump (the heart), a series of distributing and collecting tubes (the arterial and the venous system), and a transport medium (the blood).

The American Heart Association 2009 update showed that an estimated 80 millions American adults, which is approximately 1 in 3, have one or more types of cardiovascular disease (CVD). Of these, 38.1 million are estimated to be ≥ 60 years of age. Total CVD includes; High blood pressure (HBP) (73.6 million), coronary arteries disease (CAD) (16.8 million), myocardial infarction (heart attack) (7.9 million), Angina pectoris (chest pain) (9.8million), heart failure (HF) (5.7 million) and Stroke (6.5 million). People who have congenital cardiovascular defects are 650 thousands to 1.3 million Americans.

Cardiovascular Disease Risk Factors

There are several factors that increase the risk for having CVD. They include diabetes mellitus, high blood cholesterol and other lipids, hypertension, metabolic syndrome, overweight and obesity, low physical activity, and tobacco usage.
**Diabetes Mellitus**

Diabetes is a disease in which the body does not produce or properly use insulin. Insulin is a hormone that is needed to convert sugar, starches and other food into energy needed for daily life. The cause of diabetes continues to be a mystery, although both genetics and environmental factors such as obesity and lack of exercise appear to play roles. A 2009 American Heart Associate statistics report showed that in 2006, 17.0 million Americans from age 20 and older had physician-diagnosed diabetes 7.4% of them were men and 8% were women. There is also an estimated number of 6.4 million Americans have undiagnosed diabetes, 3.8% of them were men and 2.1% were women. The trend for having CAD for Individuals with diabetes mellitus are at 2 to 3 folds relative to those without diabetes.

**High Cholesterol and Other Lipids Level**

Cholesterol by itself is a critical component which performs numbers of essential functions in the body. For example, it is the structural component of all cell membranes; it is a precursor of bile acids, steroid hormones, and vitamin D. The problem with cholesterol becomes when it reaches high levels. The American Heart association 2009 statistics report showed that 98.6 million Americans age 20 and older have total blood cholesterol levels of 200 (mg/dL) or higher, 45.0 million were men and 53.6 million were women. It also showed that 34.4 million of these people have total blood cholesterol levels of 240 mg/dL or higher, 14.6 million were men and 19.8 million were women. Coronary artery disease is significantly associated with increased concentrations of low
density lipoprotein cholesterol (bad cholesterol), decreased concentrations of high density lipoprotein cholesterol (good cholesterol), and increased triglyceride concentration\textsuperscript{39}. 

**Hypertension (HBP)**

The American Heart Associate defined high blood pressure as systolic pressure \( \geq 140 \text{ mm Hg} \) or diastolic pressure \( \geq 90 \text{ mm Hg} \), or if someone uses antihypertensive medication, or being told at least twice by a physician or other health professional that he/she has hypertension\textsuperscript{36}. More than 50 million American are afflicted by this disease which is a major cause of morbidity and mortality\textsuperscript{9}. The damage that can occur from having high blood pressure surpasses CVD. For instance, hypertension can damage other organs such as kidney, brain, and eye\textsuperscript{9}. Data from 2005–06 showed that of those people with hypertension, 78.7 percent are aware they have it, 45.4 percent have it controlled, 69.1 percent are under current treatment, and 54.6 percent do not have it controlled\textsuperscript{36}. Recent data suggest that people with hypertension are more likely to develop diabetes than people with normal blood pressure. In addition, up to 75\% of CVD in diabetes may be attributable to hypertension\textsuperscript{40}. 

**Overweight and Obesity**

The epidemic of overweight and obesity was declared in the United States for awhile now. The numbers of people how are considered part of this population is increasing in a high rate. Among Americans age 20 and older, 145.0 million are either overweight or obese which mean that their BMI \( \geq 25.0 \text{ kg/m}^2 \). Of those, 76.9 million are men and 68.1 million are women. The problem is that 74.1 million of those people are
obese (BMI $\geq 30.0 \text{ kg/m}^2$). The general make up of this population is 34.7 million men and 39.4 million women$^{36}$. Obesity is a significant independent predictor of CVD, particularly among women$^{41}$. It increases the risk of CVD and premature death by releasing a large number of bioactive mediators from adipose tissue that influence body weight homeostasis, insulin resistance, alterations in lipids, blood pressure, coagulation, fibrinolysis and inflammation leading to endothelial dysfunction and atherosclerosis$^{42}$.

Low Physical Activity

Regular physical activity using large muscle groups, such as walking, running, or swimming tempt to decrease the risk for cardiac events, reduce the incidence of stroke, hypertension, type 2 diabetes mellitus, colon and breast cancer, osteoporotic fractures, gallbladder disease, obesity, depression, and anxiety$^{10, 44}$. Studies have also shown that habitual physical activity have the ability to prevent the development of CAD and reduce symptoms in patients with established CVD$^{44}$. The Center of Disease Control and Prevention and the American College of Sport Medicine recommended that every adult in the United States should accumulate 30 minutes or more of moderate-intensity physical activity on most, preferably all, days of the week$^{43, 44}$. Several studies suggested that changing activity level from low to moderate or high decreases the rates of CVD compared with those who remain sedentary or unfit$^{10, 44}$.

The AHA 2009 statistics reported that the relative risk of CAD associated with physical inactivity ranges from 1.5 to 2.4. That factor holds an increase in risk comparable to that observed for high blood cholesterol, HBP, or cigarette smoking$^{36}$. A percentage of 12.2 % of global affliction of MI, after accounting for other CVD risk
factors such as cigarette smoking, diabetes, hypertension, abdominal obesity, lipid profile, no alcohol intake, and psychosocial factors, was caused by physical inactivity\textsuperscript{36}. An approximate 17 445 (≈5\%) deaths in the United States were prevented by decline of 2.3\% in physical inactivity between 1980 and 2000\textsuperscript{36}.

\textit{Tobacco Smoking}

It has been strongly declared by the epidemiologic studies that cigarette smoking in both men and women increases the incidence of myocardial infarction (MI) and fatal coronary artery disease (CAD) even if it was low-tar cigarettes and smokeless tobacco\textsuperscript{45}. It is the leading preventable cause of premature death from CVD especially CAD in the United States. Many studies suggested that smoking cessation will reduce mortality from CAD 1.2 – 27.5\% when other risk factors are statistically controlled\textsuperscript{46}. Exercise can be useful in smoking cessation. Evidences show that 10 minutes of moderate intensity exercise session may be useful in helping reduce desire to smoke and withdrawal symptoms during smoking cessation\textsuperscript{47}. From 1997 to 2001, an estimated 438 000 Americans died each year of smoking-related illnesses, a total of 34.7\% of these deaths were related to CVD\textsuperscript{36}.

\textit{The Coronary Arteries}

The main two arteries that supply the heart with blood are the right and the left coronary arteries. They are the first two branches of the aorta near the aortic valve. Usually the right coronary artery braches deliver the blood to the right atrium, right
ventricle and the inferior wall of the left ventricle, the atrioventricular (AV) node, and the bundle of His and, in 55% of the people, the sinoatrial (SA) node.

