CHAPTER I

INTRODUCTION
An ongoing research project is presently being conducted at the Carolina Medical Center in Charlotte, NC. Dr. Joseph W. Cook, MD, as the chief of adult cardiac surgery at the Carolinas Heart Institute, is the primary investigator in this study. The research team also includes six co-investigators, one full-time research technician, and several graduate students from Virginia Tech. The overall purposes of this research project is to study the clinical, physical, and quality of life variables of patients after a coronary artery bypass graft (CABG) and to study the relationship of these variables to selected pre-surgical physical fitness, health and clinical status variables.

The overall research project is divided into two parts. The primary objectives of part I of the project are to determine the extent to which physical fitness, and quality of life can be measured in patients about to undergo CABG, and to determine if these variables influence post-surgical morbidity, mortality and quality of life as measured three months post CABG with a battery of tests that includes a self-efficacy questionnaire of functional capacity related to daily activities, anthropometric measurements, strength measurements and a maximal VO$_2$ test conducted on a treadmill. The primary objectives of part II of the study are to determine the extent to which exercise capacity, self-efficacy of physical activity, physical fitness, bone density and quality of life can be enhanced by participation in a cardiac rehabilitation program. The research conducted and reported herein is a component of part I of the overall project.

Coronary artery disease is a prevalent disease that people must face everyday. Coronary artery bypass grafts (CABG) are recommended to patients who experience angina or a heart attack caused by coronary artery disease, if the lesions are operable and if there is enough healthy myocardium. To some extent coronary artery disease is preventable. Preventable risk factors that lead to coronary artery disease and a possible need for bypass surgery include smoking, high blood pressure, a diet high in fat, and lack of physical activity. Other factors
that may put someone at risk for coronary artery disease include age, gender, diabetes, and a family history of heart disease.

Coronary artery bypass grafts (CABG) are one of the most frequently performed operations in the United States. In 1997, The Society of Thoracic Surgeons reported undertaking 684,286 CABG procedures. CABG surgeries made up 76.5% of all cardiac procedures taking place that year. (Annual Trends and Summaries, 1997) Bypass surgery is the second most common form of major elected surgery and it accounts for up to 1% of the national gross domestic product spending on health care (Weinstein, Statson, 1982). According to the National Center for Health Statistics, more than 134,000 bypass procedures have been performed in persons who are greater than 65 years old (Jaeger, MagPharm, Hlatky, Paul, Gortner, 1994). The number of graphs increased 67% in patients older than 80 years between 1987 and 1990 (Peterson et al., 1995). With this increase, bypass surgery has contributed significantly to the increased life expectancy of this same population. Bypass surgery has grown in popularity due to improvements in surgical technique, due to its ever-growing success rate, and due to an aging population.

Because of the increasing number of CABG surgeries, there is a growing need to predict the morbidity, mortality and quality of life in patients following such surgery. The quality of one’s life following CABG is particularly important and largely the focus of this study. An individual’s ability to live a physically active, high quality life is directly related to an individual’s maximal oxygen intake (VO\textsubscript{2}). With an increase in oxygen intake, an individual increases his/her ability to be active and mobile. Maximal oxygen intake is a term used synonymously with functional capacity. Oxygen intake is an established measure that reflects the physiological efficiency of the cardiovascular system during physical activity, such as a graded exercise test. Maximal oxygen uptake is an indicator of the peak level of physical activity that an individual is capable of achieving. According to Myers (1996) maximal oxygen uptake is reached when there is no further increase in oxygen uptake despite further increases in workload. This definition is considered
valid as well as the definition that oxygen uptake is considered “maximal” when
the subject reaches a point of extreme fatigue without reaching a plateau in oxygen
uptake.

In summary, the research information reported herein was designed to
provide needed information to compliment and enhance the effectiveness of bypass
surgery. More specifically, this research is designed to determine the extent in
which physical fitness measures influence the outcome of bypass surgery as
measured by functional capacity.

STATEMENT OF THE PROBLEM

The primary purpose of this study was to determine the extent to which
pre-surgical physical fitness influences the tolerance for physical activity after
surgery as defined by maximal oxygen uptake three months post bypass surgery.
The pre-surgical measures of physical fitness included strength, body composition
and a self-efficacy questionnaire of functional capacity as related to daily activities.
The information and data derived from this study will assist physicians and
surgeons in recommending patients for bypass graft. This assistance could be
valuable because previous research has not looked specifically at physical fitness
measures as predictors of functional capacity following surgery.

Various pre-surgical measures were used to predict an individual’s post-
surgical quality of life. One practical measure of physical fitness is the Veterans
Survey of Activity Questionnaire (VSAQ). This questionnaire is designed for
subjects to self-assess their functional capacity in metabolic equivalents (METs).
METs estimates the metabolic cost of activity. One MET is equal to a resting
metabolic rate of approximately 3.5 ml/O_{2}/kg/min (Myers, 1996). Physical
strength was measured with knee extension, elbow flexion and grip isometrically.
Body composition measures included skinfold measurements and anthropometric
measurements that derived the body mass index (BMI, kg/m^{2}).

The research reported herein determined the correlation between the
VSAQ predicted MET level, the VSAQ predicted MET level prior to an acute
reduction of physical activity which lead to CABG, strength measures calculated from elbow flexion, knee extension and grip strength all in relation to the subjects’ body weight, and body composition measures of the sum of three skinfold sites and Body Mass Index to the VO$_2$pk derived from a post surgical maximal treadmill test.

SIGNIFICANCE OF THE STUDY

The significance of this study is that it was designed to provide tools to predict the success of CABG. The use of these tools would better equip clinicians and patients in the decision making process prior to CABG surgery. More specifically, as previously stated, this study may demonstrate that a patient’s functional capacity after bypass surgery maybe predicted by taking simple pre-surgical physical strength and body composition measures. Since a patient’s functional capacity is a measure of the patient’s ability to be physically active, this capacity should, in turn, be directly related to a patient’s quality of life. The measures that have been utilized in this study are non-invasive, inexpensive, take minutes to complete, and are able to be conducted in a physician’s office.

Researchers could also use the results of this study as a stepping stone for the further study of the link between pre surgical physical fitness and post-surgical quality of life. There is a lack of published research that investigates fitness measures as preoperative indicators of postoperative risk appraisal and risk stratification. It seems that no one has investigated the relationship between the specific pre-surgical measures used in this study and post-surgical functional capacity.

RESEARCH HYPOTHESIS

The following research hypotheses are identified:
The pre-surgical physical fitness measures of body composition, muscular strength, and estimated self-efficacy for exercise tolerance (VSAQ) will predict functional capacity in a group of CABG surgery patients at a point 3 mo after surgery.
The pre-surgical physical fitness measures of body composition, muscular strength, and estimated self-efficacy for exercise tolerance (VSAQ) will predict functional capacity in a group of CABG patients at a point 3 mo after surgery, when pre-surgical health and clinical status variables are considered as part of the predictor set.

**DEFINITIONS OF VARIABLES AND SYMBOLS**

A comprehensive set of variables was measured prior to bypass surgery and at three months post bypass surgery. These variables included:

**Fitness Variables:**

Grip Strength: Maximal isometric strength measured with a Baseline Hand dynamometer and calculated in relationship to the subjects body weight. (kg/kg body weight); Vital Signs, Country Technologies Incorporated, Gaysmills WI.

Elbow Flexion Strength: Maximal isometric strength as measured with a CSV200 dynamometer and calculated in relationship to the subjects body weight. (kg/kg body weight) Chatillon Company, Greensboro, NC.

Knee Extension Strength: Maximal isometric strength as measured with a dynamometer and calculated in relationship to the subjects body weight (kg/kg body weight) Chatillon Company, CSV200, Greensboro, NC.

Sum of Body Fat Measurements: These measures were derived with the Harpenden skinfold calipers, Vital Signs, Country Technologies Incorporated, Gaysmills, WI. Skinfold data for males was collected at the abdominal, chest, and thigh. For females, the data was collected at the suprailium, abdominal, and thigh.

Body Mass Index: An anthropometric measurement of the weight of a subject
divided by his/her height squared (kg/m²). This index served as another indicator of body composition. Health risks begin in the score range of 25-30 kg/m² for the Body Mass Index (Keys, Fidanza, Karronen, Kimura & Taylor, 1972).

The Veterans Specific Activity Questionnaire (VSAQ): A questionnaire that indicates a patient’s perception of his/her personal maximal exercise tolerance. The VSAQ has established validity in terms of predicting maximal treadmill performance in patients with coronary artery disease and is expected to be sensitive to identifying changes in the same individuals over time (Myers, 1994). VSAQ scale values range from 2-13 metabolic equivalence (METs). For the purposes of this study, VSAQ was measured in two different ways: a) Prior VSAQ was the measurement taken retrospectively before there was an acute reduction of activity which lead to CABG, b) pre and post-surgical VSAQ were taken at the time just prior to surgery and 3 mo after surgery.

**Demographic and Clinical Health Status Variables:**
All potential predictor variables were taken from the pre-surgical STS data. These variables, as follows, were quantified and serve as potential predictors. These variables include:

Age: A patient’s age was recorded in years.

Cardiomegaly: An enlargement of the heart.

