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Prediction of performance time on a treadmill stress test following a Bruce protocol

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**PREDICTION OF PERFORMANCE TIME ON A TREADMILL STRESS TEST
FOLLOWING A BRUCE PROTOCOL**

by

Helena Nadine Boersma

**Bachelor of Science
University of Alaska, Fairbanks
1987**

**Master of Science
Golden Gate University
1991**

**A thesis submitted in partial fulfillment
of the requirements for the**

**Master of Science Degree
Department of Kinesiology Exercise Physiology
College of Health Sciences**

**Graduate College
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ABSTRACT

Prediction of Performance Time on a Treadmill Stress Test Following a Bruce Protocol

By

Helena Nadine Boersma

**Dr. John C. Young, Examination Committee Chair
Professor of Kinesiology
University of Nevada, Las Vegas**

The purpose of this study was to determine if screening tools from a self-reporting questionnaire, comprised of work-capacity questions, and physiological data, could be developed to predict treadmill test time when following a Bruce protocol. One hundred and eight subjects completed the questionnaire and performed treadmill tests. A stepwise regression analysis was used to develop equations from the research parameters established on the questionnaire, and resulted in two useful predictive equations, one for males and one for females. Results indicated 52 males and 33 females had actual treadmill times of six minutes or greater. The prediction equations predicted 59 males and 35 females would have actual treadmill times of six minutes or more, which resulted in an 88 percent prediction accuracy rate for males and 94 percent for females. It was also determined that subjects who had a pulse pressure ≤ 60 reached the six-minute threshold 87 percent of the time for women and 86 percent of the time for men.

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CHAPTER 1

INTRODUCTION

Cardiovascular disease accounts for nearly 1 million deaths (41percent of all deaths) and contributes to substantial morbidity, including 6 million hospital admissions, in the United States each year (Cohen, Stafford, & Misra, 1999).

United States physicians devote a substantial amount of clinical work to the evaluation and management of heart disease (Cohen, Stafford, & Misra, 1999). A basic diagnostic test used to establish the presence and prognosis of heart disease is the graded exercise stress test, even though it can only predict the presence of heart disease about 85 percent of the time (Mankin, 1980). Exercise stress testing is a relatively inexpensive, noninvasive tool that provides valuable cardiopulmonary information in healthy and diseased populations (Lear, Brozic, Myers, & Ignaszewski, 1999). The widespread availability and high yield of clinically useful information make the exercise stress test an important gatekeeper for more expensive and invasive procedures (Froelicher, 1994).

There are a variety of treadmill protocols used for stress testing such as the Naughton, Bruce, Weber, Ellestad, and Balke-Ware. Although different, each protocol shares the common features of an acceptable protocol. Namely, the protocol should accommodate individuals of a wide range of cardiovascular capability. The protocol

should be standardized, such as those outlined by American College of Sports Medicine and the American Heart Association, and should allow for the measurement of relevant parameters such as heart rate and blood pressure. Finally, the protocol should involve a familiar activity such as walking.

Treadmill protocols utilizing progressive and continuous increases in workload, such as a multi-stage protocol, are currently the most popular in the United States (Ellestad, Cooke, & Greenberg, 1979). Staged ramped protocol allows the patient to start at a relatively low work capacity level and gradually increase the work capacity level until a maximal workload level or symptom-limits have been reached.

Each treadmill protocol has advantages and disadvantages for the type of patient being tested, and it becomes apparent then that in order to obtain the maximal amount of information from the stress test, the protocol may need to be altered somewhat to fit the clinical situation. The standard Bruce protocol is a popular multi-stage treadmill protocol with extensive diagnostic and prognostic databases published to support the protocol's usage (Braunwald, 1997). It is also the most widely employed clinical graded exercise test protocol (Foster, Hare, Taylor, Goldstein, Anholm, & Pollock, 1984).

The American Heart Association (AHA) Guidelines state that an optimum treadmill test time should be approximately six to 12 minutes following an accepted treadmill protocol. Therefore, given the prevalence of cardiovascular disease in America and the fact that over 3 million treadmill tests are ordered each year nationwide (Cohen, Stafford, & Misra, 1999), it makes sense to evaluate total time on the treadmill, which is one critical component of a treadmill stress test. The reason to look at total time is to learn if it is possible to develop screening tools that could be used as predictive guidelines

that would determine a patient's chance of reaching the minimum six-minute threshold established by the AHA. If these screening tools could be developed, doctors would be able to order patient-specific exercise stress testing and patients would potentially avoid the financial and emotional expense associated with multiple tests.

Purpose of the Study

The purpose of this study was to determine if treadmill performance time following a Bruce protocol could be predicted from a self-reporting questionnaire and resting physiological variables. The current American Heart Association Guidelines state that an optimum treadmill test time should be approximately six to 12 minutes following an accepted treadmill protocol. This represents completion of stage II of the Bruce protocol, which corresponds to a work capacity level of 7 METs. Although a positive stress test for coronary artery disease can be achieved in less than six minutes, there is less variation in the test results when the test duration exceeds the six minute threshold (ACSM Resource Manual Third Edition, 1991; AHA Exercise Standards, 1995; Meyers, Froelicher, 1990).

Assumptions of the Study

1. Subjects were asked to complete the questionnaire as truthfully as possible.
2. Subjects were asked by their doctors not to take specific medications prior to their treadmill test, which might interfere with the heart's ability to reach its target rate during the test.

Limitations of the Study

- 1. Subjects were not exercise test volunteers, which might negate random sampling.**
- 2. Subjects are from a pre-selected group, which reduces the predictive value to this population.**
- 3. Subjects resided in the greater Rochester, New York area so inferences will be more appropriate to Rochester.**

Need for the Study

A better understanding of how screening tools could be developed into reliable predictive guidelines that offered patients a specific exercise stress test that they would be able to perform for at least six minutes when assessing heart disease.

CHAPTER 2

REVIEW OF THE LITERATURE

Exercise, a common physiological stress, can elicit cardiovascular abnormalities not present at rest and can be used to determine the adequacy of cardiac function (AHA Medical/Scientific Statement, 1995). Treadmill testing is useful in assessing physical fitness, determining functional capacity, diagnosing cardiac disease, defining the prognosis of known cardiac disease, and guiding cardiac rehabilitation. Due to its familiarity, the most common method of exercise testing used in United States laboratories is the treadmill (White & Evans, 1994).

The following review looks at the origin and development of exercise testing and its use today in stress testing and research.

Origins of Electrocardiography and Cardiology

The development of the electrocardiograph (ECG) provided a tool for diagnosing, studying, and treating heart disease. Although it has been roughly 100 years since the first, it still serves as an independent marker of myocardial infarction and remains vital for proper diagnosis and therapy of cardiovascular disease (Savoy & O'Leary, 1995).

In 1873, Gabriel Lippman developed the capillary electrometer, which ultimately recorded the first human ECG. But it was not until 1887 when Augustus Desire Waller was the first to record an ECG using a lead system that did not require opening the chest.

However, he was not a doctor and did not see the clinical application to his discovery. It was during a presentation of his experiment that Willem Einthoven, a Dutch physician, learned of the discovery and became interested in recording the electrical activity of the heart. He first used the Lippmann Capillary electrometer, but found this instrument to be frustrating because of the sluggishness of the mercury meniscus and because vibrations produced from horse-drawn carriages shook the mercury meniscus (Savoy & O'Leary, 1995). Thus Einthoven sought new equipment and was successful when he met French electrical engineer, Clement Ader, in 1897, who had developed a wire galvanometer.

Einthoven, with his galvanometer that won him the Noble Prize, standardized the ECG tracing and labeled recognizable waves as "P, Q, R, S, T" (Figure 1).

Documenting the ECG was the next milestone in ECG history and it was James Mackenzie who came to the rescue. A country doctor in Scotland in the late nineteenth century, Mackenzie had developed the first polygraph machine, which used ink-writing pens. He later transferred this technique to the ECG. What turned out to be very important about this technique was the tracing paper, which was now on a roll and tracings could be made of any length instead of limited to the width of a circular drum (Reichert, Bishop, 1969). Throughout the first decade of the twentieth century, the electrocardiography was a curiosity and the electrocardiogram a mystery (Reichert, Bishop, 1969).

The first and second World Wars had a direct impact on the development of cardiac surgeries and the practice of a physician specializing in cardiac care. Previously,

Figure 1. A typical normal electrocardiogram, composed of a P wave that represents depolarization of the atria. The P-R interval indicates the delay in the impulse at the atrioventricular (AV) node. Electrical currents generated during ventricular depolarization and contraction produce the QRS complex. The T wave and ST segment correspond to ventricular repolarization.

cardiac diagnosis and care were recognized as Europe's specialties and most heart specialists were to be found at the spas; America had no such specialty. Patients with heart disease made a yearly trip to Europe for "the cure". Full time medical research was a laboratory process and the American laboratory specialist was not troubled with the care of patients. There was logic in the thought that Europe led the medical world, especially in the diagnosis and treatment of heart diseases (Reichert & Bishop, 1969).

In 1908, Louis Faugeres Bishop, Sr., an American doctor, traveled to Europe and learned about the doctors who specialized in heart care and brought the knowledge to America (Reichert & Bishop, 1969) thus establishing heart specialists in America.

Clinical Usage of Exercise Testing

When Einthoven published the first exercise electrocardiogram at the turn of the twentieth century, stair climbing was the stress test he used for the simple reason that his office was located at the top of the stairs. When patients walked into his office, their heart rates were elevated and he would assess how they were doing (Mankin, 1980). Patients now arrive more relaxed for their exercise tests.

As reported by Tokmakova (1998), cardiopulmonary exercise testing makes it possible to assess the exercise response in patients with abnormalities that are either underestimated or not detectable at rest. Mankin (1980) further states that the exercise test enhances the clinician's understanding of the patient if for no other reason than "the more we look the more we see." Mankin felt it provided a very logical extension of the patient's history and physical exam performed.

A clinical diagnosis of coronary heart disease in an ambulatory patient is not an automatic indication for exercise testing. Although this fact is well recognized by most physicians, some still tend to approach every patient with coronary disease in a stereotyped manner and use the exercise test as part of the routine work up (McHenry, 1977). The differential diagnosis of chest pain to include or exclude ischemic heart disease is the clinical model most often subjected to exercise testing (Mankin, 1980).

Common Laboratory Modalities for Stressing the Heart

Although exercise testing is generally a safe procedure, both myocardial infarction and death have been reported and can be expected to occur at a rate of up to 1 per 2500 tests (Stuart & Ellestad, 1980). Good clinical judgment should therefore be

used in deciding which patients should undergo exercise testing (ACC/AHA Guidelines for Exercise Testing, 1997).