The left coronary artery branches into two major divisions. The first branch is called the left anterior descending (LAD). This division delivers the blood to the left ventricle, the interventricular septum, the right ventricle, and the inferior areas of the apex and both ventricles. The second main division is called the left circumflex. This branch supplies blood to the inferior wall of the left ventricular and the left atrium, and, in 45% of the people, the sinoatrial node.

**Coronary Circulation**

The heart muscle, like every other organ or tissue in human body, needs oxygen-rich blood to survive. Blood is supplied to the heart by its own vascular system, called coronary circulation. During systole the blood is pumped into the coronary arteries, however, the blood enters the coronary arteries during diastole of the heart when the muscle fibers are relaxed.

**Coronary Arteries Disease (CAD)**

Atherosclerosis is a disease that usually affects middle-to-older-age population. The fatty streak, a result of increased of lipid deposition in a discrete area of the arterial wall, form the initial atherosclerotic lesions. The atherosclerosis lesions develop in the intima of the coronary arteries. Although uncomplicated plaques rarely occlude arteries, these lesion may grow, thicken, and harden the walls of arteries reducing arterial wall elasticity and impinging upon the lumen of the vessel these plaques and structural
changes in the wall results in a decrease of coronary artery blood flow and a decrease in oxygen distribution to the myocardium. Atherosclerosis also affects the vascular tone within the coronary system by interfering with the normal function of an endogenous vasodilator. Although the mechanism is unknown it is believed to be associated with low-density lipoproteins. Individuals with CAD may be initially asymptomatic but, as the atherosclerosis progress, become symptomatic. Although there is variation among individuals, clinical manifestations of CAD usually begin to appear when the vessel is 70% occluded.

The imbalance in myocardial oxygen demand versus supply will cause what is known as myocardial ischemia. Ischemia occurs when oxygen supply to myocardial is not adequate to its metabolic demand thus the muscle cells will start using anaerobic metabolism to provide their energy. Prolonged ischemia may ultimately result in irreversible injury or infraction. The transition from ischemia to infraction is not inevitable. Ischemia that developed gradually is usually better tolerated because the collateral circulation my developed and supply the otherwise ischemic areas. Although body tissue can increase their oxygen extraction to compensate the decrease in oxygen supply, cardiac muscles do not have this luxury because at rest the heart muscle extracts 65 – 70% of the available oxygen. Cardiac cells can withstand ischemia for about 20 minutes before necrosis occur, but cardiac tissue hypoxia causes visible electrocardiogram (ECG) changes in less than 1 minute.

Infarction, or cellular death, is identified as a central core of necrotic cells that are electrically and functionally silent. Surrounding this core are cells with graduation of function dependent on the severity of the ischemia to the surrounding area.
A 1999 report of the Surgeon General showed that CAD is the single leading cause of death in the United States. The American Heart Association 2005 statistics indicated that in 2002, one in every five deaths in the United States was directly related to CAD. Furthermore, over half of cardiovascular events for men and women under the age of 75 years were accounted to CAD. It also showed that women have a 32% chance of developing CAD while men have 40 to 49% chance of developing CAD. Individuals, who experience a coronary incident, have a 41% chance of dying from the event. The presence of multiple mildly elevated risk factors increases the risk for having CAD than those with one high risk factor which will increase the mortality rate.

It has been recognized that a high exercise capacity presented with higher VO$_{2\text{max}}$ level is related to a reduction in CAD risk factors. Physical activity helps reduce other risk factors for coronary heart disease, such as cholesterol levels, obesity, and hypertension. Physical activity increases high-density lipoprotein (good cholesterol) levels and decreases the low-density lipoprotein (bad cholesterol) and total cholesterol levels.

**Graded Exercise Stress Testing (GXT)**

Graded exercise stress testing (GXT) is used in clinical setting to evaluate patients’ abilities to tolerate the increases in exercise intensities. It is usually applied while the patient’s electrocardiographic, hemodynamic, and symptomatic responses are closely monitored for any signs of myocardial ischemia, electrical instability, or any other abnormalities related to exertion. In case of chronic heart failure patients or pulmonary
limitation patients, it is common to combine GXT with gas exchange and ventilatory responses evaluation\textsuperscript{10}.

The GXT represents the most used diagnostic and prognostic tool for assessing CAD patients\textsuperscript{11}. The diagnostic aspect of GXT is best used for patient with intermediate risk factors for CAD determined by age, gender, and symptoms \textsuperscript{10}. The prognostic aspect of GXT is reliable for patients who are either very unlikely or very likely to have cardiac events\textsuperscript{12}. The AHA, ACSM and AACVPR current guidelines recommend the use of the GXT as the initial test for evaluation of known or suspected CAD when the patients have the physical ability to exercise\textsuperscript{12}.

Additionally, GXT is very useful in determine patients’ functional work capacity represented by VO\textsubscript{2max}. This characteristic makes it valuable for exercise prescriptions, exit cardiac rehabilitation evaluations, and prognostic assessments\textsuperscript{10}. This parameter can be measured by percentile ranking, percentage of expected METs, or directly measure VO\textsubscript{2max}\textsuperscript{10}.

Maximal oxygen consumption (VO\textsubscript{2max}) is a measure of cardiopulmonary fitness and equals the product of the maximal cardiac output (L blood*min\textsuperscript{-1}) and arterial-venous oxygen difference (mLO\textsubscript{2}/L blood). The variation in VO\textsubscript{2max} in significantly correlated to the maximal cardiac output; therefore, VO\textsubscript{2max} is strongly associated with functional capacity of the heart\textsuperscript{10}.

The procedure that is used to measure VO\textsubscript{2max} is open-circuit spirometry. The patients will breathe through a low-resistance valve while pulmonary ventilation and expired fractions of O\textsubscript{2} and CO\textsubscript{2} are measured\textsuperscript{10}.
One important feature the test should have to truly estimate VO2max is the sufficient duration to induce a sufficient cardiovascular response. Many studies suggested that tests with duration of approximately 10 to 12 minutes are optimal predictor of the cardiac dysfunctions. These studies explained their findings by claiming that short duration tests will have high initial workload and sharp increases in intensities. This means that patients with low cardiorespiratory fitness will poorly tolerate this workload which will overestimate their functional capacities as measured by VO2max. On the contrary, protocols that do not induce sufficient workloads for high cardiorespiratory fitness individuals, will underestimate their functional capacities. In addition, it will not stress their heart to the point where there is oxygen inadequate that is usually responsible for elicit cardiac dysfunctions. In both condition, the stress test outcome will not provide true values for the subjects’ functional capacities. It will also reduce the sensitivity and specificity of the measurement, affecting the interpretation of evaluated physiologic parameters.

**Maximal Oxygen Consumption (VO2max)**

The measure of energy expenditure in dynamic exercise characterizes the intensity of that exercise. It has been shown to be a strong independent predictor of survival in chronic heart failure. Maximal oxygen consumption (VO2max) is considered also the most accurate prognostic parameter in patient with severe heart failure and has become an essential component in the evaluation for heart transplantation.