Cerebrovascular Accident (CVA): Apoplexy, a stroke, a hemorrhage, or blood clot within a blood vessel in the brain.

Chronic Obstructive Pulmonary Disease (COPD): Severe lung disease that causes a limited ventilatory response and/or oxygen desaturation.
Congestive Heart Failure (CHF): Retention of salt and water due to impaired heart function. Symptoms include shortness of breath, swelling of the hands and feet (dropsy), and poor circulation of the blood.

Diabetes Mellitus: A chronic disease characterized by an inability to oxidize ingested carbohydrates, due to an insufficient production of insulin by the pancreas.

Ejection Fraction: The percentage of the blood pumped from the left ventricle into the body, with each ventricular contraction.

Family History: A history of myocardial infarctions or sudden death due to coronary artery disease before 55 years of age in the father or other male first-degree relative or before 65 years of age in the mother or other female first-degree relative.

Gender: The patient's gender, male or female.

Hypercholesterolemia: An elevated level of total serum cholesterol

Medications: Any medication that may have an effect on the patient's cardiovascular system.

Myocardial Infarction (MI): Damage to the heart muscle as a result of loss of its blood supply, as in a coronary thrombosis. Each patient that was determined to have an MI was ranked as having an MI > 21 days of surgery, having an MI between 15-21 days of surgery, having an MI between 7-14 days of surgery, and having an MI < 7 days of surgery.

Orthopedic Limitations: Any limitation, such as arthritis in the knee that would...
affect patient’s ability to perform a maximal effort treadmill test.

Peripheral Vascular Disease (PVD): Abnormalities of the arteries and veins located in the extremities.

Smoker: Any past or current smoking habits as an estimate of the number packs the patient had smoked per year.

**Confounding Variable:**
The following variable, although part of the discussion, was not used in any statistical analysis:

Post surgery activity: The level of activity, measured in terms of physical activity and then transposed into calorie expenditure, during the three months immediately following surgery.

**Three Month Outcome Variable:**
The following was the 3 mo outcome variable:

Maximum Oxygen Uptake: Peak VO₂(VO₂pk) is the highest oxygen level a patient can achieve while undergoing an exercise test. This data was measured with the use of the SensorMedics Vmax 29c CardioPulmonary Exercise Module (Yorba Linda, CA).
DELIMITATIONS

The following delimitations were present in this study:

1. The subjects were CABG patients 50 years old or older.

2. None of the subjects had any other contaminant cardiovascular surgical procedure other than CABG.

3. The study was conducted and the CABG procedures took place beginning in November 1996 and proceeded until 64 subjects were recruited for the study.

4. Subjects were excluded from the study if they were diagnosed with cerebrovascular, orthopedic, neurologic, or cognitive-emotive disorders that would preclude the completion of the pre-surgical test items.

5. Subjects were excluded from the study if they had a myocardial infarction within the past five days.

LIMITATIONS

The following limitations were present in this study:

1. Subjects for this study all had their CABG completed at the Carolinas Medical Center, Charlotte, North Carolina, therefore limiting the patient pool to a single hospital and a single geographic area.
2. The post-surgical functional capacity measurements involve walking on a treadmill, therefore excluded subjects with orthopedic limitations or other comorbidities.

BASIC ASSUMPTIONS

The following basic assumptions were present in this study:

1. All measurements were taken accurately.

2. Subjects answered the VSAQ questionnaire honestly and to the best of their knowledge.

3. Each subject participated in the data collection measurements as much as possible given their individual limitations.
CHAPTER II
REVIEW OF LITERATURE
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LITERATURE REVIEW

Coronary artery bypass (CABG) surgery has become an increasingly frequent procedure. This chapter examines the pertinent literature regarding the success and outcomes of CABG surgery and potential predictors of these outcomes. The categories are as follows: a) utilization of functional capacity evaluations to assess outcomes for CABG; b) the consequences of morbidity, mortality, hospitalization and selective clinical variables are useful to stratify patients for risk; c) technical studies on reliability and validity of tools for physical fitness.

Exercise and Functional Capacity Outcomes Following CABG

For years, treadmill testing has been used to evaluate surgical outcomes in CABG patients. A study conducted by Stuart, Ziprick & Ellestad, 1979 used pre and post-surgical treadmill testing to determine the degree of improvement in postoperative treadmill test performance by examining the rate pressure product at the point of ST depression. This method was used as an index to help determine maximal myocardial perfusion capacity. Other variables the were studied included: relationships between patient genders, correlation’s between angina and increased treadmill performance, relationships between preoperative angina and postsaphenous vein bypass performance and the benefits of CABG to those with ischemia at low work levels verses patient’s with late onset ischemia changes. Of the 142 patients that participated in this study, 68% of the females and 58% of the males had improvements in the rate pressure product at the onset of ischemia. Of the 132 patients that reported a history of angina prior to surgery, 78% were relieved of angina following surgery. From this same set of patients, there were overall improvements in the rate pressure product at the point of ST depression. The patient’s gender, angina during treadmill testing, and the workload associated
with ischemia was not useful in identifying patients that would benefit from bypass surgery.

A study by Deligonul et al., 1989 used treadmill testing to determine to the prognostic outcome of Percutaneous Transluminal Coronary Angioplasty (PTCA) shortly after surgery. In this study, 412 patients with successful one and two vessel PTCA were asked to undergo a symptom-limited, Bruce protocol treadmill test between one to 30 days (average = 9 days) after surgery. Of the patients with single vessel disease, 70% completed a normal treadmill test. Of the patients with multiple vessel disease, 55% completed a normal treadmill test. There was a significant (p<0.04) correlation between patients that had abnormal treadmill test and patients that suffered a post-surgical cardiac event. The overall conclusion of this study was that abnormal exercise ECG findings in post surgical treadmill test were beneficial to determine cardiac events in patients with multivessel PTCA.

In 1990, Dubach, et al. conducted a retrospective assessment comparing data from pre and post-surgical exercise test of patients undergoing CABG or PTCA. The purpose if this study was to compare the exercise responses in patients who had clinically successful revascularizations. A total of 64 patients completed both pre and post-surgical tests. Of these subjects, 28 were CABG patients. The post-surgical exercise tests took place 5 mo after CABG and 2.5 wk after PTCA. The exercise testing was conducted by selecting a maximal workload of estimated metabolic equivalence (METs). Blood pressure, rate of perceived exertion (RPE) and ECG changes where recorded at the end of each stage. Blood pressure was also recorded when the subject had negative cardiovascular symptoms or when there were changes on the ECG. The end point for the test included: severe angina, 4 mm or more of ST depression, serious dysrhythmias, or hypertensive (>220mm Hg systolic blood pressure) or hypotensive responses took place. The post-surgical testing showed similar functional capacities in the CABG patients and the PTCA patients (1.8 METs v. 2.2 METs). Pre and post-surgical test showed a three MET increase in functional capacity, from a mean (standard deviation) of 5.9 (2.3) to 8.1 (3.3). This study also showed favorable results in
post-surgical treadmill RPE and a significant decrease in abnormal ST segment responses. Overall, CABG surgery was found to be more effective in decreasing the signs and symptoms of ischemia, but the research notes that a more thorough study needs to be conducted which would incorporate randomized patients.

A study conducted by Gunning et al., 1997 used functional capacity as a measure in exercise testing in order to assess the outcomes of CABG on left ventricular function and to evaluate the role of identifying myocardial hibernation. This study involved 47 patients that were diagnosed with left ventricular ejection fraction < 35 % and three-vessel coronary artery disease. Subjects were administered symptom limited VO$_2$pk treadmill test and symptom profile evaluations less than 3 mo prior to CABG and then again three to six months after surgery. The result of this study found that though there was a high CABG patients also had mortality rate, 17% peri- and postoperatively, there were global and regional improvements in systolic left ventricular function and the symptom profile of the subjects that underwent CABG. Although a well used measure on healthy patients, there are very few studies that have utilized VO$_2$pk as an outcome measure of CABG.

**Morbidity, Mortality, Hospitalization and Selective Clinical Variables**

Hannan et al., 1990 conducted a study on open-heart surgery in New York State. This study consisted of 1,323,000 patients that were diagnosed with coronary artery disease all within the first 6 mo of 1989. The purpose of this study was to determine the set of significant clinical risk factors and to identify cardiac surgical centers most likely to have quality-of-care problems. The risk factors included in this study were clinical risk factors, demographic factors (age, race and gender) and payer (Medicaid vs. Non-Medicaid). Payer was included to determine if socioeconomic status was a factor in CABG outcome. Logistic regression analyses were conducted to determine associations between risk factors and mortality. Risk factors that were investigated in this study as predictors of in-
hospital death included: age, gender ejection fraction, previous myocardial infarction, number of open heart operations in previous admissions, diabetes requiring medication, dialysis dependence, disasters (acute structural defect, renal failure, cardiogenic shock, gunshot), unstable angina, intractable congestive heart failure, left main trunk narrowed more than 90%, and type of operation performed. Of the 28 hospitals in the study, four had increases in mortality more than expected given the risk factors of their patients.