There is an abundance of literature that guides us through the process of exercise testing (ACSM Resource Manual, 1993; AHA Exercise Standards, 1995; Amsterdam, Wilmore, & DeMaria, 1977; Cardiac Society of Australia and New Zealand, 1996; Ellestad, 1975; Froelicher, 1994). In his write-up for ACSM Resource Manual for Guidelines for Exercise Testing and Prescription, Gettman defined the term “fitness testing” as the evaluation of four main health-related areas of physical fitness: 1) cardiovascular-respiratory function; 2) body composition; 3) muscular strength and muscular endurance; and 4) flexibility. Although muscle strength and endurance, flexibility, and body composition are important, cardiorespiratory fitness is viewed as the most essential physical fitness component (Getchell, 1987). By improving cardiorespiratory fitness levels through exercise, improvements in the transportation of oxygen through the blood to the working muscles is observed. This is accomplished by the increased efficiency of the heart, which pumps the blood; the lungs, where oxygen is picked up; and the unloading of oxygen at the tissue level (Golding, Myers, & Sinning, 1989).

When looking closely at the cardio functions, blood pulse rates and arterial blood pressures are closely associated with fitness levels. Schneider (1920) reported that McCurdy’s test in 1910 showed that the resting heart rate serves as a fair indication of physical condition; a high resting heart rate suggested poor condition, and a low resting heart rate suggested good condition. Schneider (1920) further reported that other

researchers who reported the correlation between a low resting heart rate and good physical condition were Pombry and Dawson in the early twentieth century.

Types of Exercise Testing Modalities

There are three types of exercise that can be used for stressing the heart: isometric, dynamic, and a combination of the two (Froelicher, Brammell, Davis, Noguera, Stewart, & Lancaster, 1974). Isometric exercise is a constant muscular contraction without any movement, which Froelicher et al. (1974) says, “imposes a disproportionate pressure load on the left ventricle relative to the body’s ability to supply oxygen.” Dynamic exercise, or rhythmic muscular activity resulting in movement, initiates a more appropriate increase in cardiac output and oxygen exchange. Because a delivered workload can be accurately calibrated and the physiological response easily measured, dynamic exercise is preferred for clinical testing. Using progressive workloads of dynamic exercise, patients with coronary artery disease can be protected from sudden increases myocardial oxygen demand.

Submaximal exercise tests can be used to predict or estimate the VO_2 max of an individual. All of the dynamic tests that have been listed can be used as maximal tests, the difference is that instead of taking an individual to a maximum level you terminate the test at a predetermined heart rate intensity. Both heart rate and blood pressure are monitored during exercise.

A submaximal exercise test assumes a linear relationship between heart rate, oxygen uptake, and work intensity. According to Froelicher, this relationship is true for light to moderate work loads, however, the relationship between oxygen uptake and work

becomes curvilinear at heavier work loads. Submaximal tests also assume a constant mechanical efficiency during cycling or treadmill exercise. However, a client with poor mechanical efficiency while cycling has a higher submaximal heart rate at a given work load, and the actual VO_2 max is underestimated due to this inefficiency (McArdle, Katch, & Katch, 1996). VO_2 max predicted by submaximal exercise tests tends to be overestimated for highly trained individuals and underestimated for untrained, sedentary individuals.

Modalities for Isometric Exercise

There are numerous testing devices for isometric exercises utilizing resistance through weights or tubing or through simple muscle contraction. It is well documented that isometric contractions cause a rise in heart rate (Galvez, Alonso, Sangrador, & Navarro, 2000). The isometric exercise testing device used in this research is a hand grip-strength dynamometer called the Smedley III. The hand-held dynamometry is an inexpensive and easy-to-handle device (Beck, Giess, Wurffel, Magnus, Ochs, & Toyka, 1999).

Grip-strength exercises have been used to intentionally stress the heart during stress echocardiography in patients with either stable angina pectoris or other types of positive stress test (Afridi, Main, Parrish, Kizilbash, Levine, & Grayburn, 1998). Also several groups of researchers noted that hand grip has been used alone, as well as in combination with other stress agents, for the detection of coronary artery disease (Bodenheimer, Banka, Fooshee, Gillespie, & Helfant, 1978; Jones, Lahiri, Cashman,

Dore, & Raftery, 1986; Mitamura, Ogawa, Hori, Yamazaki, Handa, & Nakamura, 1981; Tawa, Baker, Kleiman, Trakhtenbroit, Desire, & Zoghbi, 1996; Peters, & Jones, 1980).

According to Afridi, Main, Parrish, Kizilbash, Levine, and Grayburn, (1998), 27 patients undergoing dobutamine atropine stress echocardiography (a pharmacological form of stress testing) performed a single hand grip for two minutes while dobutamine infusion was maintained at the peak dose. The sustained hand grip was held at 33 percent of maximal voluntary contraction. Two patients reported worsening chest pain during the hand grip stage of test. The research resulted in the understanding that the addition of an isometric hand grip exercise test during dobutamine atropine stress echocardiography was feasible and safe, and improved the detection of ischemia in patients with coronary artery disease. The identification of patients with multivessel CAD improved from 15 percent to 61 percent with the addition of hand grip. The hand grip also enhanced the severity and extent of stress-induced ischemia (Afridi et al. 1998). Interestingly enough, during their research, there was no change in heart rate associated with hand grip measurement, only changes in chest discomfort associated with ischemia.

The reason for the impact of the hand grip measurement on the heart is associated with the increase in myocardial oxygen demand resulting from an increase in blood pressure and heart rate. Hand grip has been shown to cause coronary vasoconstriction due to a sympathetic nervous reflex, thereby decreasing myocardial oxygen supply (Brown, Lee, Bolson & Dodge, 1984; Ferrara, Bigorito, Leosco, Giordano, Abete, Longobardi, & Rengo, 1988). The major mechanism of the increase in heart rate with hand grip is a centrally mediated vagal withdrawal (Mitchell, Kaufman, & Iwamoto, 1983).

More recently, Wright and Fitzpatrick (2000) took six normal subjects and looked at the effect of physiological changes in systemic blood pressure on the force output of their working abductor pollicis muscle during a hand contraction. What they discovered was that the muscle performance is strongly affected by physiological changes in central blood pressure and suggested that sensory input concerning the adequacy of muscle performance exerted a feedback control over the increase in systemic blood pressure during muscular activity.

Modalities for Dynamic Exercise

Numerous modalities have been used to provide dynamic exercise for exercise testing, including steps, escalators, ladder mills, bicycles, treadmills, cross-country skiing, and arm ergometer. Any motorized equipment that can be calibrated and can deliver specific workloads can be used. However, in today's clinical setting, the bicycle and treadmill are the most commonly used.

Bicycle Ergometer Modality

The bicycle ergometer often uses resistance applied against the flywheel using a belt and weighted pendulums. The hand wheel adjusts the workload by tightening or loosening the brake belt. The workload is raised by increasing the resistance (kg) on the flywheel. The work is usually expressed in kilogram-meters per minute or watts (W).

The bicycle ergometer is usually cheaper, takes up less space, and makes much less noise when compared to other pieces of dynamic equipment. Upper body movement is minimized, yet you have to be careful how much a subject holds onto the handle bars

potentially causing an isometric contraction. Some calibrations of the bicycle ergometer are not well calibrated and depend on pedaling speed. According to Froelicher, it is too easy for a patient to slow pedaling speed during exercise testing and decrease the administered workload. More expensive electronically braked bicycle ergometers keep the workload at a specified level over a wide range of pedaling speeds.

Treadmill Modality

The treadmill is a motor-driven conveyor belt on which an individual can run or walk with calibrated speeds and inclines. Workload is generally expressed in miles per hour and percent grade. It is difficult and expensive to measure the oxygen consumption during exercise, therefore, equations have been developed to estimate the metabolic cost of exercise (VO_2). For walking on the treadmill, $\text{VO}_2 (\text{ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}) = \text{m} \cdot \text{min}^{-1} \times \frac{0.1 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}}{\text{m} \cdot \text{min}^{-1}} + \text{grade (frac)} \times \text{m} \cdot \text{min}^{-1} \times \frac{1.8 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}}{\text{m} \cdot \text{min}^{-1}} + 3.5 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$

Treadmills can be expensive, noisy, difficult to move, have an increased likelihood of injury due to the possibility of falling off, cause increased noise on an ECG due to patient holding hand rails and moving upper body, and increase likelihood of isometric contraction of upper body due to tight railing holding during incline stages. The first treadmill was used in the Harvard Fatigue Laboratory by B. Dill in 1928 (Horvath & Horvath, 1973).

Of the various types of stress tests available for diagnosing heart disease, including pharmacological and nuclear, the treadmill test is by far the most reasonably priced and least invasive. However, the lower cost of the treadmill exercise test alone

does not necessarily result in a lower overall cost of patient care. The cost of additional testing and interventions may be higher when the initial treadmill exercise test is less accurate than more sophisticated procedures (ACC/AHA Guidelines for Exercise Testing, 1997).

Types of Treadmill Testing Protocols

There are a wide variety of treadmill exercise test protocols used today throughout the world. An ideal protocol should consider the following: 1) the purpose of the test, and 2) the subject tested (Buchfher, Hanse, Robinson, Wasserman, & Whipp, 1983; Myers, Buchana, Walsh, Kraemer, McAvley, & Hamilton-Wessler, 1991; Myers & Froelicher, 1990; Webster & Sharpe, 1989). For most exercise testing, however, the choice of protocol is dictated by either tradition, equipment, or convenience. Out of all the treadmill protocols, more than half the laboratories in North America employ the standard Bruce protocol (Stuart & Ellestad, 1980), even though its large increments in workload make it inappropriate for many patients with cardiovascular disease (Myers, Buchana, Kraemer, McAvley, and Hamilton-Wessler, 1991; Myers & Froelicher, 1990; Panza, Quyyumi, Diodati, Callaham, & Epstein, 1991; Sullivan & McKirnan, 1984).

Standardized protocols, which conform to accepted guidelines such as those developed by the American Heart Association and the American College of Sports Medicine, are designed for specific testing populations, such as disabled, elite athletics, healthy population, or known heart disease patients. What sets each protocol apart is the amount of increase in workload, or work capacity, throughout the protocol, referred to as

METs. Despite the difference in MET level for comparable stages, different protocols can be used on different testing populations and net the same submaximal information.

Froelicher et al. (1974) compared three maximal treadmill exercise protocols to evaluate the effect of the Bruce, Balke, and Taylor protocols. Each protocol was used to test 15 healthy men; each man performed one test per week for nine weeks, repeating each protocol three times in randomized order. What Froelicher found was that the maximum heart rates achieved were reproducible within each protocol, and there were no significant differences in heart rate achieved among the three protocols.

Graettinger et al. (1995) tried to further Froelicher's findings by looking at the linear relationship between age and maximal heart rate, which has often been used as an approximation for maximal cardiac work, yet according to Graettinger, this relationship accounts for only about one third of the variance in maximal exercise heart rate. They looked to evaluate which relationships in addition to age might have an impact on heart rate, thus hoping to more accurately predict the maximal heart rate response to exercise. They concluded that age was still the predominate factor influencing heart rate after having taken into consideration other known major factors influencing maximal heart rate such as cardiac size and hypertension. Graettinger stated age-adjusted goals still have significant clinical utility.

With all exercise testing, regardless of modality, there are well-established guidelines for contraindications to exercise testing (American College of Sports Medicine, 1991; AHA Exercise Standards, 1995). For example, subjects reporting with recent significant changes in resting ECG suggesting infarction or other acute cardiac events, unstable angina, third-degree A-V block, acute congestive heart failure or sever

aortic stenosis should not be tested. For some conditions, the administration of the exercise test depends on the judgment of the administering physician. Related contraindications include resting diastolic blood pressure over 120 mmHg or resting systolic blood pressure over 200 mmHg, moderate valvular heart disease, or known electrolyte abnormalities.