During exercise stress test, gas exchange increased enormously causing the respiratory exchange ratio (R) to increase. the respiratory exchange ratio is the amount
of carbon dioxides (CO₂) produced divided by the amount of oxygen (O₂) consumed.\textsuperscript{15} As the workload is increased oxygen uptake increases linearly until it become constant; which is known as maximal oxygen consumption (VO\textsubscript{2max}).\textsuperscript{4}

The American College of Sport Medicine (ACSM) advocates the direct measure of maximal oxygen consumption (VO\textsubscript{2max}) as a more precise measure of the energy expenditure\textsuperscript{16}. In addition, the ACSM fixed an absolute energy expenditure unit (METs). The METs is defined as a metabolic equivalent originates from dividing the energy expenditure value by a constant of 3.5 mLO₂. Kg. min\textsuperscript{-1}.\textsuperscript{8} Since VO\textsubscript{2max} is affected by age, gender, training, environmental conditions, and health status\textsuperscript{8}, it is important to accurately measure this parameter. For cardiac patients, METs are used to prescribe an adequate exercise program, which raise the significance of having an accurate value.

Clinically, gas exchange and ventilatory responses are used to estimate the point where lactate accumulation in the blood occurs, which is known as lactate or anaerobic threshold\textsuperscript{16}. In this point the workload increases above the VO\textsubscript{2max}, which shift the muscle cells from producing energy using the aerobic system into using the anaerobic system.\textsuperscript{4} Cardiac output, on the other side, increases linearly with work level due to increase in heart rate and stroke volume.\textsuperscript{4} Any change in stroke volume or heart rate will significantly alter the oxygen consumption of the heart.\textsuperscript{9} The amount of oxygen consumed per minute is the definition of oxygen consumption.\textsuperscript{9} The myocardial oxygen consumption is equal to the coronary blood flow multiplied by the amount of oxygen extract from the blood.\textsuperscript{9}
Many studies suggested a statistically significant correlation between having higher levels of cardiovascular fitness, represented by higher levels of VO\(_{2\text{max}}\) and a decreased risk for cardiovascular diseases.\(^{17}\)

**Indications to GXT**

The exercise stress testing is usually used for diagnostic, prognostic, and therapeutic applications. In cardiac rehabilitation settings, GXT is used to evaluate exercise tolerance for cardiac patients before beginning the rehabilitation program\(^9\). This evaluation provides guidelines for each patient the cardiac rehabilitation clinician will use in prescribe the exercise program. Appendix E shows the indication list for using GXT for cardiac patients.

**Contraindication to GXT**

Using exercise as stress test is relatively save, however; for certain individuals the risk of exercise testing outweigh the benefits\(^{10}\). Usually, there will be careful assessment to the risk versus benefits for these patients. Appendix F shows the absolute and relative contraindication to exercise testing\(^5\). Patients with absolute contraindications should not perform GXT until their conditions are stabilized. On the other hand, patients with relative contraindications may be tested using GXT after a cautious assessment to the risk/benefit ratio.
Graded Exercise Stress Testing Protocols

The optimal exercise stress test protocol should consider the reason of the test, the results that are expected from the test, and the individuality of the population that is being tested\textsuperscript{18, 5}. Exercise scientists must understand the importance of developing a stress test that can address the needs of individuals with wild diverse range of physical functional capacities. Different exercise protocols with a predicted VO\textsubscript{2} for each stage in each protocol are now available to be used according to each subject capability. For instance, Bruce and Ellestad protocols are better matched for evaluating younger and physically active individuals since the increments between each stage is relatively high. In contrast, Naughton, Modified Bruce, and Blake-Ware, smaller increments protocol, are appropriate for older, deconditioned individuals, and patients with chronic diseases\textsuperscript{18}.

In this study, we will focus on three GXT protocols, Bruce, Modified Bruce, and newly developed Accelerated Ramp Protocol (ARP).

\textit{Bruce and Modified Bruce Protocols}

Despite its limitation, Bruce Treadmill Protocol remains the most common test used by physicians because it is easy to use and has economical aspect at the same time. In 1960s a cardiologist named Robert Bruce developed a protocol to evaluate the cardiovascular functional capacity. This test is a progressive continues approach consists of several stages where each stage lasts for 3 minutes with 3 METs increase per stage. The speed and grade are incrementally increased for each stage, as well. The protocol starts out at 1.7 MPH and 10\% grade. Heart rate and blood pressure are measured in continues basis. However, this protocol is hard to apply for cardiac patients or de-
conditioned individuals since the increment in METs is high and uneven (2 to 3 METs of work every 3 minutes)\(^5\). This fact restrains some physicians from using it and encourages them to use Modified Bruce Protocol.

In the Modified Bruce protocol, the patient has two low-level initial stages to warm up before they undergo the high intensities stages. These modifications are less than complete since they just change the first stage of Bruce protocol. Currently, there is a move to individualize the test according to each patient’s capability\(^5\).

**Ramped Protocol**

In the early 1990’s a new approach with treadmill GXTs is to use a protocol design for subjects with cardiorespiratory impairment. This protocol attempts to gradually increase the workload by usually shortening the stage time and decreasing the speed and grade increments\(^14\). Subjects undergo a gradual work ramp consisting of 30 to 60 second stages instead of the traditional incremental step protocols. It was called the Ramped protocol.

**Individualized Protocols**

The general idea behind using an individualized protocol is to reach a comfortable walking or jogging speed the patient can achieve on the treadmill. In this approach the treadmill will start on low speed so the patient will get adjusted to walk comfortably on the treadmill. Then the speed will increased gradually and each time the speed increased the patient will allowed some time to get adjusted to the new speed. During the test the
patient will be closely observed to make sure that the speed is comfortable. This approach has two sets, a walking set and a running set. In the walking set, the first stage will start at 0% grade that will be increased 2.5% every 2 minutes. The starting speed will be the speed that will allow patient’s heart rate to be around 100 bpm. For the running set, the speed will be the one that allow the patient to walk/jog. The grade will start at 0% in from 1-4 minutes, 4% from 5-6 minutes, 6% from 7-8 minutes, 8% from 9-10 minutes, 10% from 11-12 minutes, and so on.

**Accelerated Ramp Program (ARP)**

In 1995, a team in cardiac rehab unit at Akron City Hospital in Akron, Ohio noticed that the ramp protocols approach are better predictors for cardiovascular functional capacity assessment for low fit cardiac patients. However, this approach does not give a true outcome when it is come to the moderate or relatively highly fit individuals. This inability prompted them to develop a protocol to meet the needs of testing fit and unfit subjects as well as subjects possessing clinical and sub-clinical cardiovascular disease. The Accelerated Ramp Protocol (ARP) design is distinctive in its ability to address unique and ongoing variability in physiological response to exercise stress ignored by both individualized and standardized ramp formatting. The protocol achieves this end by incorporating real-time assessment of perceived exertion by using the Borg Categorical Scale. This method of rating perceived exertion (RPE) incorporates an open ended scale matching odd rating numbers from 6 to 20 with somatic stress descriptors. (Appendix B) It possesses proven validity and reliability to evaluate
perceived intensity of effort during acute bouts of exercise and has been a universally accepted clinical tool over the past 30 years\textsuperscript{20, 21}. Real-time evaluation of self perceived work allows the clinician to make accelerated adjustments within the ARP protocol according to the subject’s responses. This innovative design obviates the necessity of making subjective decisions regarding the person’s fitness status, a step necessary in both individualized and standardized ramped protocols. The ARP protocol has been used effectively in over 8,000 treadmill stress tests in Akron City Hospital cardiac rehab patients over the past 14 years without major incident. It has proven a valuable clinical tool for both physicians and cardiac rehab specialists for medical screening & diagnostic purposes as well as the accurate prescription of exercise for adults presenting relatively healthy and fit and those with varying degrees of cardiovascular impairment.