In 1997, research conducted by Katz and Chase showed that surgical techniques improvements in recent years have led to a reduction of cardiac, neurologic, and renal complications following CABG, valve procedures and combined CABG and valve procedures in the elderly. Researchers from Georgetown University studied the surgical outcomes including mortality, length of stay, complications, and costs of surgery for 285 patients, 70 years and older and 568 patients under the age of 70. Standard techniques were employed for all surgeries. Clinical practices of the procedure included maintaining “normal” arterial pressure during and after operation. Measures to prevent renal failure such as preoperative volume infusion, mannitol during CABG, and low-dose dopamine hydrochloride postoperatively were administered. Moderate anticoagulation drugs and short acting anesthetic agents were administered when needed to best stabilize the patient. This research found that over a five year period, the average length of stay in a hospital after surgery decreased from 12.5 +/- 1.5 days to 8.9 +/- 0.9 days in patients above 70 years old and it decreased from 11.5 +/- 0.1 days to 6.4 +/- 0.3 days for patients under the age of 70. Multiple logistic regression was used to best evaluate the significant predictors of mortality. This model found that elevated creatinine levels, left ventricular ejection fraction of 0.30 or less, emergency operations and valve operations were all significant predictors of mortality. Age and gender were not shown to be significant factors. It was also noted that a 13% increase in overall hospital cost for patients above the age of 70. It is thought that though cardiovascular operations are more costly than less invasive procedures, most patients that undergo cardiovascular operations sustain clinical improvements
and therefore long-term, these patients spend fewer days in the hospital. Overall, it was found that modern cardiac surgical techniques along with clinical practices have been able to reduce the importance of the age as a factor when deciding to proceed with CABG surgery.

A study by Higgins, et al. (1992) attempted to find a relationship between morbidity and mortality, and preoperative severity of illness in patients undergoing bypass surgery. The study was a retrospective analysis of 5,051 bypass surgery patients at the Cleveland Clinic Foundation. In this research, morbidity was defined as a myocardial infarction, use of an intra-aortic balloon pump, mechanical ventilation for 3 or more days, a neurological deficit, oliguric or anuric renal failure, or a serious infection. This research indicated that 13 factors were significant predictors of morbidity. These factors included emergency care, serum creatine level, reoperation, LV dysfunction, mitral valve insufficiency, age, diabetes, weight, anemia, COPD, cerebrovascular disease, aortic stenosis and, prior vascular disease. The following variables were found to be predictors of mortality: unstable hemodynamics or ischemic valvular dysfunction along with preoperative serum creatine levels greater than 168 $\mu$mol/L, severe left ventricular dysfunction, preoperative hematocrit of 0.34, increased age, chronic pulmonary disease, prior vascular surgery, reoperation, and mitral valve insufficiency all participated in this study. Through regression equations, Higgins was able to assign a weight to each risk factor in order to relate a total score to postoperative mortality and morbidity. Higgins et al. (1992) found that all increasing morbidity resulted in an increase in the risk factor score and that the preoperative severity of illness was an excellent resource in determining postoperative morbidity and mortality.

After bypass surgery, even for older patients, there has been an increase in symptomatic improvements and they have excellent long-term survival prospects. A study at Vanderbilt University of Medicine conducted by (Merrill, Stewart, Frist, Hammon, Bender, 1989) reviewed post-surgical outcomes for both bypass and valve replacement surgery. This study consisted of 40 patients, all at least 80 years
old more. The purpose was to assess pre-surgical clinical variables and identify any relationship between the pre-surgical and the post-surgical mortality. The pre-surgical clinical variables included age, sex, diagnosis of coronary artery disease, risk factors for coronary artery disease, operative procedures, preoperative complications, long-term follow up as to the patients recovery, as well as the Canadian Cardiovascular Society classification to grade angina and the New York Heart Association functional classifications. This study found a 10% mortality rate for the patients, with an average postoperative stay of 14 days. This study also demonstrated that all survivors experienced sustained improvements in functional status and minimal late morbidity. The researchers noted that the level of postoperative rehabilitation was similar to that achieved by patients younger than 80 years old. One can determine from this study that age, although a good variable in determining morbidity and mortality, must be examined as part of the predictor set when making the decision to undergo CABG.

A study by O’Keefe et al., 1994 researched the relative risk and benefits of PTCA and CABG in patients greater than 70 years-of-age. This study was a retrospective analysis of 390 randomly selected patients, half underwent PTCA and half underwent CABG. In order to keep the groups similar, patients were matched to have similar left ventricular systolic function, age and, gender. Demographic descriptors were collected on every patient before surgery and follow-up data was collected through questionnaires and by telephone interviews after surgery. The results of this study found that hospital morbidity and mortality rates were significantly lower in PTCA patients. In-hospital death for PTCA patients was 2% compared to 9% for CABG patients. Five percent of CABG patients also suffered from severe in-hospital strokes, while none of the PTCA patients had in-hospital strokes. However, compared to PTCA patients, the CABG patients experienced less reoccurring angina, fewer repeat revascularization procedures and, fewer Q wave infarctions during follow-up compared to the PTCA group.

Similar to the Hannan, et al. study, a study by Peterson et al. (1995) used Medicare data from 24,461 patients between 1987 and 1990 in order to determine
the outcomes of CABG surgery in patients 80 years or older. The Medicare data from this retrospective analysis included age, sex, race, discharge status (including death), up to five discharge diagnosis and three procedures as identified by the International Classification of Diseases. Information pertaining to patient mortality and cost to charge ratios from The Health Care Resource Information System were also collected. This study found that compared to 65 to 70 year olds, 80 year olds and older patients had a significant increase in hospital stay and cost of CABG surgery. The mean hospital stay for a patient 80 years old or older was 14.2 days with an established cost for the hospital stay, not including surgery was $48,200. The mean hospital stay for a patient between 65 and 70 years old was 10.8 days with an estimated cost for the hospital stay, not including surgery was $38,000. In hospital mortality rates for patients 80 years and older was 11% compared to 4.4% for patients between 65 and 70 years old. The older patients also had a 15% increase in three-year post surgical mortality rates. However, the older patients that had successful surgery had a long-term survival rate similar to that of the general 80 year old population in the United States. This study notes that more clinical research needs to be conducted in order to determine whether the benefits from CABG in the very elderly justify the mortality and morbidity risk involved.

A study conducted by Ayanian, Guandagnolis, Clearly (1995) at the Brigham and Women’s Hospital in Boston, Massachusetts determined differences in the physical and psychosocial functioning of men and woman after surgery. This study consisted of 454 consecutive bypass surgery patients who discharged alive or who died in the hospital between June 18, 1989 and March 28, 1990. At six months post surgery, each patient was sent a packet of questionnaires to complete and return. Three hundred and six patients, 66 women and 240 men completed the six-item scale of instrumental activities of daily living (IADL). The IADL include a broad assessment of daily activities such as climbing stairs, shopping, and doing house and yard work. The questionnaires also included a social activity scale, a mental health scale, and a vitality scale that was able to assess energy levels and fatigue. For all the items on the scale, the patients were asked to complete the
questionnaire as they recalled their past month of activities. Specifically, patients rated their functioning during the months before completing the survey and they also recalled their functioning during the month before surgery. The questionnaires also included questions about education, income, marital status, living situation, race, overall health at the time of surgery, the number of days confined to bed during the prior month, and the number of days with pain, shortness of breath, or other heart related symptoms during the prior month. This study concluded that women undergoing CABG were significantly older, had more severe angina and were more likely to have a recent myocardial infarction. The study also found that women were more likely to have diabetes mellitus, anemia, and congestive heart failure before surgery. Men were found to have more severe distributions of coronary stenoses but there where no significant differences between the level of ejection fraction on men and women. Overall, women entered surgery with a much great severity of illness, women suffered a higher in-hospital mortality rate, but the results that men and woman reported similar physical and psychosocial functioning six months post-surgery. The researchers noted that links between clinical factors and functional status are important areas for further research.

The purpose of a study by Ferraris and Ferraris (1990) was to identify clinical risk factors that lead to post-operative morbidity which has been found to be more common and more costly than mortality. This study involved 938 bypass patients from Albany Medical Center Hospital, Albany, New York. Regression models were implemented in order to find a link between outcome variables of length of hospital stay, serious postoperative morbidity, and hospital mortality. Similar to the Higgins et al. (1992) investigation, serious postoperative morbidity was defined by postoperative MI, stroke, pulmonary failure, renal failure necessitating dialysis, postoperative cardio shock, necessitating left ventricular assist device or intra-aortic balloon pump, sepsis, or mediastinitis. The risk factors found to be linked to an increased length in post-surgical hospital stay include a composite variable of age in relationship to the patients’ red blood cell volume, a history of CHF, hypertension, femoral-popliteal peripheral vascular disease,
COPD, precious stroke, and renal dysfunction. The risk found to be linked to serious postoperative morbidity includes CHF, age/red blood cell volume, hypertension, and previous stroke. The risk found to be linked to hospital mortality includes a composite variable that combines multiple patient risk factors into a single risk-adjusted score, dialysis-dependent renal failure, CHF, and femoral-popliteal peripheral vascular disease. Researchers noted that 40% of the cost of bypass surgery was incurred postoperative morbidity, thereby increasing the duration of hospital stay. The conclusion of this study was that older patients with preoperative anemia and low blood volume along with other comorbidities that include CHF, stroke, COPD, and hypertension are at an increase risk of postoperative complications.