Bruce Protocol

The Bruce protocol named after Robert Bruce was called The Bruce “Multistage Treadmill Test of Symptom Limited Maximal Exercise” (Mead, 1979). Now commonly called the Bruce protocol, it has become the most widely used exercise testing protocol (Mead, 1979; Pashkow & Dafoe, 1999). According to Heyward, the Bruce protocol is a very demanding protocol and can be easily adapted for patients who are not able to perform at such high metabolic level. (Figure 2).

The current literature shows over 400 research projects that have used the Bruce protocol as either the main exercising testing protocol or have used it in a comparative state. It does not seem reasonable or necessary to list them in order to show the extensive use and popularity of this protocol.

Until the mid to late 1990's, standard treadmill testing was done on horizontal treadmills but now exercise laboratories have the ability to use a ramp protocol as part of a standardized exercise test. Kaminsky and Whaley (1998) looked at adapting a standardized ramp treadmill protocol into a protocol that corresponded to the speed and grade settings of the Bruce protocol at each three-minute time interval. They called this new protocol the Bruce ramp protocol, and used it to evaluate the possibility of using

subject demographic and exercise test data to predict peak VO_2 . After performing maximal exercise tests on 698 men and women, Kaminsky and Whaley found that peak oxygen uptake values could be predicted with reasonable accuracy from the Bruce ramp protocol. This protocol is now referred to as the Bruce Protocol.

Standard Bruce Protocol				
Stage	Duration	Speed MPH	Grade (%)	METS
Rest/Recovery		1.2	0.0	
1	3:00	1.7	10.0	4.6
2	3:00	2.5	12.0	7.0
3	3:00	3.4	14.0	10.1
4	3:00	4.2	16.0	12.9
5	3:00	5.0	18.0	15.0
6	3:00	5.5	20.0	16.9
7	3:00	6.0	22.0	19.1

Modified Bruce Protocol				
Stage	Duration	Speed MPH	Grade (%)	METS
Rest/Recovery		1.2	0.0	
1	3:00	1.7	0.0	2.3
2	3:00	1.7	5.0	3.5
3	3:00	1.7	10.0	4.6
4	3:00	2.5	12.0	7.0
5	3:00	3.4	14.0	10.1
6	3:00	4.2	16.0	12.9
7	3:00	5.0	18.0	15.0
8	3:00	5.5	20.0	16.9
9	3:00	6.0	22.0	19.1

Figure 2. Standard Bruce Protocol and a Modified Bruce Protocol. From the Quinton Treadmill/ECG computer system used for the research.

Fredriksen, Ingjer, Nystad, and Thaulow (1998) compared the Bruce protocol with the Oslo protocol to see if there was any difference in peak VO_2 or peak heart rate. After performing exercise tests on 58 subjects, they discovered there was no difference between peak VO_2 and heart rate, however, their respiratory exchange ratio and blood lactate concentration showed higher values when the Bruce protocol was used.

The Bruce protocol is broken up into stages, as is noted above in the outline of the Bruce protocol. Ward et al. (1998) looked at the fourth stage of the protocol, which is 12 minutes into a standard test, 4.2 mph, 16 percent grade and approximately at 12.9 MET level. They wanted to investigate heart rate and relative oxygen consumption measures during two modes (walking or running at stage four) of the protocol. Twenty-seven subjects performed to volitional fatigue on the two randomly assigned treadmill tests. Heart rate and VO_2 were measured each minute and at point of exhaustion. A significant difference was determined between the protocols at 11 minutes walking and at 12 minutes walking on the VO_2 values. There was also a significant difference on heart rate at 11 minutes running and 12 minutes running between the two protocols. They concluded that when testing endurance trained males, modality, age, and height are not factors in differences of VO_2 values during the 4th stage of the Bruce treadmill test but learning effect could be.

Fielding, Frontera, Hughes, Fishser, and Evans (1997) found another way to confirm the quality of the Bruce protocol by asking the question of the reproducibility of the Bruce protocol for the determination of aerobic capacity in older women. They took 17 women and had each of them perform five maximal graded exercise tests to volitional fatigue on a treadmill. They averaged each subject's VO_2 results. They were able to

show that a commonly used exercise test such as the Bruce protocol generates highly reproducible measurements of VO_2 max in this group of subjects. The mean differences between the test and the high level of agreement between repeated tests suggest that a single measurement of VO_2 max can be performed to assess functional aerobic capacity in this group of subjects.

Lewis and Amsterdam (1994) decided to study the safety and efficacy of immediate exercise testing for patients admitted to the hospital for a suspected myocardial event. Following a modified Bruce protocol, they tested 93 patients who had been admitted to the emergency room, with suspected cardiac events, immediately on admission to the hospital. They found twelve patients had positive exercise ECG with six having significant coronary narrowing by angiography. One patient had an uncomplicated non-Q-wave event. However, 59 patients had negative tests and 22 had nondiagnostic exercise ECG. None of the patients testing suffered from complications associated with the exercise test. The conclusion reached by Lewis and Amsterdam was that immediate exercise testing of low-risk patients who are admitted into the emergency room was a helpful tool in deciding who could be safely discharged immediately and those who required hospitalization.

With the popularity and widespread use of the Bruce protocol, other protocols have often been compared with the Bruce for the purpose of standardization or efficacy. Riley, Northridge, Henderson, Stanford, Nicholls, and Dargie (1992) decided to compare a standard exercise protocol (STEEP) used with a treadmill or bicycle to a modified Bruce protocol in subjects with chronic cardiac failure. STEEP had been previously validated in normal subjects. They discovered that VO_2 was very similar at

equal exercise states in both modalities with exercise time being greater with the modified Bruce protocol than STEEP.

Predictive Value of Exercise Testing

If there were a crystal ball, everyone would be looking into it trying to see what the future holds. Until then, predictive values, tables, estimates and more have become common place in medicine. Trying to predict the outcome of an event is turning into an expectation in the medical community as the medical environment encourages a more conservative approach to resources used, and exercise tests that are deemed “clinically unnecessary” are being scrutinized and refused (McConnell, 1996). There is another side to predictive values: can a patient circumnavigate invasive and expensive medical treatment if there is a way to predict how they might do on a test and thus go directly to the appropriate test? Or would it be possible to predict how an individual might do on a test thus predicting an outcome without the individual ever having to do the test?

Ellestad and Wan (1975) collected follow-up data on 2700 subjects who had completed maximum stress tests. Based on characteristics they set up to define a positive or negative test, they were able to predict that an incident of some new coronary event would be 9.5 percent a year for a subject with a positive test compared to 1.7 percent with a negative test. The number of infarctions and death was significantly higher in the positive test group compared to the negative group. Despite accounting for previous myocardial infarction, which increased the number of events in both the positive and negative groups, the subjects in the positive group who had a previous infarction had more than double the incidence of coronary events than the positive group who had no

previous event. These predictive measures have become common place in practicing medicine today.

Noonan and Dean (2000) looked at the predictive value of maximal exercise testing to submaximal exercise testing in a physical therapy environment. They understood that maximal exercise testing was not always possible for patients not because of muscle fatigue but due to pain or physical limitations, thus submaximal exercise testing was a good way to overcome some of the limitations associated with maximal exercise testing. They compared and evaluated a variety of submaximal bicycle and treadmill tests, home fitness tests, walk tests and others to give the physical therapist the most reliable information and options for submaximal exercise testing. They cautioned to apply the tests selectively, based on the indications, to adhere to methods including the requisite number of practice sessions and to use measurements such as heart rate, blood pressure, exertion, and pain to evaluate test performance and to safely monitor patients.

Prediction of VO_2 max is necessary as most individuals are unable to undergo a max VO_2 test for a variety of reasons such as time, money, or physical ability. Clark and Coats (2000) looked at peak oxygen consumption as a powerful predictor of outcome in patients with chronic heart failure. They sought to establish a method of assessing peak VO_2 from non-invasively acquired data. They analyzed data from 60 treadmill tests, including metabolic gas exchange during exercise, heart rate and blood pressure, exercise time, heart rate at peak exercise, change in heart rate, rate pressure product at peak exercise, and change in systolic blood pressure: all of these factors correlate with peak VO_2 . They determined that exercise time was the most powerful predictor of peak VO_2 .

They concluded that peak VO_2 can be estimated from non-invasively acquired parameters.

In 1998, Dr. Scott Strayer asked if the predictive power of standard exercise stress testing could be improved using additional clinical data. He discovered that using multivariable equations in addition to visual measurements might increase the number of correctly classified exercise stress tests (Strayer, 1998).

Physical Activity Questionnaires

Research questionnaires have been used universally across the research spectrum to gather data. In the last decade, questionnaires have gained in popularity due to their relative ease of use and ability to gather data quickly and efficiently. Self-reporting questionnaires, used most often, are questionnaires completed by the subject, without the assistance or input from a researcher. Self-reporting questionnaires have been used in a variety of clinical settings ranging from dental offices to general health surveys such as the Short-Form 36.

According to Walker and Lowe (1998), they used a self-reporting questionnaire to identify a nurse's belief about medication incident reporting. They were able to learn that nurses feared being reprimanded from those in authority, and that possibly the questionnaires also indicated an unwillingness on the nurses' part to accept responsibility for errors in which they may be merely the final player in a complex series of events. In this case, Walker et al, concluded that there were problems with self-reported medication incident monitoring and challenged its effectiveness in collecting data that could be extrapolated and used by supervisors and development staff.

Roup (1997) looked at a group of critical care nurses to learn their level of compliance with universal precautions. He used direct observation and self-reporting questionnaires and concluded a 67 percent compliance score.

El-Rufaie, Absood, and Abou-Saleh (1997) used the self-reporting questionnaire SRQ-20 as part of their research into the validity of a screening scale for states of anxiety and depression among primary health care patients. After establishing cut-off points, they discovered that one of the cut-off points, which was more appropriate for clinical use, could be used to alert the busy general practitioner to the possibility that clinically significant anxiety or depression may be present.

Martine, Nieto, Jimenez, Ruiz, Vazquez, Fernandez, Gomez, and Fernandez (1999) used an anonymous self-reporting questionnaire to collect data on adolescent eating disorders. When they compared their data to that of a group of adolescents with normal eating habits, they detected significant differences. They were able to conclude that there is unhealthy eating behavior among adolescents in their population group.

Another group, Gilbert and Nuttall (1999) looked at self-reporting of periodontal disease. Patients completed the questionnaire and then underwent a dental exam. The researchers were able to conclude that the self-reporting was not successful because many people who tested positive for periodontal disease did not know they had the symptoms for the disease. Therefore, they were unable to answer the questionnaire in a manner that correlated with their positive dental exam.

According to Walker (1997) who used a self-reporting questionnaire to identify neonatal nurses' views on barriers to parenting in the intensive-care nursery, he was able to conclude that there was an understanding of the environmental and emotional barriers

confronting parents. The results of the questionnaire were of value to the neonatal nurses, staff, and policy administrators.