**Coronary Arteries Disease and GXT**

Coronary arteries diseases are diagnosed using several noninvasive and invasive tools including: graded exercise test (GXT), radionuclide imaging, echocardiography, and coronary angiography\textsuperscript{5}. The GXT is an important tool because of its lower cost and the useful information that can be derived from it. Fortunately, there are different modalities of GXT to meet the individual needs and the physical abilities of cardiac patients.

Exercise testing has a sensitivity of 78\% and a specificity of 70\% for detecting coronary artery disease\textsuperscript{3}. Furthermore, it is considered a safe tool, if used properly, as it has a low rate (0.01\%) of serious complications that include death or acute myocardial infraction\textsuperscript{3}. Treadmill exercise testing is widely used as a primary screening tool for
detecting CAD and provides vital information for proper design of cardiovascular exercise prescription\textsuperscript{5}.

The clinical information that can be disclosed from exercise stress testing is divided into two major categories: (1) diagnostic information and (2) prognostic information. The diagnostic indications for exercise testing may include the assessment of chest pain in patients with intermediate probability for coronary artery disease, initiate arrhythmia provocation, and estimation of symptoms occurring during or after exercise\textsuperscript{3}. On the other hand, the prognostic indications from using exercise testing may include the determination of risk stratification after myocardial infarction and/or in patient with hypertrophic cardiomyopathy, the assessment of revascularization or drug treatment, the estimation of exercise tolerance and cardiac function, the measurement of cardiopulmonary function in patients with dilated cardiomyopathy or heart failure, and the evaluation of treatment for arrhythmia\textsuperscript{3}.

It is also vital to estimate the maximum physical intensity for cardiac patients since it will be the reference point that cardiac rehabilitation specialists will use to prescribe the exercise plan for patients and evaluate their progresses. The physiologic intensity often is classified as relative or absolute in nature\textsuperscript{10}. The relative intensity is focused on the percentage of the individual’s maximum oxygen uptake reserve or heart rate reserve, however, the absolute intensity is focused on the metabolic equivalents (METs)\textsuperscript{10}. The MET is a reflection of oxygen consumption and one MET equals 3.5 ml oxygen/kg per minute\textsuperscript{10}. The activity of daily living has at least 5 METs intensity\textsuperscript{10}, which means to carry a normal simple daily physical requirements a person should have at least physical ability to work at 5 METs. Maximal aerobic capacity is also affected by
degeneration syndrome, hence, using METs represents a higher relative intensity for older compared by younger individuals\textsuperscript{15}.

During the performance of GXT, which is articulated as workload; the metabolic activity of the contracting muscles increase\textsuperscript{8, 9}. This increased metabolic activity is largely depending on pulmonary function, cardiac performance, peripheral muscle mass, and blood flow\textsuperscript{8, 9, 22}. Therefore, maximal oxygen consumption (\(\text{VO}_2\text{max}\)) as well as exercise capacity may play a significant role as a prognostic indicator in cardiac patients\textsuperscript{22}.

The duration of the optimal test should be approximately 10 to 12 minutes\textsuperscript{14}. Protocols that have high initial workloads and abrupt gradations in workload tend to be short in duration. They are also poorly tolerated in less fit subjects and tend to overestimate of the subjects functional capacity as measured by oxygen consumption (\(\text{VO}_2\)). On the contrary, protocols that have low initial workloads do not provide a sufficient aerobic challenge to more fit subjects which will underestimate the functional capacity and the oxygen consumption. In both situations deficits in measurement sensitivity & specificity will occur. These deficits will affect the interpretation of evaluated physiologic parameters\textsuperscript{14}. The \(\text{VO}_2\text{max}\) values are very important parameters for cardiovascular patient especially for those who should be prioritized for heart transplantation. It is additionally a strong marker to classify functional capacity in patient with congestive heart failure (CHF) \textsuperscript{17}. For those reasons it is essential to acquire the most accurate values.

Another important application for cardiopulmonary exercise testing is the determination of the reason behind the exertional dyspnea whether it is cardiac or ventilatory problem\textsuperscript{23}. 
Summary

There is a significant correlation between having higher level of VO$_{2\text{max}}$ and lower risk for cardiovascular disease. GXT is commonly use to estimate VO$_{2\text{max}}$ levels; however, the search for optimal exercise stress test protocol that consider the reason of the test, the results that are expected from the test, and the individuality of the population that is being tested is still needed. Protocols that have high initial workloads and abrupt gradations in work load tend to be short in duration and overestimate patients’ functional capacity. On the contrary, protocols that have low initial workloads that do not provide a sufficient aerobic challenge to more fit subjects tend to underestimate the functional capacity and the oxygen consumption.
CHAPTER III

METHODOLOGY

The purpose of this research was to compare the capability of a new protocol (ARP protocol) in categorizing patients into high or low functional capacity categories prior to exercise with Bruce and Modified Bruce protocols. To achieve this purpose, we compared the maximum time the patient spent on the ARP, Bruce, and Modified Bruce to determine which one of these protocols predict the maximum oxygen consumption (VO$_{2_{\text{max}}}$), presented by METs, within the acceptable time period (8-12 min).

Research Hypothesis

$H_{01}$: There is no significant difference in ARP, Bruce and Modified Bruce protocols in predicting peak exercise times during graded exercise testing while controlling for peak estimated work output in METs, gender, and age at test administration.

$H_{02}$: The ARP will not have higher sensitivity in predicting optimal treadmill times (8min. to 12 min.) over that accounted for by the Bruce and Modified Bruce Protocols while controlling for peak estimated work output in METs, gender, and age at test administration.
Methods

The research methods were approved by Akron City Hospital (Summa) Institutional Review Board.

Study Population

The study consisted of a randomly selected sample of 73 patients who underwent stress testing and completed Summa’s Phase II outpatient Cardiac Rehab program from 1996 to date. The patients were assigned to each protocol based on clinical judgments by the stress tests clinician or the patient’s physician. According to Cardiac Rehab demographic data, 81% of the population subjects are males, 89% white, 7% African American and 4% of other races. A power analysis was completed using Sample Power software (Borenstein, Rothstein, & Cohen) and indicates for a Power = .82 and Alpha = .05, an N of 66 was required.