Tu (1996) developed a cardiac surgery risk index to stratify and predict risk of death, prolonged intensive care, and prolonged post-operative hospitalization. The developed index had six categories that included gender, age, left ventricular function, the number of repeat surgeries the patient had to undergo, urgency as well as type of surgery were significant indicators of the varied risk. A risk index score of “0” was assigned for patients under 65 yr old, a score of “2” was assigned to patients between 65 and 74 yr old and a score of “3” was assigned to patients 75 yr old and older. Left ventricular function was given a risk score between “0” and “3” depending on the ventricle’s ability to function. The type of surgery was divided into CABG which received a “0” score, single-valve procedure which received a “2” score and complex surgery, which included CABG and valve surgery, received a “3” score. The urgency of the surgery was divided into elective which received a “0” score, urgent, which received a “1” score and emergency which received a “4” score. If the patients did not have repeat surgery, then they received a “0” risk score. If they had repeat surgery, they received a “2” risk score. All of the categories were found to be good indicators of varied surgical risk. This study originally stratified 6,213 patients undergoing bypass surgery and then repeated the risk stratification with additional 6,885 patients. In both groups of patients, this study showed that the risk of in-hospital mortality, prolonged
intensive care unit stay, and prolonged overall postoperative hospitalization after cardiac surgery can be predicted with the use of the six variable cardiac surgery risk index.

An interesting study at the Newark Beth Israel Medical Center devised a risk stratification system that eliminated statistically optional fields and reweighing of variables in order to provide a consistent procedure to best stratify various variables of risk. The purpose of this research was to gain a realistic comparison of results among surgeons and institutions. Using the newly devised system, researchers found a suggested decline in length of hospital stay and beneficial changes in operational procedures (Parsonnet, Bernstein, EngScD, Gera, 1996).

Technical Studies on the Measurements of Physical Fitness

Body composition can be measured by various methods including hydrostatic weighing and dual energy x-ray absorptiometry (DEXA) scans. These methods can have excellent results, but due to the cost and time in a clinical setting, anthropometric measures have become the preferred method of measurement. Jackson and Pollock (1985) found excellent results when they used the skinfold sum method to predict body composition. The purpose of the Jackson and Pollock study was to evaluate a practical assessment of body composition in order to determine a desirable body weight for adults and athletes. This study compared various methods for measuring body composition, including hydrostatic weights and anthropometric techniques, which include height/weight indexes, skinfold fat, body circumference, and bone diameters. Different skinfold measures were found to be more valid for males versus females. For men, the skinfold sites were chest, thigh and abdomen. For women, the skinfold sites included the suprailium, thigh and abdomen. The chest measurements were taken with a diagonal fold taken half of the distance between the anterior axillary line and the nipple. The abdominal skinfold was a vertical fold taken at a lateral distance of approximately two centimeters from the umbilicus. The thigh skinfold was a vertical fold on the anterior aspect of the thigh midway between hip and knee joints. The triceps skinfold was taken as a vertical fold on the posterior midline of
the upper arm, halfway between the acromion and olecranon process. The
suprailium was taken as a diagonal fold above the crest of the ilium at the spot
where an imaginary line would come down from the anterior axillary line. This
study found that hydrostatic weighting was most accurate, but that the skinfold
sum method was considerably more accurate than the traditional method of using
height and weight. This study used multiple linear regression in order to determine
an equation to predict body density. The equation derived from this study is able
to predict body density for healthy non-athletes, although there is a question of its
applicability to elderly subjects since the oldest individual in the study was 63 yr
old. Unfortunately, there is a lack of research on anthropometric body
composition measures in the elderly.

The Veterans Specific Activity Questionnaire (VSAQ) is a questionnaire
designed to determine functional capacity levels in patients that may be subject to
cardiocascular disease. The specific goal of the developers of the VSAQ was to
device a questionnaire to establish individualized ramping protocols for exercise
testing that would elicit a maximal exercise responses from patients within a
standard period of 8 to 12 minutes of treadmill walking. From this goal, self
perceived peak activity levels might also be measured. This study involved 212
patients, mean age of 62 yr and a standard deviation of +/- 8 years, that had been
referred for exercise testing between February and September of 1992. The
subjects remained in the study if they where able to endure a maximal treadmill test
without any limitations due to symptoms or without termination of the test by the
supervising physician. Of the subjects involved, 46 patients were receiving beta-
blockers, 84 patients were on calcium antagonists and 16 patients were in digoxin.
Sixty-four of the patients had a history of MI, and 41 patients had undergone
bypass surgery. Before undergoing the treadmill test, each subject was given the
VSAQ. The questionnaire yielded metabolic equivalence (METs) for each set of
activities listed in the VSAQ. An analysis of the data was based on a dependent
variable of peak METs dependent from the treadmill test, and independent
variables as follows: age, METs by VSAQ, current activity status, body mass
index, smoking history (yes/no and pack years), history of MI, history of CHF, use of beta-blockers, and resting heart rate and blood pressure as independent variables. The results of this study showed that only metabolic equivalence by VSAQ and age were significant predictors of treadmill performance. It is important to note that the regression equations developed that distinguish age as an important risk factor are specific to the subjects noted above. From these results, the VSAQ nomogram was developed that is able to predict a patient’s exercise capacity in minutes.

A study by Jaeger, et al. (1994) used the Duke Activity Status Indexes an indicator of functional capacity in bypass surgery patients both prior to and one year following surgery. The specific purpose of this study was to determine if cardiac surgery, including bypass surgery and valve replacements, was able to increase the functional capacity of patients over the age of 70 and to identify factors that are associated with both good and poor functional capacity. One hundred and ninety nine patients, all between the ages of 70 and 91, filled out the questionnaire which yielded the functional capacity index, pre-surgery and post-surgically. The researchers also collected data on each patient, including admission symptomatology, preoperative cardiac history, preoperative surgical history, presence of any coronary artery disease risk factors, the New York Heart Association functional class, and the Charleston co-morbidity index which was used to classify the co-morbidity conditions. From the data collected, it was found that smoking, gender, the score on the Charleston co-morbidity index, syncope, previous cardiac surgery, old age, and preoperative complications were all factors which correlated with the one-year functional capacity results. As with any surgical study, it is important to note that all patients were determined by their physician to be good candidates for surgery. This study concluded that patients over the age of 70 are likely to have an elevated functional capacity one year after surgery and that clinical factors do appear to modify the degree to which patients improvement in their functional capacity.

Isometric strength measurements refer to exercises that develop high
intensity contractions in the muscle with no change to the muscle length. This measurement is caused from a maximal contraction against an immovable object. It is also caused when the muscle force is equal to the resistive force therefore causing no movement. The contraction is limited to only the joint angle in which the contraction occurs (Sudy, 1991).

According to Myers (1996), it is more difficult to determine functional capacity in subjects with heart disease than in normal subjects. The difficulty stems from the need to identify limitations of exercise for patients with heart disease. A measurement of VO$_2$ in normal subjects is directly related to maximal cardiac output. It is thought that exercise impairment in normal subjects directly reflects the degree of left ventricular dysfunction, which in turn would impact the heart’s ability to deliver oxygen. While this is the general belief for normal subjects, heart disease subjects may have several factors that may impair cardiac output. Heart disease patients have been found to have conditions that modify the relationship between functional capacity and left ventricular function. Research has shown that maximal heart rate, maximal cardiac output and changes from rest to maximal exercise appear to account for some of the exercise response, although 50% or more of the variance in VO$_2$ maximal is unexplained and needs to be researched more thoroughly.

Summary

Research has shown that CABG surgery has become a widely used surgical procedure and that the surgical techniques are increasing in effectiveness. Functional capacity has been used to test patient outcomes following CABG. Research incorporating functional capacity has been useful in determining physical quality of life outcomes of CABG. Studies that looked at morbidity, mortality, hospitalization and selective clinical variables as outcomes of CABG found those pre-surgical variables were able to determine post-surgical outcomes. Increases in risk factor scores had more problematic outcomes. Measurements such as skinfolds, VSAQ, and the Duke Activity Status Index have been shown to be good
measures to help predict physical wellbeing. Little research has been done to use strength measurements and predicted functional capacity as predictor variables for surgical outcomes.
CHAPTER III
JOURNAL MANUSCRIPT

Prepared to be submitted to The American Heart Journal
Functional Capacity Outcomes following Coronary Artery Bypass Graft Surgery