Washburn and Montoye (1986) argued that it was difficult at best to associate heart disease with levels of physical activity due to the lack of quantifiable standardized procedures available for measuring physical activity. Because he felt the cost and time burden on both research subjects and researchers themselves was too great to use available assessing techniques for epidemiological studies, he supported the use of physical activity questionnaires to be the most practical approach for the assessment of physical activity.

Activity questionnaires generally require a subject to recall a specific physical activity or to give a general appraisal of their level of physical activity. This data can be from an immediate activity or one performed over a period of time. Washburn et al, looked at four areas of physical activity questionnaires: 1) validity, 2) reliability, 3) practicality, 4) relationship to disease. Of the nine physical activity questionnaires they reviewed, one being the Framingham questionnaire, they discovered that many of the questionnaires determined the level of physical activity in an absolute sense by calculating an average level of energy expenditure over a certain period of time (such as metabolic equivalents or kilocalories) while others provided for a relative ranking of physical activity among subjects in the study population. They also noted that several investigators reported relationships between self-reported physical activity in leisure time or occupation and measures of cardiovascular fitness. Washburn et al, stated, "the magnitude of the relationship between a physical activity questionnaire and a measure of

cardiovascular fitness should not, in itself, be interpreted as strong evidence for the validity of activity questionnaires.”

Ainsworth, Jacobs, and Leon (1992) devised a physical activity questionnaire that differentiated between trained and untrained individuals for the purpose of selection of target heart rates for treadmill graded exercise tests. The purpose of their study was to assess the validity of this questionnaire, compare a two-point and four-point scoring system, and test the 1-month test-retest reliability of the questionnaire. Working with 28 men and 50 women, Ainsworth asked subjects to visit the clinic to fill out questionnaires regarding physical activity habits either during the past week, month or year, and then reviewed their physical activity and food intake record with trained clinic interviewers.

During three of the clinic visits, subjects performed maximal treadmill graded exercise tests in addition to completing questionnaires. Results from the physical activity questionnaire were validated against cardiorespiratory fitness levels. The conclusion drawn from this study was that subjects who depicted themselves as active or inactive according to the questionnaire differ significantly in their levels of cardiorespiratory fitness, body composition, and leisure-time physical activity.

But by 2000, Ainsworth had looked at the compendium of physical activity and metabolic equivalents to assist with more accurate estimates of physical activity levels. A Compendium of Physical Activities has been developed to facilitate the coding of physical activities for the purpose of comparing physical activity intensity levels across a variety of observational studies.

The compendium has corresponding metabolic equivalents intensity levels, which have been used in this research to learn a subject's self-reporting ability to perform at a specific physical work capacity.

Summary of Related Literature

In summary, it's been over 100 years since electrocardiographs were first developed and later used to diagnose, study and treat heart disease. And still today, an electrocardiogram serves as an independent marker of myocardial infarctions and remains vital for proper diagnosing and therapy of cardiovascular disease. There are three forms of exercise that are used for stressing the heart: isometric (a constant muscular contraction without any movement), dynamic (a rhythmic muscular activity resulting in movement), and a combination of isometric and dynamic. Because a delivered dynamic workload can be accurately calibrated and the physiological response easily measured, dynamic exercise is preferred for clinical stress testing.

Modalities for isometric exercise testing utilize resistance through weights or tubing or through simple muscle contraction. Modalities for dynamic exercise include stair climbing, ladder mills, bicycles, treadmills, cross-country skiing, and arm ergometer. In today's clinical setting, the bicycle and treadmill are the most commonly used. Bicycle ergometers are generally cheaper, take up less space and make less noise than treadmills, however, walking is a more comfortable and familiar form of exercise and thus the most common form of dynamic exercise used for stress testing.

There are a variety of treadmill protocols that are used for exercise testing such as the Naughton, Bruce, Weber, Ellestad, and Balke-Ware. An ideal protocol should

consider the purpose of the test and the subject being tested. For most exercise testing, the choice of protocol is dictated by either tradition, equipment or convenience. Out of all the treadmill protocols, more than half the laboratories in North America employ the standard Bruce protocol (Stuart & Ellestad, 1980), even though its large increments in workload make it inappropriate for many patients with cardiovascular disease (Myers, Walsh, Kraemer, McAvley, & Hamilton-Wessler, 1991; Myers & Froelicher, 1990; Panza, Diodati, Callahan, & Epstein, 1991; Sullivan & McKirnan, 1984). The Bruce protocol is a multistage exercise program that begins at a slow speed and incline and increases in speed and incline every three minutes until an individual is unable to go any further.

Like other treadmill protocols, the Bruce protocol is a submaximal exercise test where VO₂ max and metabolic levels can be predicted based on workloads. These predictive values have proven useful when maximal exercise testing isn't feasible such as in physical therapy when pain or mobility impair movement or advanced heart disease or physical limitations. Researchers agree that prediction values are useful and have a value with exercise testing (Ellestad & Wan, 1975; Clark & Coats, 2000; Noonan & Dean, 2000).

Self-reporting questionnaires have been used in a variety of clinical settings ranging from dental offices to general health surveys such as the Short-Form 36. Researchers have discovered that there is a high test-retest reliability in a variety of research fields that merit using self-reporting questionnaires for research (El-Rufaie, Absood, & Abou-Saleh, 1997; Gilbert & Nuttall, 1999; Martin, Rejeski, Miller, James, Ettinger, & Messier, 1998; Walker & Lowe, 1998).

CHAPTER 3

METHODS AND PROCEDURE

Participants

Participants recruited were 108 adults from the greater Rochester area who were referred by their doctors for a treadmill stress test. Participants received an explanation of the testing procedures and signed informed consents. The risks and benefits of the study were explained. The study was reviewed and approved by the University of Nevada, Las Vegas Institutional Review Board. Every effort was made to have an equitable distribution of male and female participants.

Questionnaire

The research questionnaire was a self-reporting questionnaire that addressed a subject's work capacity level and looked at a variety of physiological data points to determine their usefulness as screening tools (Appendix I).

Work Capacity Questions

The purpose of establishing work capacity levels was to determine if self reporting of work capacity levels would be a useful screening tool for predicting time on a treadmill test following a Bruce protocol. The American Heart Association (AHA)

recommends that an optimal treadmill test be between six and 12 minutes. Thus, a subject would need to have a minimum work capacity of 7 METs in order to complete stage 2 of a Bruce protocol (which is six minutes) to meet the AHA recommendations. In an effort to determine the current work capacity of a subject, a set of 10 questions representing 10 different metabolic-equivalent activities were developed (Appendix I). Numbers 1 – 10 on the questionnaire reflect the metabolic level of that activity (1 = 1 MET level of work capacity, 2 = 2 MET level of work capacity and so forth).

Physiological Data

In addition to using self-reported work capacity levels as screening tools, physiological parameters were measured to determine if they would be useful in screening for performance. They were 1) resting heart rate, 2) resting blood pressure, 3) hand-grip strength measuring peak heart rate after five-second squeeze, 4) absolute grip strength, 5) time for peak heart rate to return to pre-squeeze level.

Design

A stepwise regression analysis was used in this study. The dependent variable was total time on the treadmill. The work capacity questions and physiological data points on the questionnaire were the independent variables.

Procedure

Patients arrived at the exercise testing center for their scheduled appointment. They were given a research questionnaire and two informed consent forms, one required for the testing facility and one for the participants in this research project.

Following standard operating protocols set forth by the testing center, the technician prepared the subject for the treadmill exercise test, which included a description of the treadmill test itself, a review of patient symptoms and current medications, and the attachment of a 12-lead electrocardiogram. Once patients had completed resting supine and standing ECG's and blood pressures without any indication of contraindications for treadmill testing, and all other medical information was within testing norms, subjects were considered ready for the exercise test. After recording the subject's resting blood pressure the questionnaire was collected and the additional physiological data point measurements were made.

Questionnaire (Appendix I)

- 1. The questionnaire and consent forms were collected from the subject and reviewed to verify both had been properly completed.**
- 2. The subject was asked if there were any additional questions about the research, which were answered accordingly.**
- 3. The highest work capacity question that was answered yes was considered the subject's highest level of work capacity and called HighMET.**

Grip-Strength Dynamometer Measurement (Smedly III Grip-Strength Dynamometer)

- 1. Subjects were asked to stand with their feet slightly apart and arms straight to**

their sides. (Because a subject's heart rate goes up slightly when moving from sitting to standing, all subjects stood while receiving their instructions for the grip-strength measurement. This helped ensure a small amount of time had passed and their heart rates had stabilized before the ECG strips were printed.)

2. The ECG monitor was checked to ensure all leads were properly registering.
3. Subjects were asked which hand they wrote with and were asked to use this hand for the dynamometer.
4. Subjects held the dynamometer with the face pointing away from their leg, their fingers were bent at a 90 degree angle over the gripping bar in a comfortable position, grip adjustments were made when needed. Subjects were instructed to continue holding the position until they were told to squeeze the dynamometer.
5. Further instructions were given to the subjects as they stood. Once they were told to begin, they were to squeeze the dynamometer as hard as possible for a five-second count, which was counted out loud by the researcher. They were not to talk or move during the squeeze or for any period after the completed squeeze until instructed to do so. It was explained that an ECG strip would be printed for the duration of the squeeze and until the heart rate had returned to pre-squeeze level to measure the heart rate recovery time.
6. Simultaneously, the researcher pressed the print button on the ECG monitor to begin printing the ECG strip and instructed the subject to squeeze the dynamometer. Measurements were recorded.

Following the completion of a treadmill test, the total time the subject was on the treadmill, the time needed for the subject to reach 85 percent of age-predicted maximum heart rate, and the reason for stopping the test, were recorded.

CHAPTER 4

RESULTS

A total of 115 subjects participated in the research study of which seven were excluded due to medical conditions that prevented them from performing treadmill tests. Of the remaining 108 subjects, 64 were male (mean age in years 57 ± 12) and 44 were females (mean age in years 57 ± 13).

A stepwise regression analysis was used to develop equations from research parameters established on the questionnaire. Table 1 presents the means and standard deviations across all subjects for parameters used in the regression analysis.

TABLE 1

Stepwise regression analysis parameters for all 108 research participants.

Parameters	Mean	Standard Deviation
Age (in whole years)	57	13
Grip Strength (in kilograms)	35	11
Grip Rating (in percentile)	51	26
Heart Rate - start (in BPM)	80	13
Heart Rate - 5 seconds (in BPM) (During grip strength measurement)	89	15
Heart Rate Return (in seconds)	6	5
Lowest Met (work capacity level)	7	3
Highest Met (work capacity level)	9	2
Resting Systolic Blood Pressure (mmHg)	129	19
Resting Diastolic Blood Pressure (mmHg)	78	10

The regression analysis resulted in two useful predictive equations, one for males and one for females.

The male predictive equation derived was:

$$\text{Predicted time on treadmill test (seconds)} = 640.842 - 6.945 (\text{Age}) + 32.473 (\text{HighMET}),$$

where age is the subject's age in whole years and HighMET is the highest self-reported MET level (work capacity level) the subject could perform per the questionnaire the subject completed. Table 2 presents the means and standard deviations for the parameters used in this equation for all 64 male subjects. The R-squared value was .359. Figures 3 and 4 show the relationship between age and actual treadmill time for males and females, respectively.