Data Collection

Clinical and demographic data was abstracted from hard-copy and electronic cardiac rehab clinical files. The existing data abstracted included patients’ name, gender, medical record #, DOB, body weight, test date, entry or discharge test, time-on-mill, test protocol, heart rates, and blood pressures. These data were entered into a separate electronic Microsoft Access research database by the researchers. All collected data are part of clinical and demographic patient materials routinely accrued for the management of patients attending the phase II cardiac rehab program during this time period. All data abstraction processes took place in Center for Cardiovascular Research institution at
Akron City Hospital. A separate database created in SPSS version 16.0 containing these demographic and research variables de-identified by converting subject names and medical record numbers into project patient ID numbers. DOB was also converted to age at test administration. These de-identified data were used by investigators to conduct inferential analysis.

**Study Design**

Ex post facto experimental design was used to examine the effectiveness of extant clinical practices (treadmill protocols) in predicting optimal treadmill exercise times.

**Statistical Analysis**

1. Means, standard deviations and correlation matrices were generated.

2. Multinomial Logistic Regression was incorporated to evaluate if there was a significant difference between treatments while controlling for peak estimated work output in METs, gender, and age at test administration.

3. Nagelkerke R² was conducted to determine the percent of variance accounted for; age, gender, and METs.

4. Wald Statistic was used to test the hypotheses that a coefficient on an independent variable (peak exercise time) is significantly different from zero.
Summary

This chapter reviewed the study design, power analysis for determining sample size, sampling techniques, and procedures for the protection of human subjects. Finally, information regarding statistical analyses was provided.
CHAPTER IV
RESULTS

The research was casual – comparative in its design where we compared the possible effect of GXT protocols in predicting peak exercise time in cardiac patients. The results of statistical analyses, both descriptive and inferential, are presented in Chapter IV to address the study purpose and confirm research hypotheses that there is significant difference in ARP, Bruce and Modified Bruce protocols in predicting peak exercise times during graded exercise testing. And the ARP will account for unique variance in predicting optimal treadmill times (8 min. to 12 min.) over and above that accounted for by the Bruce and Modified Bruce Protocols while controlling for peak estimated work output in METs, gender, and age at test administration. Research hypotheses are addressed through the use of multinominal logistic regression analysis.

The data was collected from the patients’ exit test records to minimize the anxiety factor. The sample for this research was randomly selected for the ARP and Bruce protocols; however, Modified Bruce sample was all the patients who did that test as their exit test. Data were entered into the SPSS (version 16.0) database and screened prior to analysis for accuracy in terms of outliers, unusual frequencies or means indicating improper data entry, and missing data. There were no missing data because the information was collected via files screening. The principal investigator collected all data
and made certain that information was complete for each participant. The data was examined carefully and cleaned as necessary.

### Descriptive Statistics

The study consisted of 73 patients, 29 female and 44 male. The sample has mean age of 67.06 years ($SD = 10.37$; range = 43.39 years). Table 1 provides descriptive statistics for the sample.

**Table 1: Means and Standard Deviations of the Study’s Variables.**

<table>
<thead>
<tr>
<th>Variable</th>
<th>ARP</th>
<th>Bruce</th>
<th>Modified Bruce</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>33</td>
<td>26</td>
<td>14</td>
</tr>
<tr>
<td>Age in years</td>
<td>70.5 ± 9.6</td>
<td>62.4 ±10.1</td>
<td>67.6 ±10.1</td>
</tr>
<tr>
<td>METs</td>
<td>7.14 ± 2.5</td>
<td>8.82 ±2.8</td>
<td>11.96 ± 3.46</td>
</tr>
<tr>
<td>Peak Exercise Time in Minutes</td>
<td>7.96 ± 2.2</td>
<td>7.85 ± 2.8</td>
<td>10.39 ±3.14</td>
</tr>
</tbody>
</table>

As it shown in table 1, 33 patients performed the ARP protocol (14 men and 19 women), 26 performed the Bruce protocol (19 men and 7 women), and finally, 14 performed the Modified Bruce protocol (11 men and 3 women). The patients were categorized into three time groups; group time 1 was all the patients who completed the GXT within 0 – 7.98 minutes which consisted of 32 patients, group time 2 (the optimal time) was all the patients who completed the GXT within 8 – 11.98 minutes and
consisted of 34 patients, the third and final group was the 7 patients who reached their maximal capacity any time between 12 and 16 minutes. Theoretically, the categorical demographic variables of interest in the current study were protocol types, time groups, gender and age.

In figure 1, the descriptive statistics revealed that 32 patients (16 men and 16 women) reached their peak exercise time within (0 – 7.98) minutes. There were 34 patients (21 men and 13 women) finished their test within (8 – 11.98) minutes; which we acknowledge as the optimal time. Seven patients (all men) reached their peak exercise time within (12-16) minutes. These men performed either Bruce or Modified Bruce protocols.

Figure 1: Patient’s Protocol Type and Time Groups
The graph in figure 2 clearly shows the number of patients, the gender demographics, and the time groups that was achieved for each protocol.

![Graph showing patients' gender and peak exercise times]

**Figure 2: Patients’ Gender and Peak Exercise Times**

**Inferential Statistics**

Two research hypotheses guided inferential statistical analyses for the study: (a) there is no significant difference in ARP, Bruce and Modified Bruce protocols in predicting peak exercise times during graded exercise testing, and (b) the ARP will not have higher sensitivity in predicting optimal treadmill times (8min. to 12 min.) over that accounted for by the Bruce and Modified Bruce Protocols.

Multinomial logistic regression was conducted to build a model that attempts to predict which GXT protocol has a better capability in categorizing patients into high or low functional capacity categories prior to exercise and which one of these protocols predict the maximum oxygen consumption (VO$$_{2\text{max}}$$), presented by METs, within the
acceptable time period (8-12 min). The model compared the ARP protocol to Bruce and Modified Bruce. Table 2 provides the Chi-square results that suggested a statistically significant difference between Bruce and Modified Bruce and the ARP in predicting peak exercise time. From that the study first null hypothesis is rejected and it is concluded that there is a significant difference between the ARP and the other two protocols in predicting peak exercise time.

Table 2: The chi-square Test Result between the Protocols.

<table>
<thead>
<tr>
<th>Likelihood Ratio Tests</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chi-square</td>
</tr>
<tr>
<td>44.354</td>
</tr>
</tbody>
</table>

$\alpha = 0.05$

In table 3, the researcher tested the significant difference between genders in predicting peak exercise times. The result showed no significant difference in predicting times between genders.

Table 3: The chi-square Test Result between Gender and the Protocols.

<table>
<thead>
<tr>
<th>Likelihood Ratio Tests</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chi-square</td>
</tr>
<tr>
<td>6.056</td>
</tr>
</tbody>
</table>

$\alpha = 0.05$
Table 4: Comparison between Bruce and Modified Bruce and the ARP in Predicting the METs.