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The objective of this study was to determine if it is possible to predict 3 mo post-CABG treadmill VO₂pk outcomes from a combination of pre-surgical physical fitness and health and clinical status variables. To determine the VO₂pk, subjects performed a maximal treadmill test using a ramp protocol and gas analysis. When all pre-surgical variables were included in a multiple linear regression, the analysis yielded a model that included the prior to surgery VSAQ, orthopedic limitations, and angiotensin converting enzymes (ACE) inhibitor drugs as significant predictors ($R^2 = 0.50$, $N = 63$). When an RER of 1.1 was achieved during the treadmill test, myocardial infarction (MI) and if so, the length of time lapse from the MI, chronic heart failure, lipid lowering drugs, BMI, ACE inhibitor drugs, and orthopedic limitations ($R^2 = 0.56$, $N = 29$) were significant predictors. The data suggest that there is some relationship between post-surgical outcomes and pre-surgical physical fitness.
Coronary artery bypass grafting (CABG) is frequently recommended for patients who experience angina or a heart attack caused by coronary artery disease provided the lesions are operable and there is enough healthy myocardium to anticipate beneficial increases in perfusion. It is one of the most frequently performed operations in the United States. In 1997, The Society of Thoracic Surgeons\textsuperscript{1} reported undertaking 684,286 CABG procedures. The CABG surgeries made up 76.5\% of all cardiac procedures taking place that year. Due to the increasing number of CABG surgeries, there is a growing need to gather information that will facilitate improvements in surgical practices and techniques, which may reduce morbidity and mortality. Also, this information may identify features that can predict the outcomes of CABG. The quality of one’s life following CABG is particularly important and largely the focus of this study. Treadmill performance, although not a direct measurement of health related quality of life, is a desirable measure to study because it is a laboratory measure of functional capacity and, as such, indicates the overall physiological capacities of muscular-skeletal and cardio-pulmonary systems. An individual’s ability to live a physically active, high quality life is directly related to an individual’s maximal oxygen intake (VO\textsubscript{2}). With an increase in oxygen intake, an individual increases his/her ability to be active and mobile. For years treadmill testing has been considered an excellent tool for determining post-surgical improvements following CABG.\textsuperscript{2} Research has found that abnormal exercise ECG findings in post-surgical treadmill tests were valuable in determining cardiac events in patients with multivessel Percutaneous Transluminal Coronary Angioplasty (PTCA).

Some researchers have examined pre- and post-surgical exercise testing of patients undergoing CABG or PTCA in order to compare the pre- and post-exercise exercise responses in patients who have had clinically successful revascularizations.\textsuperscript{5-6} This research has shown that CABG is a very effective method of reducing the signs and symptoms of ischemia. Research has also
investigated relationships between morbidity and mortality, and preoperative severity of illness in patients undergoing CABG.\textsuperscript{6-10} Risk factor scores that include clinical and descriptive data have been developed to help physicians and patients make decisions about undergoing cardiovascular procedures.\textsuperscript{11-12} Research by Tu et al. found that patients’ severity of illness and their age prior to surgery serve as good predictors of CABG outcomes. An analysis of 1,323,000 coronary artery disease patients was conducted to determine the association between risk factors and mortality. The significant predictors in this study were similar to previous research, i.e. age, gender, ejection fraction, and previous myocardial infarction.\textsuperscript{13} A study by O’Keefe researched the relative risk and benefits of PTCA and CABG in patients 70 years or older. The researchers in this study found more severe complications in CABG than PTCA. But, they also found that once patients recovered from CABG, they sustained cardiovascular improvements comparable to those patients that underwent PTCA.\textsuperscript{14} Ayanian et al. recommended further study of the links between clinical factors and functional status.\textsuperscript{10}

Although health and clinical data have been examined, there has been a lack of research that has used physical fitness measures both independently and together with clinical status variables as predictors of CABG outcomes. The research reported herein was designed to provide needed information to complement and enhance the effectiveness of bypass surgery. More specifically, this research was designed to determine the extent to which pre-surgical physical fitness influences the outcome of bypass surgery as measured by functional capacity 3 mo after the surgery. The purpose of this study was to provide a resource to better enable patients and physicians to reach decisions about CABG in the context of outcome expectations. All measures for this study were non-invasive, inexpensive, non-time consuming, safe, and can easily be taken in a physician’s office or hospital setting.

METHODS
**Subjects**

Sixty-four male and female patients, who underwent CABG at the Carolinas Medical Center, Charlotte, North Carolina, served as subjects in this study. Patients had to be first time CABG patients and at least 50 yrs old. Patients did not qualify for in the study if they were undergoing any other cardiovascular surgical procedure other than bypass, or if they had been diagnosed with cerebrovascular, orthopedic, neuralgic, or cognitive-emotive disorders that would preclude the completion of the various test. Patients were also excluded from the study if they were diagnosed with two or more of the following morbidities: cancer, peripheral vascular disease (PVD), chronic heart failure (CHF), chronic renal disease, myocardial infarction within five days of collecting pre-surgical data, or an ejection fraction (EF) less than 35%.

**Procedure**

Just prior to surgery, the patients were given a battery of physical fitness tests and a standard questionnaire (VSAQ) in order to measure their strength, body fatness and their self-reported physical activity capabilities. After the tests were completed, the subjects were reminded of their 3 mo return commitment at which time strength, body composition and their self reported physical fitness level (VSAQ) measures were repeated, in addition to a maximal treadmill test. Three mo post-surgery, subjects returned to the Sanger Clinic to repeat the test and to undergo a VO$_2$pk test on a treadmill (Quinton, model 5000, Seattle, WA).

Grip strength was administered with the Baseline hand held dynamometer (Country Technologies Incorporated, Gaysmills, WI). For this test, males were tested with dynamometer position three and females were tested with dynamometer position two. Maximal static strength for elbow flexion and knee extension were assessed with the CSV200, a special physical therapy isometric strength dynamometer by Chatillon Company (Greensboro, NC). To measure elbow flexion strength, subjects were directed to place their forearm in the horizontal position with the palm up and the elbow joint angle at 110 degrees. Once the forearm was in position, the test technician positioned the dynamometer
at the midpoint of the forearm. The test was then executed by the subjects contracting their forearm flexors. Knee extension strength was measured by having the subjects sit at the edge of a bed with their knee bent to a 90-degree angle. The test technician then positioned the dynamometer at the midpoint of the subject’s right lower limb. The subjects were asked to extend their leg as forcefully as they could. Subjects were advised not to hold their breath for the strength measurements. Grip strength, elbow flexion, and knee extension were all recorded in relation to a subject’s body weight. Body fat was measured using Harpenden calipers (Country Technologies Incorporated, Gaysmills, WI) taking the sum of three standard skinfold sites. For males, the three skinfold sites were the abdomen, chest, and thigh, and for females, suprailium, tricep, and thigh. The same technician performed all skinfold measurements in triplicate, on the right side of the subject’s body. Weight and height were also measured to calculate body mass index (BMI, kg/m²). The Veterans Specific Activity Questionnaire (VSAQ) was used to evaluate the patients’ perceptions of their peak exercise tolerance in multiples of resting metabolism (METs). The VSAQ variables recorded were the pre-surgery VSAQ, the VSAQ they were able to accomplish that day and the VSAQ prior to any reduced activity due to the health decline that precipitated their CABG surgery decision. The rationale for measuring two pre-surgical VSAQ variables was to distinguish between physical activity when healthy and just prior to surgery and to determine if either measure was a better predictor of CABG outcome.

Medical data including health and clinical status measures were collected from the Society of Thoracic Surgeons (STS) database. The STS database is a national collection of health information, which is gathered by nurses and physicians as patients are admitted to hospitals. The variables collected from the STS database include: ejection fraction, family history, gender, hypercholesterolemia, medications, myocardial infarction (MI) and time of having MI, orthopedic limitations, smoking pack years, peripheral vascular disease, congestive heart failure, diabetes mellitus, chronic obstructive pulmonary disease,
and cardiomegaly. At 3 mo post-CABG, subjects returned to the Sanger Clinic to repeat the strength tests, body composition measurements, anthropometric measurements, and the VSAQ as described above, and also underwent a maximal VO$_2$ test on a treadmill. Caloric expenditure, due to physical activity, was estimated from the time of surgery to 3 mo post-surgery. All statistical analyses including multiple linear regression models, paired t-tests, Wilcoxon Signed-Rank tests, and Spearman-Rho analyses were run with JMP, a product of the Statistical Analysis System (SAS) Cary, NC.

RESULTS

Subjects. There was very little difference between the descriptive data of the patients that participated in this study and to the 904 CABG patients that had surgery during the same time frame, but did not participate in this study. Patients in this study did have more MI’s 21 days before surgery (27%), where as the larger population had MI’s closer to surgery (24% within seven days of surgery). Physical, clinical and fitness related data for all subjects who completed the 3 mo VO$_2$pk treadmill test (N=64) are presented in Table 1. A paired t-test analysis was conducted comparing the pre-surgical subjects that entered the study (N= 153) and the subjects who completed the VO$_2$pk treadmill test (N = 64). Subjects who completed the 3 mo evaluation had significantly greater elbow flexion strength (p<0.0003), knee extension strength (p<0.0001), and a higher VSAQ score at the time of surgery (p<0.0016) compared to the subjects who did not return for the 3 mo VO$_2$pk treadmill test.

Changes in physical fitness. Many of the physical fitness means including knee extension, BMI and sum of three skinfolds did not change between pre-surgery and 3 mo post-surgery. However, significant increases in grip strength (p<0.028), elbow flexion strength (p<0.005), and the VSAQ score at the time of surgery (p<0.000) compared to 3 mo after surgery.