TABLE 2

Mean and standard deviations for parameters used in the male predictive equation. 64 male subjects in total.

Parameters	Mean	Standard Deviation
Age (years)	57	9
Highest MET (MET)	12	2

The female predictive equation derived was:

$$\text{Predicted time on a treadmill test (seconds)} = 275.474 + 33.451 (\text{HighMET}) - 4.934 (\text{Systolic Blood Pressure}) + 7.164 (\text{Diastolic Blood Pressure}),$$

where HighMET is the highest self-reported MET level (work capacity level) the subject could perform per the questionnaire the subject completed. Systolic and diastolic blood pressure were reported in mmHg. Table 3 presents the means and standard deviation for the parameters used in this equation for all 44 female subjects. The R-squared value was .418. Figures 5-8 show the relationship between systolic blood pressure and diastolic blood pressure for males and females respectively. Figures 9 and 10 show the relationship between HighMET and actual treadmill time for males and females respectively.

TABLE 3

The mean and standard deviations for parameters used in the female predictive equation. 44 female subjects.

Parameters	Mean	Standard Deviation
HighMET (MET)	8	2
Systolic Blood Pressure (mm Hg)	126	20
Diastolic Blood Pressure (mm Hg)	75	10

Out of 108 subjects, 52 males and 33 females had actual total treadmill times of six minutes or greater. The prediction equations predicted that 59 males and 35 females would have exercise times of six minutes or more, which resulted in an 88 percent prediction accuracy rate for males and 94 percent prediction rate for females. Figures 11 and 12 show actual versus predicted test time for males and females respectively.

Figure 3. Relationship between age and actual treadmill time for males.

Figure 4. Relationship between age and actual treadmill time for females.

Figure 5. Relationship between resting systolic blood pressure and actual treadmill test time for males.

Figure 6. Relationship between resting systolic blood pressure and actual treadmill test time for females.

Figure 7. Relationship between resting diastolic blood pressure and actual treadmill test time for males.

Figure 8. Relationship between resting diastolic blood pressure and actual treadmill test time for females.

Figure 9. Relationship between HighMET and actual treadmill test time for males.

Figure 10. Relationship between HighMET and actual treadmill test time for females.

Figure 11. Actual vs. predicted test time for males.

Figure 12. Actual vs. predicted test time for females.

CHAPTER 5

DISCUSSION

The purpose of this study was to determine if screening tools from a self-reporting questionnaire could be developed to predict treadmill test time when following a Bruce protocol.

On the surface it is unclear why the regression model developed different variables, and subsequently, different predictive equations for men and women. One plausible explanation is that the two variables that differ between the equations, age and blood pressure, may have an implicit relationship. Since we know that arteries lose some of their elasticity with age, which causes blood pressure to increase, we might be able to infer a relationship.

In females, the systolic and diastolic blood pressures are correlated predictive variables in the predictive equation, suggesting that in isolation, systolic or diastolic blood pressure would not be a predictive factor, yet in combination with each other they are strong predictors. It appears that with this implicit relationship, a greater sample population might result in a predictive equation with the same predictive variables for each gender instead of different ones.

Variable Discussions

Prediction Equation Variable - HighMET

When comparing male and female participants, the coefficients for HighMET are almost the same, therefore suggesting that both groups answered the work capacity questions with the same self-reporting accuracy. When controlling for age, the increase in age correlated with an increase in an overestimated MET level. For example, when a 50-year-old subject and a 90-year-old subject both answered the work capacity level with a HighMET of 4, they should have had the same outcome, yet there is a difference. The propensity for self reporting MET could be related to an increase in overestimating with age. In other words, an individual's pride possibly influenced how the work capacity questions were answered. These results can be supported with the mix of findings about self-reporting questionnaires.

Martin et al. (1998) looked at energy expenditure and physical activity in older populations using PASE (Physical Activity Scale for the Elderly) and found PASE was a valid and reliable measurement of physical activity among adults who had no serious physical limitations. The test-retest reliability coefficient was .75 for self-administration of the test.

Weller and Corey (1997) examined the reliability of the Canada Fitness Survey questionnaire. They found that males generally reported leisure activities more reliably than non-leisure activities, whereas the opposite was true for females. What is interesting about their research was the least reliable self-reported component they found was the intensity of the work activity for both genders. This finding would support the results of

the current study by stating that over and under predicting of work capacity could be problematic with self-reporting reliability factors.

Jacobs, Ainsworth, and Hartman (1992) evaluated the reliability and validity of 10 commonly used physical activity questionnaires. The highest reliability for all questionnaires was found in subjects who repeated the test within one month. This helped validate the findings of the current study because all subjects were asked to answer work capacity questions pertaining to activities that they were currently able to perform. Because Jacobs et al. (1992) were able to validate a high one-month reliability, it is possible then to speculate that the reliability of the initial subject responses was high and, therefore, an accurate depiction of the subject's work capacity level.

Prediction Equation Variable - Age

The results suggest that as age increases the actual time on the treadmill decreases, which is an expected physiological occurrence. It could also imply there is a higher chance of deconditioning with age.

Prediction Equation Variable - Systolic Blood Pressure

It appears that as systolic blood pressure increases there is more variability in treadmill times than when blood pressure is lower. As is depicted in the systolic blood pressure figures, there is a downward trend suggesting that the majority of participants who had higher treadmill times also had lower systolic blood pressure. This would support the premise that a participant with a lower resting systolic blood pressure would be more likely to be healthy and thus make the six-minute threshold. Yet why there were so many with elevated systolic blood pressure able to perform to the six-minute threshold

remains unexplained at this time. The following explanations are offered for consideration.

White Coat Syndrome

One explanation for reaching the six-minute threshold despite elevated systolic blood pressure could be the “white coat syndrome” which can be defined as an elevation in blood pressure that occurs in a clinical setting and is not present outside the physician’s office, and is generally considered benign (Ooi, Madhavan, & Cohen, 1992). It is possible that this brief period of increase in systolic blood pressure is due to nervousness or anxiety associated with visiting the doctor's office. However, this explanation does not have universal support.

Celis, Staessen, Gaszowski, Thijs, and Fagard (2000), reviewed isolated systolic hypertension and showed that it predicted cardiovascular risk over and above conventional pressure and that was after accounting for the white coat effect. On the other hand, in his literature review, Celis et al. (2000) found research conducted by Verdecchia that indicated morbidity was not significantly different between a group of normotensive control subjects and a group of patients with white coat hypertension. The research is inconclusive in this area and merits additional review.

Of the 14 subjects who had an isolated hypertensive systolic blood pressure (>140 mm Hg), nine of them reached the six-minute threshold on their exercise test. It could be speculated that these subjects were a little nervous when they arrived for their test, thus, explaining the elevated systolic blood pressure. It is possible to further speculate that after the subject became accustomed to the testing environment, the blood pressure likely

decreased suggesting that the subject was not hypertensive at all, but simply nervous, and the impact on the six-minute threshold was minimal if at all.

Pulse Pressure

Another explanation for reaching the six-minute threshold despite elevated systolic blood pressure could be pulse pressure, which according to Glynn, Chae, and Guralnik (1999), incorporates the effects of both high systolic and low diastolic pressure. According to the American Heart Association, a blood pressure $< 140/80$ mm Hg is considered to be the high end of a normal blood pressure range. The difference, the pulse pressure, between the two figures is 60 (140-80). Using 60 as a baseline for an acceptable range between systolic and diastolic blood pressure, we looked at female subjects to determine if the pulse pressure was ≤ 60 . The results indicated that out of 31 female subjects whose pulse pressure was ≤ 60 , 87 percent had treadmill test times of six minutes or greater. Of the 13 subjects who had a pulse pressure of >61 , 46 percent had treadmill test times of six minutes or greater. The results indicated out of 52 male subjects whose pulse pressure was ≤ 60 , 86 percent had treadmill test times of six minutes or greater. Of the 12 subjects who had a pulse pressure of >61 , 59 percent had treadmill test times of six minutes or greater.

These results are supported by Blacher, Staessen, Girerd, Gasowski, Thijs, Liu, Wang (2000) who determined that patients with isolated systolic hypertension had pulse pressures that independently predicted the incidence of cardiovascular complications. These findings might help explain why some of the subjects were unable to reach the six-minute threshold despite having no other cardiac or physical conditions that might have otherwise inhibited them from reaching the six-minute threshold. These results are

further supported by Glynn, Chae, and Guralnik (1999) who determined that in older persons, both systolic and diastolic blood pressure provided independent prognostic information about the risk of cardiovascular and total mortality.

Staessen and Fagard (1990) determined that pulse pressure widens with advancing age. Figures 13 thru 15 show the strong relationship between an increase in pulse pressure and age in males, females and both. Table 4 shows the raw data supporting the relationship figures.

Prediction Equation Variable - Diastolic Blood Pressure

It is possible that an isolated hypertensive diastolic blood pressure (>80 mm Hg) could be associated with the white coat syndrome, as Ooi, Madhavan, and Choen (1992) discovered. However, according to Blacher et al. (2000), with any given level of systolic blood pressure, the cardiovascular risk increased when the diastolic blood pressure was lower. Blacher's findings confirmed that the wider pulse pressure was driving the risk of major complications, which might give an indication as to why subjects with low or high diastolic blood pressure were not able to reach the six-minute threshold.

R-Squared Discussions

It is important to note that the R-squared value is reviewed as an explanation of variability within the research data. Ideally, the R-squared value would be close to 100 percent. However, in this situation, the proportion of variability in time (the dependent variable) is not as important as predicting a dichotomous answer to the question of predicting a treadmill time of six minutes or greater, which was accomplished with the regression equations. Therefore, the R-squared values of .359 and .4177 for men and

women, respectively, does not offer much information about the predictive equations developed from the regression model.

Prediction Accuracy Rate Discussions

Out of 108 subjects, 52 males and 33 females had actual treadmill times of six minutes or greater. The prediction equations predicted that 59 males and 35 females would have exercise times of six minutes or more. The prediction accuracy rate for males was 88 percent and for females was 94 percent.

Practical Application Discussions

This research has a useful and practical application for patients, doctors and insurance companies. Currently, the amount of time scheduled for a treadmill test is dictated by the testing parameters established by paying insurance companies. However, this time is often wasted by patients who are not able to reach what the American Heart Association considers an optimal treadmill test time (6-12 minutes), therefore, requiring another stress test be ordered. Based on this research, 19 percent of the sample population did not reach the six-minute threshold.

With the use of prediction equations, the physician can assess a patient's probability of reaching the six-minute threshold on a treadmill test following a Bruce protocol before the patient leaves the physician's office. If it is determined that the patient has a high probability of not reaching the six-minute threshold, then a different testing protocol can be ordered that would enable the patient to reach the six-minute threshold. Patient testing would become very specific, saving the testing facility time and

money, the patient the emotional stress of multiple tests, and the insurance companies the financial burden of additional testing.

Figure 13. Male age and pulse pressure comparisons.

Figure 14. Female age and pulse pressure comparisons.

Figure 15. Male and female age and pulse pressure comparisons.