<table>
<thead>
<tr>
<th>GXT protocol</th>
<th>B</th>
<th>Wald</th>
<th>df</th>
<th>Sig</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bruce</td>
<td>0.287</td>
<td>1.894</td>
<td>1</td>
<td>.169</td>
</tr>
<tr>
<td>Modified Bruce</td>
<td>0.955</td>
<td>10.620</td>
<td>1</td>
<td>.001</td>
</tr>
</tbody>
</table>

Table 4 provides Wald Statistic results that suggested that there was no significant different between the ARP and Bruce protocol in predicting patients’ maximum functional capacities presented by METs; however, there was significant different between ARP and Bruce in predicting patients’ functional capacities.

The classifications of each protocol and its sensitivity in predicting peak exercise time is presented in table 5.

Table 5 clearly shows that the overall predictive accuracy is 60.3%. The most common outcome protocol is the ARP with 57.5% of all cases being predicted in this protocol. The ARP is predicted most accurately (75.8%), while the other protocols, Bruce 53.8% and Modified Bruce 35.7%, are predicted with less accuracy. This information rejected the study second null hypothesis and suggested that the Accelerated Ramp Protocol (ARP) has higher accuracy in predicting the maximum work capacities in cardiac patients within the optimal time period 8 – 12 minutes.
Table 5: GXT Protocol Predictability.

<table>
<thead>
<tr>
<th>GXT Protocol</th>
<th>GXT Protocol Predicted</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Observed</strong></td>
<td>Bruce</td>
</tr>
<tr>
<td>Bruce</td>
<td>14</td>
</tr>
<tr>
<td>Modified Bruce</td>
<td>3</td>
</tr>
<tr>
<td>ARP</td>
<td>5</td>
</tr>
<tr>
<td>Overall Percentage</td>
<td>30.1%</td>
</tr>
</tbody>
</table>

Nagelkerke $R^2$ indicates that 52% of the variation in predicting time is explained by age, gender, and METs.

Summary

This chapter provided statistical descriptions of the research sample and study variables including the moderator variables, the predictor variable of protocol types, and the outcome variable of peak exercise time. Multinomial logistic regression concluded that the Accelerated Ramp Protocol (ARP) has higher accuracy in predicting the maximum work capacities in cardiac patients within the optimal time period 8 – 12 minutes.
Chapter V provides a description and interpretation of results found in the current study. Findings are then compared to previous research. Limitations of the study are discussed and implications for future research are presented.

The purpose of the current study was to examine the ability of a newly developed ramp protocol (ARP) in predicting the maximum work capacities in cardiac patients within the optimal time period 8 – 12 minutes. Two research hypotheses guided the study and included: (a) there is no significant difference in ARP, Bruce and Modified Bruce protocols in predicting peak exercise times during graded exercise testing, (b) the ARP will not has higher sensitivity in predicting optimal treadmill times (8 min. to 12 min.) over that accounted for by the Bruce and Modified Bruce Protocols.

Through this thesis research, protocol type was identified as a significant predictor of peak exercise time during GXT for cardiac patients. Patients’ gender, METs, and age were moderators that strengthened the correlation between the protocol types and predicting the optimal peak exercise time.

Graded exercise stress testing is used to categorize patients into low, moderate, or high risk for exercise participation depending on their METs level. According to ACC
and AHA guideline for perioperative cardiovascular evaluation for non-cardiac surgery, Duke Activity Status Index (DASI) can be used to estimates energy requirements in METs for various activities. Energy expenditures for activities such as eating, dressing, walking around the house, and dishwashing, range from 1 to 4 METs. Patients who show peak functional work capacity (FWC) after performing GXT less than 4 METs considered at high risk for exercise participation. Climbing a flight of stairs, walking on level ground at 6.4 km per hour, running a short distance, scrubbing floors, or playing a game of golf represents 4 to 10 METs. Patients who show maximal FWC between 4 and 10 METs considered at moderate risk for exercise participation. Strenuous sports such as swimming, singles tennis, and football often exceed 10 METs. Patients with maximal FWC over 10 METs considered at low risk for exercise participation and cardiac complications during exercise.

Chi-square results implied that there was a significant difference between the ARP and the other two protocols in predicting peak exercise time for this sample. The ARP revealed accuracy in predicting the optimal time 75.8% of the times compared to Bruce and Modified Bruce. These finding reject the null hypothesis and suggested that the ARP protocol has higher sensitivity in predicting optimal treadmill times (8min. to 12 min.) over that accounted for by the Bruce and Modified Bruce Protocols.

The ramp approach to exercise testing has recently been advocated because it tends to stress the cardiac patient’s heart slowly and adequately. A study by Martin Noël et al (2007) has found that the myocardial ischemic threshold is significantly higher on the ramp protocol ergocycle compared with the standard Bruce treadmill protocol despite similar exercise energy expenditure at the occurrence of myocardial ischemia. Another
study by Bader et al (1999), suggested that in an older population, the peak cardiopulmonary responses to GXT as well as the accuracy of prediction VO₂ are similar between the individualized ramp and step exercise treadmill protocols. They found no significant differences in VO₂max, heart rate, rate–pressure product, or ventilatory anaerobic threshold between the two types. These findings agree with Will and Walter (1999), study that proposed that the ramped modification of the Bruce protocol achieves equivalent cardiopulmonary responses in middle aged population. However, according to their finding, ramp modifications of Bruce protocol give better duration and higher comfort to cardiac patients.

There is agreement in the literature about the effectiveness of the ramp protocol in predicting maximum functional capacity in cardiac patients. Findings of this study concur with the literature and suggest that the ARP protocol unique design addresses the variability in physiological response to exercise stress test ignored by both individualized and standardized ramp formatting. In the ARP protocol, the intensity increment is ramped; however, there is a unique aspect about that protocol allows the relatively fit patients to jump stages if their rating perceived exertion (RPE) was lower than 9. Many studies suggested that the RPE provides a physiologically valid method of regulating exercise intensity. It will allow the patients to set their comfortable intensity and reach their maximum functional capacity within the optimal time of 8 -12 minutes. This aspect is not present in both Bruce and Modified Bruce. The results showed that there were patients in Bruce and Modified Bruce who exceeded this optimal time but no one in the ARP protocol exceeded the 12 minutes limit.
A study by McInnis et al (1992)\textsuperscript{24} suggested that although myocardial ischemic threshold is the same when patients performed Bruce and Modified Bruce and is not altered by varying the work-rate increment between the protocols, exercise capacity is greater with the standard than with the Modified Bruce protocol. This was explained by the patients’ ability to achieve a higher peak heart rate, higher blood pressure, and higher VO\textsubscript{2}\text{max} performing Bruce protocol. As it was mentioned earlier, obtaining an accurate measure of VO\textsubscript{2}\text{max} is becoming more critical for cardiac patients and their physicians. Nevertheless, using Bruce protocol is sometimes inapplicable in severely de-conditioned patients. From the Wald Statistic results that showed a significant difference between the ARP and Modified Bruce in predicting patients’ maximum functional capacities presented by METs and no significant difference between ARP and Bruce in predicting patients’ functional capacities, the researcher suggested the use of ARP protocol in testing patients reveals more accurate values of VO\textsubscript{2}\text{max} levels than Modified Bruce.