Prediction of Outcome. Backwards step-wise multiple linear regression, with the alpha to enter and leave the model established at 0.15, was utilized to develop a
prediction equation for post-surgical VO₂pk. This alpha level, 0.15, was established because it is considered a moderately liberal but standard alpha when measuring regression equations. When the analysis was completed using only the physical fitness measures, results indicated that grip strength calculated in relation to the subject’s weight and the Veterans Specific Activity Questionnaire (VSAQ) score prior to the reduction of activity that lead to the bypass surgery were significant predictors of post-surgical VO₂pk. This analysis was conducted when VO₂pk was defined as the end point for all treadmill tests (R² = 0.26, N = 55). In a second analysis, a technically more rigorous threshold of acceptance was established for a valid VO₂pk treadmill test by including only those cases in which RER exceeded 1.1 at peak exercise. This analysis yielded a regression equation in which grip strength calculated in relation to the subjects weight, VSAQ score at the time prior to the reduction of activity that lead to the bypass surgery, and the VSAQ score measured at pre-surgery were significant predictors (R² = 0.36, N = 25). When pre-surgical health and clinical status data along with the physical fitness measures were considered within the pool of potential predictors, the multiple linear regression analysis yielded a model that included orthopedic limitations, ACE inhibitor drugs, platelet inhibitor drugs, and the VSAQ at the time of surgery. This set explained 50% of the variance in the 3 mo VO₂pk outcome (R² = 0.50, N = 60), with the probability to be in the model of 0.05. As seen in Figure 1, when a technically more rigorous threshold of acceptance was established for a valid VO₂pk treadmill test by including only those cases in which RER exceeded 1.1 at peak exercise the significant predictor variables from the physical fitness and health and clinical status variables include myocardial infarction (MI) and if so, the length of time lapse from the MI, chronic heart failure, ACE inhibitor drugs, body mass index, lipid lowering drugs, and orthopedic limitations (R² = 0.56, N = 29). The best results in predicting functional capacity outcome of CABG are obtained when maximal VO₂pk with an RER of 1.1 is achieved (Table 3).

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Insert Figure 1 about here
DISCUSSION

The demographics of the population of patients that underwent CABG at Carolinas Medical Center and the patients that participated in this study were very similar. Forty-nine percent of all patients undergoing CABG (N = 1104) had an MI prior to CABG, 50% of the patients involved in this study (N = 200) had an MI prior to CABG, and 43% of the patients that returned for the 3 mo VO$_2$pk treadmill test (N = 64) had an MI prior to surgery. More patients in the overall study (N =200) where diagnosed with diabetes mellitus, COPD and slightly more CHF than patients in the large group of surgical patients at Sanger Clinic all who underwent CABG between November 1996 to the end of collection which was December 1997. In this study, physical fitness measures were found to be somewhat useful in determining CABG outcome. However physical fitness measures in combination with health and clinical status variables were more effective in determining CABG outcomes. Due to the large pool of potential predictors available in the stepwise procedure, including the health and clinical status variables, it was considered prudent to generate the multivariate regression models using a more restrictive alpha of 0.05 for admitting or excluding variables. By decreasing the alpha to 0.05, the number of outcome variables were easier to manage, six outcome variables was significant predictors in the model compared to 12 outcome variables when the alpha was established at 0.15. But by decreasing the alpha, the amount of variability ($R^2$) that explained the model decreased from $R^2 = 0.815$ to $R^2 = 0.43$. In addition to varying the alpha in order to better understand and clinically implement the results, the VO$_2$pk outcome was measured in two ways: a) with all treadmill tests, b) with all tests that achieved an RER of 1.1. Although there is no way pre-surgically to determine if subjects will achieve an RER of 1.1 while undergoing a three month post-surgery VO$_2$pk treadmill test, when this standard was applied, the multiple linear regression results in a better prediction model. Of the 64 patients involved in the study, only 29 were able to
achieve an RER of 1.1 during their maximal VO$_2$ treadmill test. Many of the multiple linear regression models were analyzed with fewer subjects because some of the subjects did not complete all of the tests over the course of the study. For example, the elbow flexion test was not administered to some subjects who had an interior venous lead in their right arm when the measurements were taken. Missing data of one or two variables occurred in approximately 5-10% of the patient pool.

All of the predictors that each model established were analyzed with backward multiple linear regression. After the significant predictors were identified from the model that contained all of the predictors, the predictors were once again analyzed in the same manner as predictors set in and of themselves. Because all data were not able to be collected, the second analysis, which contained only the significant variables, caused some of the probability for significance for individual variables to increase above the set probability for significance (p<0.05). In reviewing the raw data, the increase in probability is because most of the missing data were located in the variables that did not appear in the sub-set model.

Presently, there is no literature comparing pre-surgical physical fitness measures to post-surgical VO$_2$pk. A study by Higgins involved 5,051 CABG patients at the Cleveland Clinic Foundation$^7$. This study used pre-surgical severity of illness variables on order to investigate potential relationships between these variables and post-surgical morbidity and mortality outcomes. Similar to Higgins’ findings, we found that a clinical scoring system is useful for preoperative estimates of postoperative outcomes. Although the exact same variables were not examined, and Higgins did not incorporate any physical fitness measures, and we did not include as many health and clinical variables, both Higgins and this study found that age and PVD were significant in determining the outcomes of surgery. Overall Higgins and our study pinpointed similar health and clinical status predictors.

Similar to the Higgins study, research by Tu$^{12}$ attempted to develop a cardiac surgery risk index. Tu$^{12}$ attempted to risk stratify 6,213 CABG patients
who were undergoing either valve replacement procedures or a combination of CABG and valve procedures. The risk stratification variables used in this model included age, sex, left ventricular function, whether they were or were not undergoing a repeat surgical procedure, urgency of surgery, and type of surgery being conducted. Once again, this study did not incorporate physical fitness measures. From the index that Tu\textsuperscript{12} devised, age, once again was a significant variable in determining the outcome of CABG surgery.

When physical fitness measures were used to predict the VO\textsubscript{2pk} outcome in this study at 3 mo, it is interesting to note that the upper body measures of grip strength and elbow flexion strength, when both were adjusted for body weight, effectively improved the prediction model. However, knee extension strength did not improve the model, whatsoever. In pilot work completed with a subset of 22 patients from this study, an effort was made to validate these static elbow flexion and knee extension tests against patient performances on dynamic strength tests, using isokinetic machines and involving comparable exercises for the arm and leg. The results of that pilot work strongly suggested that the static elbow flexion test valid ($R^2 = 0.8$), but the static knee flexion test was not ($R^2 = 0.28$) Thus, the results from this study of upper body strength improving after CABG would be in accordance with the studies that have already been conducted. The VSAQ, which is a questionnaire of the self-perception of physical activity, prior to the reduction of physical activity that led to CABG was the most consistent variable used when determining post-surgical maximal VO\textsubscript{2}. Prior to testing any of the prediction models, the VSAQ data were analyzed by using the age corrected VSAQ and the raw VSAQ, without any consideration of age. Better results were achieved by not using the age correction regression analysis. The original regression analysis that determined the age factor model was specific to a certain population.\textsuperscript{18} The non-corrected VSAQ score is most likely a better predictor variable because of the varied population used in this study. The VSAQ at the time of pre-surgery, calculated without the age factor analysis, was found to be a significant variable in the maximal VO\textsubscript{2} outcome when the maximal VO\textsubscript{2} of RER of 1.1 or more is taken
The VSAQ has been established by Myers et al\textsuperscript{6} as a valid indicator of cardiorespiratory exercise capacity, there were some problematic issues affecting its application in our study sample. A Spearman-Rho analysis was conducted between the 3 mo VSAQ and the maximal VO\textsubscript{2} treadmill test. The results of this analysis indicated a R\textsuperscript{2} = 0.62 (p<0.001). The results from this study varied from Myers’ results.\textsuperscript{6} According to Myers et al, an R\textsuperscript{2} = 0.82 was achieved when an age correction factor was included. The Myers’ study was conducted with 212 patients that had various cardiovascular diagnosis and treatments. Because the current study had a specific population, a new correction factor was developed, but only resulted to be significantly lower. This variance may be the result of not finding an appropriate age correction factor.

Although not included as part of the multiple linear regression analysis, the subjects were questioned about their physical activity between the time of their surgery and the date that they returned to the clinic for testing for their 3 mo post-surgical follow-up. Of the 64 subjects, 52 reported participating in some form of activity. Of these 52, 50 reported that walking was their mode of activity. One subject reported using a cycle ergometer and another subject reported using the Nordic Track. The subjects were questioned about their daily duration and frequency of activity. Assuming that walking constituted a MET level of 3.3, the approximate calorie expenditure for week, derived from the patients METs and weight, was 680 Kcal per week for reported physical activity. According to the recommendations established by the Center for Disease Control\textsuperscript{19}, expending 1,200 Kcal due to physical activity is recommended per week. The subjects in this study were slightly above the recommended amount of calorie expenditure per week. Future research in this area may help to determine the affects, if any that the post-surgical exercise has on CABG patients. Researchers may want to adjust the fitness measures of grip strength, elbow flexion strength and knee extension strength to non-isometric measures in order to measure the strength of these limbs.
through their full range of motion. Also, non-isometric measures may better take into account the subject orthopedic limitations. Future investigations may wish to investigate post-surgical VO$_2$ measures at a submaximal level as well as using cycle ergometer instead of a treadmill while conducting the maximal VO$_2$ test. These changes in protocol may result in a better prediction variable for the overall population. Isometric strength measure of grip, elbow flexion and knee extension although feasible because of financial limitations and mobility, may have limited the findings because these tools can only measure the patients’ strength at one point. Researchers wish to study the subject’s strength through full range of motion. Also a similar study could be conducted in which the submaximal VO$_2$ measures are measured. A submaximal standard could take into account all test instead of having a question about the test being considered and peak effort. Ventilatory threshold maybe an interesting variable to examine during further research with functional capacity. To explore further the results of subject’s functional capacity, regression equations also were computed using the ventilatory threshold as the criterion measure of functional capacity. These equations yielded similar outcome variables including prior VSAQ, MI when and cardiovascular drugs to be good predictors of CABG outcome, but the reported $R^2 = 0.39$. As indicated in this study, ventilatory threshold may produce better results of functional capacity outcomes when the overall CABG population is considered.
References


Table and Figure Captions

Table 1: Clinical characteristics of study patients prior to CABG surgery

Table 2: Changes in physical fitness: Pre-surgical and 3 mo post-surgery

Table 3: Pre-surgical physical fitness measures and health and clinical status variables as predictor variables for VO\textsubscript{2pk} when RER is 1.1 or more is achieved (alpha 0.05)

Table 4: Pre-surgical physical fitness measures and health and clinical status variables as predictor variables for functional capacity when defined by ventilatory threshold.