CHAPTER 6

CONCLUSION

The purpose of this study was to determine if screening tools from a self-reporting questionnaire could be developed to predict treadmill test time when following a Bruce protocol. Subjects completed a self-reported assessment of physical work capacity and physiological data were measured. Subjects then performed treadmill exercise tests. According to the American Heart Association, an optimal treadmill test time is between six and 12 minutes, thus the basis for the six-minute threshold used in this research.

Based on the results of a self-reported assessment of physical work capacity and physiological data, a stepwise regression analysis resulted in two useful predictive equations, one for males and one for females.

The male predictive equation derived was:

$$\text{Predicted time on treadmill test (seconds)} = 640.842 - 6.945 (\text{Age}) + 32.473 (\text{HighMET}),$$

where age was the subject's age in whole years and HighMET was the highest self-reported MET level (work capacity level) the subject could perform per the questionnaire the subject completed.

The female predictive equation derived was:

$$\text{Predicted time on a treadmill test (seconds)} = 275.474 + 33.451 (\text{HighMET}) - 4.934 (\text{Systolic Blood Pressure}) + 7.164 (\text{Diastolic Blood Pressure}),$$

where HighMET is the highest self-reported MET level (work capacity level) the subject could perform per the questionnaire the subject completed. Systolic and diastolic blood pressure were reported in mmHg.

Measured variables that did not enter into the prediction equations included, resting heart rate, absolute grip strength, heart-rate peak after five-second hold, heart recovery time from peak grip-strength hold to resting level, resting blood pressure for males, and age for females.

Out of 108 subjects, 52 males and 33 females had actual treadmill times of six minutes or greater. The prediction equations predicted that 59 males and 35 females would have exercise times of six minutes or more. The prediction accuracy rate for males was 88 percent and for females it was 94 percent. Thus, the prediction equations were able to predict within a reasonable prediction accuracy rate, indicating that it is possible to use a self-reporting questionnaire and physiological data as screening tools to predict treadmill performance time.

Further studies are needed to confirm the test-retest reliability of a self-reporting questionnaire that focuses primarily on work capacity questions.

APPENDIX I

FORMS

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Submission Request to Human Subjects Committee

Title: Clinical Prediction of a Successful Exercise Stress Test

1. **Subjects:** One hundred adults from the greater Rochester area who have been referred by their physicians for a treadmill stress test. Every effort will be made to have an equitable distribution of male and female participants.
2. **Purpose, Methods, Procedure:** The purpose of this study is to learn if it's possible to predict if a patient will have a successful treadmill stress test as set forth by the American Heart Association: Successful is defined when a patient reaches 85 percent of age-predicted maximal heart rate and at least six minutes on the treadmill following a standard treadmill stress protocol such as the Bruce Protocol. If it's possible to predict an outcome, then it might be possible to select a more patient-appropriate method of stressing the heart, which could be a less aggressive treadmill stress test protocol or a more invasive test such as pharmacological stress testing.

The predictive measures are based on a two-part questionnaire. The first part asks patients to answer a series of self-reporting questions about their activity level to learn what metabolic rate they are currently working at on a daily and/or weekly basis. To walk on a treadmill for a Bruce protocol, a patient would need to have a work capacity of at least a four-met level, which is level one of the Bruce Protocol. If patients are having problems working at this level, it would be possible to predict they wouldn't be able to make it to a successful level on the treadmill because they wouldn't be able to reach six minutes on the Bruce protocol, which requires the patient to exercise at a ten-met level.

Part two of the questionnaire is to gather some physiological data points on the patient to use as a determinant of current health status and ultimately possible prediction factors. Points to be measured are: resting heart rate, resting blood pressure, total time on treadmill, time on treadmill to reach 85 percent of age-predicted maximal heart rate, single-hand grip strength with associated measurements of heart rate increase during grip contraction and amount of time for heart rate to recover from contraction to pre-grip level.

When patients arrive for their appointments at the cardiologists office, they will be given the research questionnaire and an informed consent form by the receptionist to complete. A signed informed consent form is required by the testing facility before a treadmill test maybe be given. All of the measurements in part two of the questionnaire are included in a standard treadmill test except the single-hand grip test. Upon completion of forms, the patient will be escorted to a testing room where a medical technician will attach a 12-lead electrocardiogram and take resting blood pressure and resting heart rate, which are then recorded by researcher.

Next, the patient will be asked to stand and hold the grip-strength dynamometer in one hand and squeeze as hard as possible for a five second count. Meanwhile, the electrocardiogram machine will be recording on graph paper the patient's heart rate during the five-second hold and the subsequent rate as the heart rate decreases to pre-grip levels.

Once all measurements have been completed, the researcher will leave the testing room while the patient performs the treadmill test under the guidance of the medical staff. At the end of the test,

the medical staff will inform the researcher of the patient's total time on the treadmill and time to reach 85 percent of age-predicted maximal heart rate.

3. **Risks:** There are minimal risks associated with completing the questionnaire and taking the measurements as specified above taken. The measurements follow generally accepted practices and are widely performed in the health field. The information obtained from this study will be reported in a non-identifiable manner.
4. **Benefits:** If it can be determined that predictive measurements would direct patients to a stress test that would be successful, then it would save time and money for the insurance companies, doctors, nurses and medical staff. It would also be less invasive to patients to have one stress test instead of two.
5. **Risk-Benefit Ratio:** The further understanding of predictive values of treadmill stress tests provides benefits for a large number of stakeholders in the health industry. Since, as specified in #3, there are minimal risks with the procedures used in conducting this research project, the benefits far outweigh any remotely possible risks the participants will undertake.
6. **Cost to Subjects:** There is no monetary cost to the subjects other than the investment of their time.
7. **Informed Consent:** Before beginning any of the measurements other than the questionnaire, the researcher will witness the reading and signing of the informed consent form required by the testing facility. All informed consent forms and questionnaires will be stored separately in locked filing cabinets in my home (Helena Boersma) in Pittsford, New York for at least three years after completion of the study. At any point in time during the study, subjects will be encouraged to resolve any questions regarding the research or their participation. Their questions may be directed to Dr. Jack Young, thesis advisor, who can be reached at 702-895-4626, or to Dr. Maurice Varon and Helena Boersma who can be reached at 586-8577. If you have any questions regarding the rights of research subjects please contact the UNLV Office for the Protection of Research Subjects at 702-895-2794.

Informed Consent

Title: Clinical Prediction of a Successful Exercise Stress Test

Description of the Study: You are being asked to participate in a research trial looking at the effectiveness of treadmill stress testing. As part of the research process, you will be given a two-part questionnaire. The first part asks you to answer a series of self-reporting questions about your activity level. Part two of the questionnaire requires the researcher and medical staff to take the following measurements: resting heart rate, resting blood pressure, and a hand-grip strength measurement while concurrently measuring your heart rate. All measurements except for the hand-grip measurement are part of a normal treadmill stress test. At no point will the researcher be involved with your treadmill stress test except to escort you to the testing room. You will not be compensated for participation in the study.

Risks: There are minimal risks associated with completing the questionnaire and having the specified measurements taken.

Confidentiality: The information obtained in this experiment will be used only for statistical research purposes and will be treated as privileged and confidential. All information obtained from this study will be reported in a non-identifiable manner. All informed consent forms and questionnaires will be stored separately in locked filing cabinets in my home (Helena Boersma) in Pittsford, New York for at least three years after completion of the study.

Questions: If you have any questions, you are encouraged to ask them to Helena Boersma the primary research who will be conducting all your measurements, or Dr. Maurice Varon of the University Cardiovascular Associates at 442-5320, or Dr. Jack Young, thesis research advisor, at 702-895-4626. All individuals will be happy to answer any questions you may have. If you have any questions regarding the rights of research subjects please contact the UNLV Office for the Protection of Research Subjects at 702-895-2794.

Right to Withdraw: You are free to refuse to participate in this study, or to withdraw at any time. Your decision will not cause a loss of benefits to which you might otherwise be entitled.

Your signature below will indicate that you have decided to volunteer as a research subject, that you have read the information provided above and understand the measurements that'll be taken, and certify that there is no medical reason why you should not participate in this study.

Thank you for your participation in this research project.

Subject Signature	Date	Print Name
Witness Signature	Date	Print Name

Treadmill Research Questionnaire

Name _____ Age _____ M/F Date of Test _____

Which of the following activities are you currently able to perform:

1	Eating and dressing independently	yes	no
2	Taking a shower/bath independently	yes	no
	Walking down eight steps, and/or walking very slowly	yes	no
3	Doing a moderate amount of work around the house
(i.e., vacuuming, sweeping the floors, washing dishes)	yes	no
	Carrying groceries and/or going household shopping	yes	no
4	Doing light yard work (i.e. raking leaves, weeding, or pushing
a power mower), painting or doing light carpentry, pulling a
golf bag, cleaning windows, walking briskly (i.e. 3 miles/hour).	yes	no
5	Walking briskly (i.e. about 4 miles/hour), dancing, washing a car	yes	no
6	Playing nine holes of golf carrying your own clubs, mowing
lawn with a push mower, doing heavy carpentry	yes	no
7	Performing heavy outdoor work (i.e., digging, spading soil)	yes	no
	Playing tennis (singles) and/or can carry 60 pounds	yes	no
8	Moving heavy furniture or playing basketball	yes	no
	Jogging slowly or climbing stairs quickly or carrying 20 pounds upstairs	yes	no
9	Bicycling at a moderate pace or jumping rope (slowly)	yes	no
10	Swimming briskly or bicycling up a hill or walking briskly uphill	yes	no

To be completed by researcher:

Grip strength: _____ HR at rest/start _____ HR at peak Grip _____
 Time for HR to return to pre-squeezing level _____
 Resting Blood Pressure _____ Total Time on Treadmill _____ Time to 85% _____

Note to reader: Work capacity numbers 1-10 represent actual metabolic levels (work capacity activities listed for 1 = 1MET level of activity → 10 = 10 MET level of activity)

DATE: March 29, 2001

TO: Helena Boersma
Kinesiology
M/S # 3034

FROM: Dr. Carl Reiber
UNLV Biomedical Sciences Institutional Review Board

RE: Status of Human Subject Protocol Entitled:
"Clinical Predictions of a Successful Exercise Stress Test"

OPRS #504s0301-283

This memorandum is official notification that the protocol for the project referenced above has been reviewed by the Office for the Protection of Research Subjects and has been determined as have having met the criteria for exemption from full review by the UNLV Biomedical Sciences Institutional Review Board. In compliance with this determination of exemption from full review, this protocol is approved for a period of one year from the date of this notification and work on the project may proceed.

Should the use of human subjects described in this protocol continue beyond a year from the date of this notification, it will be necessary to request an extension.

If you have any questions or require assistance, please contact the Office for the Protection of Research Subjects at 895-2794.

cc: OPRS File

Office for the Protection of Research Subjects
4505 Maryland Parkway • Box 451046 • Las Vegas, Nevada 89154-1046
(702) 895-2794 • FAX (702) 895-4242

APPENDIX II DATA TABLES

TABLE 4
Pulse Pressure Levels in Male Subjects.