The safety of using Bruce protocol after acute myocardial infarction was questioned by Senaratne et al (2000)\textsuperscript{25} study. They suggested that exercise testing can be done using the Bruce protocol within three days of admission with a very low incidence of complications. According to their study, applying the test can lead to early triage and potential cost saving. The question now will be what if applying Bruce protocol is hard because of patient conditions; another lower intensity test should be available to address this problem. This study suggested that ARP protocol is comparable to Bruce protocol in predicting VO\textsubscript{2}\text{max} with lower intensity meets the de-conditioned patients’ abilities.

In a study that was conducted by Lewis et al (2005)\textsuperscript{26} showed that Modified Bruce test appears to be of limited diagnostic value in women with suspected myocardial
ischemia. It has poor sensitivity and specificity in detecting CAD. These finding are signifying the importance of considering the unique improvement the ARP protocol holds that can increase the sensitivity and specificity of GXT in detecting CAD.

These population-based data showed that there was a significant difference between men and women in predicting maximum exercise time during GXT. That agrees with literature\textsuperscript{50, 51, 52}; however, for this sample it may be interpreted by the sample small size. Furthermore, the patients were assigned to each protocol based on previous clinical judgment from the stress test clinician or the patients’ physician which might affect the research results.

**Limitations**

This study is limited by its small sample size ($N=73$). The sampling in this study was random for the ARP and Bruce protocols; however, the population patients were not randomly assigned to each protocol which internally threatens the results of this study. The database did not have enough patients who did Modified Bruce protocol as their exit test; therefore, Modified Bruce sample is all the patients’ records that were available. Another limitation in this study was the peak exercise time and estimated METs in Modified Bruce protocol sample which can be explained by the sample size and characteristics. This study also lacks information about heart rate variability and hemodynamic evaluations such as blood pressure.
Recommendations for Future Research

Maximum oxygen consumption direct measurements are needed in future studies to validate the accuracy of METs predicted by ARP protocol in cardiac patients. This study also could be replicated with a larger sample size that randomly assigned to the three GXT protocols. The researcher recommends that future studies include heart rate variations and hemodynamic measures to give a more precise measure of heart dysfunctions. The researcher acknowledges the importance of measuring VO$_{2\text{max}}$ in clinical sitting; however, GXT is also used to give ideas about the electrical activity of the heart, which is used as an important tool in diagnosing cardiac diseases. The researcher recommends the need for future studies to evaluate the ARP protocol ability in revealing cardiac dysfunctions by testing the correlation between the ECG results from applying the ARP protocol with more intensive diagnostic tool.
REFERENCES


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33. Martin Noël, Jean Jobin, *Different Thresholds of Myocardial Ischemia in Ramp and Standard Bruce Protocol Exercise Tests in Patients With Positive Exercise Stress Tests and Angiographically Demonstrated Coronary Arterial Narrowing*


APPENDICES
May 27, 2009

Jim Roanack, MS
Cardiovascular and Pulmonary Rehab
Akron City Hospital
95 Arch Street
Akron, OH 44319

Dear Mr. Rosneck,

The IRB #2 has received and reviewed your proposal and associated documents for
the study entitled:

RP#09045  Ramped Protocol Time Project

The project was reviewed and approved through expedited review procedures,
effective May 29, 2009 for a twelve-month period.

This means that your project must be reviewed by the IRB #2 (MRC) Chairperson (or
designee) and/or the full committee for renewal no later than May 25, 2010. Federal
regulations do not allow for ANY grace period for renewal. As a courtesy, IRBNet
will notify you prior to the project expiration date and request that a renewal
application be submitted. If the renewal application is submitted too late for IRB
review, your project will be inactivated and your department notified. This
inactivation would mean that you may not accrue patients, obtain data and/or review
charts until proper renewal is obtained. It is your responsibility, as the
investigator to renew the project.

It is the IRB’s opinion that you will provide adequate safeguards for the rights and
welfare of the participants in this study. Your project appears to be in compliance
with the institution’s FWA and the appropriate federal regulations for the protection
of human subjects. We wish you success with your project.

Sincerely,

Thomas Alexander, PhD
Chair, Institutional Review Board 2

www.summahealth.org
SUMMA HEALTH SYSTEM
PROCEDURE: ENTRY GRADED EXERCISE TEST REHAB RAMPED PROTOCOL©

AKRON CITY HOSPITAL
SAINT THOMAS HOSPITAL
AMBULATORY SERVICES

CARDIAC REHABILITATION POLICIES AND PROCEDURES

SUBJECT:

OBJECTIVE:
- To outline criteria for the Cardiac Rehab Nurse/Exercise Physiologist (N/Ex) to conduct a Ramped GXT protocol in order to provide safe/quality testing and consistent procedures.

- To provide a guideline for advancement of exercise workloads using the 6-20 Borg Rate of Perceived Exertion Scale (RPE) in order for the patient to achieve peak exertion treadmill levels within a 8 to 12 minute time period.

PROCEDURE:
- Prior to exercise testing staff evaluates patient for absolute and relative contraindications to exercise testing per cardiac rehab departmental guidelines. (See GXT contraindications below)

- Patient prepped and oriented to procedure following departmental guidelines.
• Patient instructed to verbalize and point to Borg 20 point scale exertion number corresponding to or in-between somatic descriptors.

• Patient is then instructed regarding *volitional maximal exertion*. (Explain the importance of maximal effort to the patient emphasizing maximal exhaustive effort results in enhanced predictive specificity in ECG interpretation and maximal workload analysis for exercise prescription…. i.e. “Push it as hard as you can in order to get the best results”. When patient states a desire to stop the test ask “Can you go a little longer”. Subjective perceived exertion levels desired: (≥ 17 on the 6-20 Borg RPE scale.) Document reason for cessation of the test and/or if patient is unable to attain volitional max levels due to S&S of cardiovascular decomposition, neuromuscular, orthopedic or other comorbidive symptoms.

• Pt. is instructed in treadmill walking with emphasis on free-hand/finger-tip-grip technique. (Remind patient to use finger-tip contact with forward hand-rail)

• The “Ramped Exercise Protocol” (RR) protocol selected on the stress ECG database.

• The (RR) exercise protocol is characterized by an increase in mill elevation every 60 seconds that approximates a relative increase in workload of 15% while holding speed constant and then an increase in speed every 3 minutes that also reflects an approximate relative increase in workload of 15% from the previous stage.

• At 3-minute intervals staff assesses BP and RPE and enters data in stress ECG database.

• Advancement Protocol: If RPE rating ≤ 9 advance two speeds levels (see example below) and reevaluate after 3 minutes.