Figure 1: Predicted VO\textsubscript{2pk} plotted against actual VO\textsubscript{2pk} when physical fitness measures and health and clinical status data were considered and RER of 1.1 was achieved
Table 1:
Clinical characteristics of pre-surgical Patients

<table>
<thead>
<tr>
<th></th>
<th>Total</th>
<th>Males</th>
<th>Females</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>64</td>
<td>54</td>
<td>9</td>
</tr>
<tr>
<td>Age, years</td>
<td>61.4(7.0)</td>
<td>61.1(7.6)</td>
<td>63.3(3.0)</td>
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<tr>
<td>Height, cm</td>
<td>174.2(6.1)</td>
<td>177.5(5.8)</td>
<td>153.9(6.35)</td>
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<tr>
<td>Weight, kg</td>
<td>86.95(16.2)</td>
<td>89.6(16.4)</td>
<td>70.8(14.9)</td>
</tr>
<tr>
<td>BMI, kg/m²</td>
<td>28.62(5.0)</td>
<td>28.1(4.8)</td>
<td>29.6(6.9)</td>
</tr>
<tr>
<td>Ejection Fraction, %</td>
<td>45.5(9.3)</td>
<td>46.0(10.3)</td>
<td>44.4(14.0)</td>
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</table>
Table 2:
Changes in Physical Fitness: Pre-surgery and 3 mo post-surgery (SEM?)

<table>
<thead>
<tr>
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<th>Pre-surgical</th>
<th>Post-surgical</th>
<th>Percent</th>
<th>Statistic</th>
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<tr>
<td></td>
<td>Total</td>
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<td>Female</td>
<td>Total</td>
</tr>
<tr>
<td>Grip Strength, kg</td>
<td>38.2</td>
<td>40.9</td>
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<tr>
<td>Elbow Flexion, kg</td>
<td>28.6</td>
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<td>15.8</td>
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<td>Knee Extension, kg</td>
<td>25.1</td>
<td>26.2</td>
<td>17.1</td>
<td>26.4</td>
</tr>
<tr>
<td>VSAQ at surgery*</td>
<td>5.2</td>
<td>5.4</td>
<td>4.0</td>
<td>7.52</td>
</tr>
<tr>
<td>Prior VSAQ**</td>
<td>7.4</td>
<td>28.1</td>
<td>29.6</td>
<td>7.52</td>
</tr>
<tr>
<td>Skinfold fat index&lt;sup&gt;d&lt;/sup&gt;</td>
<td>66.9</td>
<td>7.6</td>
<td>6.2</td>
<td>63.7</td>
</tr>
<tr>
<td>BMI, (kg/m²)</td>
<td>28.6</td>
<td>30.00</td>
<td>91.6</td>
<td>30.0</td>
</tr>
</tbody>
</table>

*VSAQ at surgery = The measure taken at the time just prior to surgery
** Prior VSAQ = the measure taken prior to an acute decrease in activity which lead to CABG
* Paired data t-test: Statistic = t-ratio
** Wilcoxon Signed-Rank Analysis: Statistic = W-Statistic
<sup>a</sup> p<0.05
<sup>b</sup> p<0.01
<sup>c</sup> p<0.001
<sup>d</sup> Skinfold index = sum of chest, abdomen, thigh (males) and sum of suprailium, abdomen, thigh (females)
### Table 3:
**Multiple Linear Regression: Pre-surgical physical fitness measures along with health and clinical status variables as predictor variables for functional capacity when RER of 1.1 or greater is achieved**

N = 29

<table>
<thead>
<tr>
<th>Variable</th>
<th>Estimates</th>
<th>Ratio</th>
<th>P</th>
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</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>6.802</td>
<td>1.56</td>
<td>&lt;0.135</td>
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<tr>
<td>MI When</td>
<td>-0.851</td>
<td>-1.74</td>
<td>&lt;0.09</td>
</tr>
<tr>
<td>CHF</td>
<td>3.908</td>
<td>2.19</td>
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</tr>
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<td>BMI</td>
<td>0.216</td>
<td>0.13</td>
<td>&lt;0.1</td>
</tr>
<tr>
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<td>0.66345</td>
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<td>&lt;0.3</td>
</tr>
<tr>
<td>ACE Inhibitor Drugs</td>
<td>1.42</td>
<td>1.82</td>
<td>&lt;0.08</td>
</tr>
<tr>
<td>Orthopedic Limitations</td>
<td>4.56</td>
<td>3.66</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Analysis of Variance: <0.003  
**R**² = 0.56  
**R**² Adjusted = 0.44

Regression Equation:

\[ \text{VO}_2 \text{ pk} = 6.802 - 0.851 \text{(MI When)} + 3.908 \text{(CHF)} + 0.216 \text{(BMI)} + 0.66 \text{(Lipid Lowering Drugs)} + 1.42 \text{(ACE Inhibitor Drugs)} + 4.56 \text{(Orthopedic Limitations)} \]

* * This model is obtained with step-wise linear regression when the probability to enter and leave the model is established at 0.05
Table 4:
Multiple Linear Regression: Pre-surgical physical fitness measures along with health and clinical status variables as predictor variables for functional capacity when defined by ventilatory threshold

N = 55

<table>
<thead>
<tr>
<th>Variable</th>
<th>Estimate</th>
<th>Ratio</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>8.21</td>
<td>4.76</td>
<td>&lt;0.0001</td>
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<td>Prior VSAQ</td>
<td>0.36</td>
<td>1.65</td>
<td>&lt;0.11</td>
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<td>Lipid lowering drugs</td>
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<td>&lt;0.22</td>
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<td>Anti-coagulants</td>
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<td>-0.85</td>
<td>&lt;0.40</td>
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<tr>
<td>Potassium</td>
<td>1.88</td>
<td>1.82</td>
<td>&lt;0.08</td>
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<tr>
<td>PVD</td>
<td>2.06</td>
<td>3.28</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>MI when</td>
<td>-0.67</td>
<td>-2.33</td>
<td>&lt;0.24</td>
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</table>

Analysis of Variance <0.0004
R² = 0.39
R² Adjusted = 0.31

Regression Equation
VT = 8.21 + 0.36 (Prior VSAQ) + 0.48 (Lipid lowering drugs) - 0.59 (Anti-coagulants) + 1.88 (Potassium) + 2.06 (PVD) - 0.67 (MI when)
Predicted VO₂pk plotted against actual VO₂pk when physical fitness measures and health and clinical measures were considered and RER of 1.1 was achieved (alpha: 0.05)

Figure 1:
CHAPTER IV

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS
CHAPTER IV

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

SUMMARY

There has been a lack of research previously conducted that has looked at pre-surgical measurements of physical fitness as tools to predict CABG outcomes. The present study investigated the question, “Can physical fitness measures predict post-surgical functional capacity?” Stepwise multiple linear regression models were conducted when clinical health status was and was not considered, these models were conducted with the alpha to enter and leave set at 0.15 in all cases and at 0.05 in the models that included the health and clinical status data. One-way t-tests, and Signed-Rank tests were conducted to determine differences in the physical fitness between pre-surgical data and 3 mo post-surgical data. T-test was also utilized to determine any correlation between all subjects that began the study and of the subjects that returned to be tested at 3 mo. In order to test the relationship between the post-surgical VSAQ and the VO$_2$pk treadmill test, a Spearman Rho analysis was conducted between the post-surgical, VSAQ and the VO$_2$pk treadmill test. In addition calorie expenditure for physical activity was estimated between the time of surgery to 3 mo post-surgery.

Sixty four patients (mean age = 61.4 yr) all about to undergo bypass surgery were administered physical fitness measures in order to determine muscular strength, body composition, and self-efficacy physical fitness. At 3 mo post-surgery, these subjects repeated the physical fitness measures and participated in a clinically designed ramping treadmill test in order to determine VO$_2$pk.