Gender	Age (years)	Systolic (mmHg)	Diastolic (mmHg)	Actual Time (seconds)	Actual < 360 seconds	Pulse Pressure (systolic- diastolic)
Male	82	138	80	395	Y	58
Male	79	136	74	274	N	62
Male	78	130	78	690	Y	52
Male	76	124	74	164	N	50
Male	76	160	90	375	Y	70
Male	75	128	78	559	Y	50
Male	74	104	72	486	Y	32
Male	74	170	102	372	Y	68
Male	72	180	94	180	N	86
Male	72	148	86	564	Y	62
Male	71	118	62	219	N	56
Male	70	140	84	191	N	56
Male	68	134	76	269	N	58
Male	68	116	60	523	Y	56
Male	67	140	90	637	Y	50
Male	67	122	72	425	Y	50
Male	66	130	78	660	Y	52
Male	66	148	82	356	N	66
Male	65	150	80	745	Y	70
Male	65	120	74	420	Y	46
Male	65	124	68	365	Y	56
Male	64	150	92	289	N	58
Male	64	152	80	573	Y	72
Male	62	100	70	457	Y	30
Male	59	108	76	775	Y	32
Male	58	132	80	540	Y	52
Male	58	142	88	621	Y	54
Male	58	118	70	768	Y	48
Male	58	137	62	23	N	75
Male	57	105	70	553	Y	35
Male	56	160	90	605	Y	70

TABLE 4 continues

Pulse pressure levels in males subjects.

Gender	Age (years)	Systolic (mmHg)	Diastolic (mmHg)	Actual Time (seconds)	Actual < 360 seconds	Pulse Pressure (systolic- diastolic)
Male	56	116	78	479	Y	38
Male	55	150	104	373	Y	46
Male	55	162	90	675	Y	72
Male	54	112	60	632	Y	52
Male	54	130	82	165	N	48
Male	54	122	84	819	Y	38
Male	53	144	90	739	Y	54
Male	52	140	82	641	Y	58
Male	51	124	88	618	Y	36
Male	51	138	84	627	Y	54
Male	51	110	80	601	Y	30
Male	51	145	82	315	N	63
Male	50	120	90	642	Y	30
Male	50	124	90	693	Y	34
Male	50	118	74	510	Y	44
Male	49	140	82	795	Y	58
Male	49	118	82	667	Y	36
Male	46	110	64	702	Y	46
Male	46	130	90	829	Y	40
Male	46	140	90	630	Y	50
Male	46	114	66	606	Y	48
Male	45	126	80	693	Y	46
Male	45	116	70	671	Y	46
Male	45	110	84	611	Y	26
Male	44	140	82	280	N	58
Male	43	108	80	643	Y	28
Male	43	114	90	594	Y	24
Male	42	148	98	751	Y	50
Male	39	126	70	795	Y	56
Male	37	130	90	820	Y	40
Male	37	112	84	660	Y	28
Male	36	150	90	459	Y	60

TABLE 4 continues

Pulse pressure levels in males subjects.

Gender	Age (years)	Systolic (mmHg)	Diastolic (mmHg)	Actual Time (seconds)	Actual < 360 seconds	Pulse Pressure (systolic- diastolic)
Male	35	108	76	657	Y	32

Summary of table: Number of subjects who had a pulse pressure of <60: 52
 Number of subjects who had >61: 12

Results: Out of 52 subjects who had a pulse pressure <60, 45 had times of 6
 minutes or >, approximately 86 percent
 Out of 12 subjects who had > 60, 7 had times of 6 minutes or >,
 approximately 59 percent

TABLE 5

Pulse Pressure Levels in Female Subjects.

Gender	Age (years)	Systolic (mmHg)	Diastolic (mmHg)	Actual Time (seconds)	Actual < 360 seconds	Pulse Pressure (systolic- diastolic)
Female	49	102	76	750	Y	26
Female	54	108	82	631	Y	26
Female	49	106	78	545	Y	28
Female	50	90	60	715	Y	30
Female	52	110	80	481	Y	30
Female	53	106	76	553	Y	30
Female	51	112	80	601	Y	32
Female	32	98	60	589	Y	38
Female	38	108	70	450	Y	38
Female	46	114	76	548	Y	38
Female	30	100	60	736	Y	40
Female	30	102	62	95	N	40
Female	46	100	60	606	Y	40
Female	54	128	88	573	Y	40
Female	56	120	80	633	Y	40
Female	62	112	70	361	Y	42
Female	46	102	58	592	Y	44
Female	54	110	66	536	Y	44
Female	60	120	76	594	Y	44
Female	50	138	92	572	Y	46
Female	46	124	76	40	N	48
Female	55	140	90	370	Y	50
Female	70	132	80	563	Y	52
Female	73	112	60	324	N	52
Female	73	120	68	547	Y	52
Female	64	144	90	660	Y	54
Female	64	138	84	142	N	54
Female	69	124	70	376	Y	54
Female	75	126	72	368	Y	54
Female	52	153	98	739	Y	55
Female	61	134	78	579	Y	56
Female	71	142	80	121	N	62

TABLE 5 continues

Pulse pressure levels in female subjects.

Gender	Age (years)	Systolic (mmHg)	Diastolic (mmHg)	Actual Time (seconds)	Actual < 360 seconds	Pulse Pressure (systolic- diastolic)
Female	51	162	98	350	N	64
Female	62	124	60	200	N	64
Female	75	134	70	293	N	64
Female	78	142	78	366	Y	64
Female	43	146	80	450	Y	66
Female	52	150	80	583	Y	70
Female	81	150	80	66	N	70
Female	70	140	68	480	Y	72
Female	73	150	70	191	N	80
Female	78	162	82	488	Y	80
Female	74	164	82	265	N	82
Female	72	154	68	367	Y	86

Summary of table: Number of subjects who had a pulse pressure of <60: 31
 Number of subjects who had >61: 13

Results: Out of 31 subjects who had a pulse pressure <60, 27 had times of 6
 minutes or >, approximately 87%
 Out of 13 subjects who had > 60, 6 had times of 6 minutes or >,
 approximately 46%

TABLE 6

Six-Minute Threshold Comparisons: Agreements Between Actual and Predicted Time for Male Subjects 60 years of age and above.

Gender	Age (years)	Highest MET	Actual Time (seconds)	Predicted Time (seconds)	Actual < 360 seconds	Predicted 360 seconds	Agree
Male	82	9	395	363	Y	Y	Y
Male	79	9	274	384	N	Y	N
Male	78	10	690	424	Y	Y	Y
Male	76	10	164	438	N	Y	N
Male	76	3	375	210	Y	N	N
Male	75	10	559	445	Y	Y	Y
Male	74	9	486	419	Y	Y	Y
Male	74	6	372	322	Y	N	N
Male	72	10	180	466	N	Y	N
Male	72	10	564	466	Y	Y	Y
Male	71	3	219	245	N	N	Y
Male	70	9	191	447	N	Y	N
Male	68	10	269	493	N	Y	N
Male	68	10	523	493	Y	Y	Y
Male	67	10	637	500	Y	Y	Y
Male	67	10	425	500	Y	Y	Y
Male	66	10	660	507	Y	Y	Y
Male	66	9	356	475	N	Y	N
Male	65	10	745	514	Y	Y	Y
Male	65	7	420	417	Y	Y	Y
Male	65	4	365	319	Y	N	N
Male	64	10	289	521	N	Y	N
Male	64	10	573	521	Y	Y	Y
Male	62	9	457	503	Y	Y	Y

Summary of table: Number of agreements between actual and predicted was 14 yes and 10 no.

Results: 58.3 percent agreement between actual and predicted test time for males subjects over age 60

TABLE 7

Six-Minute Threshold Comparisons: Agreements Between Actual and Predicted Time for Male Subjects Below 60 years of age.

Gender	Age (years)	Highest MET	Actual Time (seconds)	Predicted Time (seconds)	Actual < 360 seconds	Predicted 360 seconds	Agree
Male	59	10	775	556	Y	Y	Y
Male	58	10	540	563	Y	Y	Y
Male	58	10	621	563	Y	Y	Y
Male	58	10	768	563	Y	Y	Y
Male	58	3	23	335	N	N	Y
Male	57	10	553	570	Y	Y	Y
Male	56	10	605	577	Y	Y	Y
Male	56	10	479	577	Y	Y	Y
Male	55	10	373	584	Y	Y	Y
Male	55	10	675	584	Y	Y	Y
Male	54	10	632	591	Y	Y	Y
Male	54	10	165	591	N	Y	N
Male	54	10	819	591	Y	Y	Y
Male	53	10	739	597	Y	Y	Y
Male	52	10	641	604	Y	Y	Y
Male	51	10	618	611	Y	Y	Y
Male	51	10	627	611	Y	Y	Y
Male	51	10	601	611	Y	Y	Y
Male	51	5	315	449	N	Y	N
Male	50	10	642	618	Y	Y	Y
Male	50	8	693	553	Y	Y	Y
Male	50	6	510	488	Y	Y	Y
Male	49	10	795	625	Y	Y	Y
Male	49	10	667	625	Y	Y	Y
Male	46	10	702	646	Y	Y	Y
Male	46	10	829	646	Y	Y	Y
Male	46	10	630	646	Y	Y	Y
Male	46	7	606	549	Y	Y	Y
Male	45	10	693	653	Y	Y	Y
Male	45	10	671	653	Y	Y	Y
Male	45	3	611	426	Y	Y	Y
Male	44	10	280	660	N	Y	N

TABLE 7 Continues

Six-Minute Threshold Comparisons: Agreements Between Actual and Predicted Time for Male Subjects Below 60 years of age.

Gender	Age (years)	Highest MET	Actual Time (seconds)	Predicted Time (seconds)	Actual < 360 seconds	Predicted 360 seconds	Agree
Male	43	10	643	667	Y	Y	Y
Male	43	10	594	667	Y	Y	Y
Male	42	10	751	674	Y	Y	Y
Male	39	10	795	695	Y	Y	Y
Male	37	10	820	709	Y	Y	Y
Male	37	10	660	709	Y	Y	Y
Male	36	10	459	716	Y	Y	Y
Male	35	10	657	722	Y	Y	Y

Summary of table: Number of agreements between actual and predicted was 37 yes and 3 no.

Results: 92.5 percent agreement between actual and predicted test time for males subjects below 60 years of age.

TABLE 8

Six-Minute Threshold Comparisons: Agreements Between Actual and Predicted Time for Female Subjects 60 years of age and above.

Gender	Age (years)	Systolic (mmHg)	Diastolic (mmHg)	Actual Time (seconds)	Predicted Time (seconds)	Predicted < 360 seconds	Actual 360 seconds	Agree
Female	81	150	80	66	242	N	N	Y
Female	78	142	78	366	401	Y	Y	Y
Female	78	162	82	488	197	N	Y	N
Female	75	134	70	293	317	N	N	Y
Female	75	126	72	368	337	N	Y	N
Female	74	164	82	265	188	N	N	Y
Female	73	150	70	191	338	N	N	Y
Female	73	112	60	324	420	Y	N	N
Female	73	120	68	547	304	N	Y	N
Female	72	154	68	367	337	N	Y	N
Female	71	142	80	121	449	Y	N	N
Female	70	140	68	480	406	Y	Y	Y
Female	70	132	80	563	365	Y	Y	Y
Female	69	124	70	376	433	Y	Y	Y
Female	64	144	90	660	544	Y	Y	Y
Female	64	138	84	142	431	Y	N	N
Female	62	112	70	361	559	Y	Y	Y
Female	62	124	60	200	395	Y	N	N
Female	61	134	78	579	508	Y	Y	Y
Female	60	120	76	594	562	Y	Y	Y

Summary of table: Number of agreements between actual and predicted was 12 yes and 8 no.