EXAMPLE: Ramped Protocol Accelerated Stage Progression Based on Borg RPE

EXAMPLE:

\[
\begin{cases}
\text{At stage #3: If RPE} \leq 9 \rightarrow \text{then advance the workload to stage 7} \\
\text{At stage #9: If RPE} \leq 9 \rightarrow \text{then advance the workload to stage 12} \\
\text{At stage #14: If RPE} \leq 9 \rightarrow \text{then advance the workload to stage 17}
\end{cases}
\]
BORG EXERTION SCALE

6
7 VERY VERY LIGHT
8
9 FAIRLY LIGHT
10
11 FAIRLY LIGHT
12
13 SOMEWHAT HARD
14
15 HARD
16
17 VERY HARD
18
19 VERY VERY HARD
20

- Assess test termination criteria procedure following departmental guidelines. (See GXT P&P)

Summa Cardiac Rehab:  Rehab Ramped GXT Protocol©

<table>
<thead>
<tr>
<th>Stage</th>
<th>Time</th>
<th>Speed (mph)</th>
<th>% Grade</th>
<th>METs</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1 min</td>
<td>1.5</td>
<td>1.0</td>
<td>2.3</td>
</tr>
<tr>
<td>2</td>
<td>1 min</td>
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*JSR (1995)*
Indications for Terminating Exercise (ACC/AHA guidelines for exercise testing. J Am Coll Cardiol 1997;30:260-3150)

Absolute Indications:
- Drop in systolic blood pressure of $\geq 10$ mm Hg from baseline blood pressure despite an increase in workload, when accompanied by other evidence of ischemia
- Moderate to severe angina
- Increasing nervous system symptoms (e.g., ataxia, dizziness, or near syncope)
- Signs of poor perfusion (cyanosis or pallor)
- Technical difficulties monitoring the ECG or systolic blood pressure
- Subjects desire to stop
- Sustained ventricular tachycardia
- ST elevation ($\geq 1.0$ mm) in leads without diagnostic Q-waves (other than $V_1$ or aVR)

Relative Indications:
- Drop in systolic blood pressure of $\geq 10$ mm Hg from baseline blood pressure despite an increase in workload, in the absence of other evidence of ischemia
- ST or QRS changes such as excessive ST depression ($\geq 2$ mm horizontal or downsloping ST-segment depression) or marked axis shift
- Arrhythmias other than sustained ventricular tachycardia, including multifocal PVC’s, triplets of PVC’s, supraventricular tachycardia, heart block, or bradyarrhythmias
- Fatigue, shortness of breath, wheezing, leg cramps, or claudication
- Development of bundle-branch block or intraventricular conduction delay that cannot be distinguished from ventricular tachycardia
- Increasing chest pain
- Hypertensive response (systolic blood pressure $\geq 250$ mm Hg and/or a diastolic blood pressure $\geq 115$ mm Hg)

Manager       Medical Director
APPENDIX C
BRUCE PROTOCOL

<table>
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<th>Stage</th>
<th>Time (min)</th>
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APPENDIX D

MODIFIED BRUCE PROTOCOL

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## APPENDIX E

### INDICATION TO EXERCISE TESTING

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<tr>
<th></th>
<th>Evaluation of patients with suspected coronary artery disease (CAD).</th>
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<tr>
<td></td>
<td>• Atypical Angina Pectoris</td>
</tr>
<tr>
<td></td>
<td><strong>2</strong> Evaluation of patients with known coronary artery disease (CAD).</td>
</tr>
<tr>
<td></td>
<td>• After myocardial infarction</td>
</tr>
<tr>
<td></td>
<td>• After intervention</td>
</tr>
<tr>
<td>3</td>
<td>Evaluation of exercise capacity</td>
</tr>
<tr>
<td>4</td>
<td>Evaluation of cardiac rhythm disorders</td>
</tr>
<tr>
<td>5</td>
<td>Screening of healthy, asymptomatic patients</td>
</tr>
<tr>
<td></td>
<td>• Persons in high-risk occupations</td>
</tr>
<tr>
<td></td>
<td>• Men over age 40 and women over age 50 who are sedentary and plan to start vigorous exercise programs</td>
</tr>
<tr>
<td></td>
<td>• Men or women with multiple risk factors or patients with cardiac or associated conditions that wish to be evaluated or begin an exercise program</td>
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</tbody>
</table>
### Absolute Contraindications

<table>
<thead>
<tr>
<th></th>
<th>Description</th>
</tr>
</thead>
<tbody>
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<td>Resent significant change in the resting ECG suggesting acute infarction.</td>
</tr>
<tr>
<td>2</td>
<td>Recent complicated Myocardial infarction</td>
</tr>
<tr>
<td>3</td>
<td>Unstable angina</td>
</tr>
<tr>
<td>4</td>
<td>Uncontrolled ventricular arrhythmia</td>
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<tr>
<td>5</td>
<td>Uncontrolled arterial arrhythmia that compromises cardiac function</td>
</tr>
<tr>
<td>6</td>
<td>Acute congestive heart failure</td>
</tr>
<tr>
<td>7</td>
<td>Severe aortic stenosis</td>
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<tr>
<td>8</td>
<td>Third degree AV block without the pacemaker</td>
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<tr>
<td>9</td>
<td>Suspected or known dissecting aneurysm</td>
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<tr>
<td>10</td>
<td>Intracardiac thrombi</td>
</tr>
<tr>
<td>11</td>
<td>Active or suspected myocarditis</td>
</tr>
<tr>
<td>12</td>
<td>Recent systemic or pulmonary embolus</td>
</tr>
<tr>
<td>13</td>
<td>Acute infection</td>
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<tr>
<td>14</td>
<td>Significant emotional distress</td>
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### Relative Contraindications

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<th>Description</th>
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<td>Resting diastolic blood pressure ≥115 mm Hg or resting systolic blood pressure ≥ 200 mm Hg</td>
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<tr>
<td>2</td>
<td>Moderate valvular heart disease</td>
</tr>
<tr>
<td>3</td>
<td>Known electrolyte abnormalities</td>
</tr>
<tr>
<td>4</td>
<td>Fixed rate pacemaker</td>
</tr>
<tr>
<td>5</td>
<td>Frequent or complex ventricular ectopy</td>
</tr>
<tr>
<td>6</td>
<td>Ventricular aneurysm</td>
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<tr>
<td>7</td>
<td>Uncontrolled metabolic disease</td>
</tr>
<tr>
<td>8</td>
<td>Chronic infectious disease</td>
</tr>
<tr>
<td>9</td>
<td>Neuromuscular, musculoskeletal, or rheumatoid disorders that exacerbated by exercise</td>
</tr>
<tr>
<td>10</td>
<td>Advance or complicated pregnancy.</td>
</tr>
</tbody>
</table>
APPENDIX G
ABBREVIATIONS LIST

GXT: Graded Exercise Stress Test
ECG: Electrocardiography
MET: Metabolic Equivalents
CVD: Cardiovascular Disease
CAD: Coronary Arteries Disease
HBP: High Blood Pressure
MI: Myocardial Infarction
AHA: American Heart Association
ACC: American College of Cardiology
ACSM: American College of Sport Medicine
AACVPR: American Association of Cardiovascular and Pulmonary Rehabilitation
VO\textsubscript{2}\text{max}: Maximum Oxygen Consumption
APR: Accelerated Ramp Protocol
RPE: Rating Perceived Exertion
CHF: Congestive Heart Failure