Results: 60.0 percent agreement between actual and predicted test time for females subjects above 60 years of age.

TABLE 9

**Six-Minute Threshold Comparisons: Agreements Between Actual and Predicted Time
for Female Subjects Below 60 years of age.**

Gender	Age (years)	Systolic (mmHg)	Diastolic (mmHg)	Actual Time (seconds)	Predicted Time (seconds)	Predicted < 360 seconds	Actual 360 seconds	Agree
Female	56	120	80	633	591	Y	Y	Y
Female	55	140	90	370	464	Y	Y	Y
Female	54	108	82	631	631	Y	Y	Y
Female	54	128	88	573	575	Y	Y	Y
Female	54	110	66	536	373	Y	Y	Y
Female	53	106	76	553	631	Y	Y	Y
Female	52	150	80	583	443	Y	Y	Y
Female	52	110	80	481	607	Y	Y	Y
Female	52	153	98	739	524	Y	Y	Y
Female	51	112	80	601	564	Y	Y	Y
Female	51	162	98	350	446	Y	N	N
Female	50	90	60	715	596	Y	Y	Y
Female	50	138	92	572	588	Y	Y	Y
Female	49	106	78	545	646	Y	Y	Y
Female	49	102	76	750	651	Y	Y	Y
Female	46	100	60	606	546	Y	Y	Y
Female	46	102	58	592	522	Y	Y	Y
Female	46	114	76	548	391	Y	Y	Y
Female	46	124	76	40	275	N	N	Y
Female	43	146	80	450	429	Y	Y	Y
Female	38	108	70	450	411	Y	Y	Y
Female	32	98	60	589	556	Y	Y	Y
Female	30	100	60	736	546	Y	Y	Y
Female	30	102	62	95	350	Y	N	N

Summary of table: Number of agreements between actual and predicted was 22 yes
and 2 no.

Results: 91.7 percent agreement between actual and predicted test
time for females subjects below 60 years of age.

NOTE TO USERS

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APPENDIX III

RAW DATA

Note to Reader explaining the Raw Data:

Stepwise Regression Analysis:

Data was sorted: by Gender

Dependent variable: Total Time

Potential Independent variables: Age, HighMET, Grip, Grip Rating, HR Start, HR 5 sec hold, RBP Systolic, RBP Diastolic, Met Equivalent, MPHR 100% HR.

Results:

Males: The independent variables Age and HighMET were the only significant contributors to the model predicting Total Time.

Females: The independent variables HighMET, RBP Systolic, and RBP Diastolic were the only significant contributors to the model predicting Total Time.

Subj	Gender	Age	High MET	Grip	Grip Rating	HR Start	HR 5 Sec Hold	RBP Systolic	RBP Diastolic	Total time In Seconds	Met Equivalent	MPHR 100% Level
1	1.00	54	10	38	25	76	89	112	60	632	12.9	166
2	2.00	54	9	29	90	109	109	108	82	631	12.9	166
3	1.00	58	10	44	50	88	109	132	80	540	10.1	162
4	1.00	66	10	41	50	86	95	130	78	660	12.9	154
5	1.00	45	10	42	25	90	100	126	80	693	12.9	175
7	1.00	37	10	47	25	82	108	130	90	820	15.1	183
8	1.00	50	8	57	90	91	100	124	90	693	12.9	170
9	2.00	55	7	29	90	73	83	140	90	370	7.0	165
10	2.00	46	10	23	25	86	87	100	60	606	12.9	174
11	1.00	57	10	41	50	82	90	105	70	553	10.1	163
12	1.00	68	10	37	50	58	63	134	76	269	7.0	152

13	1.00	43	10	38	10	93	86	108	80	643	12.9	157
14	2.00	62	10	27	75	111	120	112	70	381	7.0	158
15	2.00	46	4	33	90	78	100	114	76	548	10.1	174
16	2.00	61	10	29	90	75	87	134	78	579	10.1	159
17	2.00	30	10	31	75	84	99	100	60	736	12.9	190
18	1.00	44	10	41	25	84	82	140	82	280	7.0	176
19	2.00	56	10	27	75	79	94	120	80	633	12.9	164
20	1.00	71	3	39	50	58	62	118	62	219	4.6	149
21	1.00	58	10	49	75	78	92	142	68	621	12.9	162
22	1.00	46	10	48	50	78	84	110	64	702	12.9	174
23	2.00	64	10	25	75	74	74	144	90	680	12.9	158
24	1.00	72	10	48	90	79	100	180	94	180	4.6	148
25	1.00	45	3	32	10	68	76	110	84	611	12.9	175
26	1.00	51	10	50	75	76	88	124	88	618	12.9	169
27	2.00	30	4	24	25	71	92	102	62	95	10.1	190
28	1.00	79	9	36	50	63	64	136	74	274	7.0	141
29	1.00	56	10	46	50	76	92	160	90	605	12.9	164
30	2.00	48	10	21	25	83	89	106	78	545	10.1	171
31	1.00	50	6	32	10	81	79	118	74	510	10.1	171
32	2.00	52	9	17	10	98	96	110	80	481	10.1	168
33	1.00	74	6	30	25	75	77	170	102	372	7.0	146
34	1.00	49	10	62	90	75	90	140	82	795	15.1	172
35	2.00	60	10	31	90	86	98	120	76	594	12.9	160
36	1.00	74	9	35	50	112	135	104	72	486	10.1	146
37	1.00	66	9	41	50	74	81	148	82	356	7.0	154
38	2.00	73	9	28	90	85	92	150	70	191	7.0	147
39	2.00	51	8	24	50	75	84	112	60	601	12.9	169
40	1.00	55	10	38	25	87	106	150	104	373	7.0	166
41	1.00	56	10	41	50	85	94	116	78	479	10.1	164
42	2.00	38	5	29	75	96	99	188	70	450	10.1	182

43	1.00	39	10	54	50	89	105	126	70	795	15.1	181
44	2.00	54	5	24	50	85	90	110	68	536	10.1	166
45	2.00	53	10	25	50	77	86	106	76	553	10.1	167
46	1.00	51	10	42	50	98	110	138	84	627	12.9	189
47	1.00	59	10	48	50	70	79	108	76	775	15.1	161
48	2.00	62	9	20	25	90	95	124	60	200	4.6	159
49	1.00	46	10	40	25	76	90	130	90	829	15.1	174
50	1.00	72	10	37	50	82	96	148	86	584	10.1	148
51	2.00	72	10	20	50	78	83	154	68	367	7.0	149
52	2.00	74	4	19	50	71	72	164	82	265	7.0	146
53	1.00	45	10	36	10	64	79	116	70	671	12.9	175
54	1.00	64	10	42	50	76	81	150	92	289	7.0	157
55	2.00	69	8	28	90	65	70	124	70	376	7.0	151
56	1.00	70	9	45	90	80	80	140	84	191	4.6	150
57	1.00	48	10	34	10	92	120	140	90	630	12.9	174
58	2.00	51	8	27	75	69	95	162	98	350	7.0	169
59	2.00	71	9	21	50	80	92	142	80	121	4.6	149
60	2.00	73	8	24	75	88	90	112	60	324	7.0	147
61	2.00	78	4	27	90	80	81	162	82	488	10.1	142
62	1.00	48	7	31	10	79	86	114	68	606	12.9	175
63	1.00	64	10	50	90	71	76	152	80	573	10.1	156
64	1.00	51	5	34	10	81	80	145	82	315	7.0	169
65	1.00	51	10	36	25	73	77	110	60	601	12.9	169
66	2.00	75	6	32	90	89	96	134	70	293	7.0	145
67	2.00	78	8	24	75	120	120	142	78	366	7.0	142
68	2.00	70	10	21	50	62	66	140	68	480	10.1	150
69	2.00	50	10	24	50	52	64	90	60	715	12.9	170
70	2.00	52	10	18	10	73	74	150	60	583	10.1	168
71	1.00	68	10	45	75	68	74	116	60	523	10.1	152
72	1.00	65	4	33	25	89	99	124	66	365	7.0	155

73	1.00	58	3	34	10	84	88	137	62	23	1.0	162
74	2.00	70	5	22	50	61	65	132	88	583	10.1	150
75	1.00	78	10	30	25	77	86	124	74	164	4.6	145
76	1.00	75	10	38	50	56	70	128	78	559	10.1	145
77	2.00	46	10	25	50	69	75	102	58	592	12.9	174
78	1.00	82	9	29	25	93	84	138	80	395	7.0	138
79	2.00	54	9	26	75	74	80	128	88	573	10.1	166
80	1.00	49	10	48	50	80	102	118	82	667	12.9	171
81	1.00	54	10	42	50	98	105	130	82	165	4.6	166
82	2.00	43	9	40	90	84	95	146	80	450	10.1	177
83	1.00	52	10	47	50	79	87	140	82	641	12.9	168
84	1.00	35	10	51	50	100	112	108	76	657	12.9	185
85	1.00	65	7	37	50	73	83	120	74	420	10.1	155
86	1.00	67	10	52	90	67	76	140	90	637	12.9	153
87	1.00	67	10	35	25	65	68	122	72	425	10.1	153
88	2.00	46	2	20	25	91	95	124	76	40	1.0	174
89	1.00	50	10	49	75	74	96	120	90	642	12.9	170
90	1.00	54	10	65	90	72	79	122	84	819	15.1	166
91	1.00	43	10	48	50	87	93	114	90	594	12.9	177
92	2.00	64	7	25	75	61	63	138	84	142	4.6	156
93	2.00	81	4	24	75	83	101	150	80	66	4.6	139
94	1.00	42	10	44	25	121	131	148	98	751	12.9	178
95	1.00	76	3	34	50	79	81	160	90	375	7.0	144
96	1.00	53	10	39	25	68	72	144	90	739	12.9	167
97	1.00	37	10	40	10	62	78	112	84	660	12.9	183
98	2.00	49	10	33	90	74	80	102	76	750	12.9	171
99	1.00	36	10	58	75	108	109	150	90	459	10.1	184
100	2.00	52	9	19	25	84	86	153	98	739	12.9	168
101	1.00	55	10	45	50	96	109	162	90	675	12.9	165
102	2.00	75	5	21	50	78	86	126	72	368	7.0	146

103	2.00	73	4	22	50	68	77	120	68	547	10.1	147
104	2.00	50	10	27	75	77	88	198	92	572	10.1	170
105	1.00	62	9	36	25	77	90	100	70	457	10.1	158
106	2.00	32	10	29	75	80	97	98	60	589	10.1	188
107	1.00	58	10	34	10	61	72	118	70	768	12.9	162
108	1.00	65	10	37	50	63	73	150	80	745	12.9	156
109	1.00	78	10	25	10	62	62	130	78	690	12.9	142

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