This study found that when the predictor set was restricted to the pre-surgical fitness measures, and 3 mo treadmill results were included for all patients, grip strength/body weight and the VSAQ score explained only 26 % of the variance in the VO$_2$pk treadmill outcome at 3 mo when the regression model alpha to enter and alpha to leave was set at 0.15. By eliminating all treadmill tests that did not reach the clinical standards of RER of 1.1, the significant predictors in the
regression equation were grip strength, VSAQ score at the time prior to the reduction of activity that lead to the bypass surgery and the VSAQ score measured at pre-surgery when the regression model alpha to enter and alpha to leave was set at 0.15.

When the pre-surgical health and clinical variables were added to the predictor set, the regression analysis, with an alpha to enter and leave set at 0.15, yielded an equation that included elbow strength/weight, history of chronic obstructive pulmonary disease, peripheral vascular disease, duration since MI, VSAQ prior to the reduction of physical activity which led to CABG, age, orthopedic limitations, ACE inhibitor drugs, platelet inhibitor drugs, lipid lowering drugs, and potassium lowering drugs. By including pre-surgical health and clinical variables to the predictor set, the regression analysis, with an alpha to enter and leave set at 0.05, yielded a model that included pre surgical VSAQ, orthopedic limitations, and ACE inhibitor drugs.

Post-surgical physical fitness along with health and clinical status variables of pre-surgical VSAQ, VSAQ prior to the reduction of activity which lead to a CABG, family history, duration since MI, CHF, Anterior Arrhythmia drugs, lipid lowering drugs, and orthopedic limitations were significant in predicting post-surgical VO\textsubscript{2pk} when the clinical standard of RER of 1.1 was taken into account and the alpha to enter and leave the model was 0.15. (R\textsuperscript{2} = 0.87). By duplicating the variables in this model and decreasing the alpha to enter and leave to 0.05, the significant predictors of post-surgical VO\textsubscript{2pk} were CHF, duration since MI, lipid lowering drugs, ACE inhibitor drugs, BMI, and orthopedic limitations.

Changes in physical fitness measures between pre-surgery and 3 mo post-surgery indicates that there were significant increases in grip strength (p<0.03), elbow flexion strength (p<0.005) and the pre-surgical VSAQ (p<0.000) at 3 mo post-surgery. There was a 59% variability in response (p<0.001) between post-surgical VSAQ scores the were not corrected with an age factor and the VO\textsubscript{2pk} treadmill test. A Spearman Rho analysis was conducted between the 3 mo VSAQ and the maximal VO\textsubscript{2} treadmill test. The results of this analysis indicated a R\textsuperscript{2} =
The correlation between all of the subjects that entered the study and the subjects that completed the 3 mo treadmill test showed significant increases in pre-surgical elbow flexion strength (p<0.0003), knee extension strength (p<0.0001), ejection fraction, and pre surgical VSAQ (p<0.0016) for the subjects that completed the three month test. Estimated caloric expenditure for physical activity between surgery and three months post surgery was estimated to be 680 k/cal per week.

CONCLUSIONS

This study concluded that the use of physical fitness measurements of strength and body composition, and of a self perceived activity questionnaire better equip clinicians and patients in decision making prior to CABG surgery. This study also demonstrated that a patient’s functional capacity after bypass surgery maybe predicted by taking these simple pre-surgical physical strength and body composition measures. These measures are effective, non-invasive, inexpensive, take minutes to complete, and are able to be conducted in a physician’s office. The results herein have indicated that physical fitness variables are most effective in determining outcome when they are used along with measurements of health and clinical status variables.

RECOMMENDATIONS

Recommendations for Further Research

Due to the lack of research that has been collected on physical fitness measures as predictors of CABG outcome, there are various areas of future research that are waiting to be examined. An unanswered question in this investigation, that could be examined in future research, was the effect, if any, that physical activity that occurred between the time of surgery and 3 mo post-surgery has on the 3 mo outcome of CABG. In the current study, the activity during this time was measured through subject recall and caloric expenditure was estimated.
from the information gathered. Further research in this area could devise a more systematic approach for data collection and this data could be part of the regression model in determining predictors of CABG outcome. Another project for further research could examine the physical fitness measures of grip strength, elbow flexion and knee extension as a non-isometric variable. By measuring strength throughout the range of motion, the measure may be a better representation of the subject’s ability to perform the activity. This may better take into account subjects that have orthopedic limitations. By using a non-isometric tool of measure, the expense and easy of utilization may become problematic factors, but these questions may be addressed in further research in this area. A follow-up study could measure VO$_2$pk on a cycle ergometer. By including another mode of measure, researchers may better account for orthopedic limitations. Also a similar study could be conducted in which the submaximal VO$_2$ measures are measured. A submaximal standard could take into account all test instead of having a question about the test being considered and peak effort. Ventilatory threshold maybe an interesting variable to examine during further research with functional capacity. As indicated in this study, ventilatory threshold may produce better results of functional capacity outcomes when the overall CABG population is considered. The overall suggestion for further research is to use the predictor variables already established in this study as well as the variables mentioned above in a study that would last one yr. By lengthening of the study and by taking measurements of functional capacity at intervals throughout the duration of the study, results can better establish the best predictors of functional capacity.

**Recommendations for Clinical Practice**

From the results of this study, it is recommended for physician and patients to utilize physical fitness measures, in addition to health and clinical status data in making the decision to undergo CABG. The VSAQ prior to an acute reduction of activity, pre-surgical VSAQ, grip strength, several cardiovascular drugs and orthopedic limitations all were significant predictors in CABG outcomes. It is
recommended to utilize the regression equations as described earlier in order to make the most accurate prediction. The benefits from the information gathered through these physical fitness measures far outweigh the cost of these measurements.
References


Older MB, Smith R, Courtney P, Hone R. Preoperative evaluation of cardiac
failure and ischemia in elderly patients by cardiopulmonary exercise testing. *Chest* 1993; 104:701-704.


Peterson ED, Cowper PA, Jollis JG, Bebchuk JD, Delong ER, Muhlbaiер LH, Mark DB, Pryor DB. Outcomes of coronary artery bypass graft surgery in 461 patients aged 80 years or older. *Circulation* 1995; 92 [Suppl II]:II-85-II-91


APPENDIX A

DETAILED METHODOLOGY AND DATA ANALYSIS
APPENDIX A
METHODOLOGY

Subject Screening and Selection

This research was an observational study of patients undergoing a CABG. Forty-seven males and eighteen females between 50 and 86 years-of-age from the Carolinas Medical Center, Charlotte, North Carolina served as subjects in this study. Within 48 hours prior to bypass surgery, patients who were undergoing pre-surgical evaluations at the Carolinas Medical Center and patients that had already been admitted to the hospital were approached by the test technicians and asked to be involved in this study.

In order to qualify for this study, patients had to be first time CABG patients and at least 50 years old. Patients did not qualify to participate in the study if they were undergoing any other cardiovascular surgical procedure other than bypass, or if they had been diagnosed with cerebrovascular, orthopedic, neuralgic, or cognitive-emotive disorders that would preclude the completion of each test. Also, patients did not qualify for the study if they were diagnosed with two or more of the following morbidities: cancer, PVD, SVD, CHF, chronic renal failure, MI within five days of pre-surgical testing, and an EF less than 35%. Also, patients were not included in the study if they were unwilling to return to the Carolinas Medical Center for follow-up testing 3 mo after surgery. Patients who did qualify for the study were given general information about the study. They were told that testing would be conducted pre-surgically and again post-surgically, that the pre-surgical testing consisted of physical fitness tests, body composition measures, selected anthropometric measures, and a physical activity questionnaire, and that the testing would be repeated three months after surgery along with a maximal treadmill test. The general objectives of the study were also discussed with the subjects. These objectives were to provide tools to predict the success of CABG and to determine if the use of these tools would better equip clinicians and
patients in the decision making process prior to CABG. The risk and benefits of participation, including the risk of a maximal treadmill test and the benefits of a maximal treadmill test, a physical fitness test battery, and body composition measures were also discussed. All participants in the study signed an informed consent (APPENDIX C) acknowledging their voluntary participation in the study. The experimental procedures utilized in this study were reviewed and approved by both the Human Subjects’ Committee of Virginia Polytechnic Institute and State University and the Carolinas Medical Center.

**GENERAL METHOD**

*Pre-surgical Measurements*

Once the subjects had agreed to be a part of the study, they were given the pre-surgical battery of tests to measure their strength, body composition and their self-reported physical activity level (VSAQ). After the tests were completed, the subjects were reminded of their post-surgery commitment at which time strength, body composition and their self reported physical activity level (VSAQ) were again measured, and the maximal treadmill test was administered.

The strength measurements included grip strength, elbow flexion and knee extension. Grip strength was administered with a handheld grip dynamometer. The subjects held the dynamometer in their right hand and were advised to squeeze the dynamometer as forcefully as they could. Males were assessed with grip position (position three) than the females (position two). Strength measures were repeated twice unless there was a large difference between trials one and two in which case, a third trial was administered. The highest score of the trials was recorded.

The maximal isometric static strength tests for elbow flexion and knee extension were assessed with an isometric strength dynamometer. To measure elbow flexion strength, subjects were directed to place their forearm in the horizontal position with the palm up and the elbow joint angle at 110 degrees. Once the forearm was in position, the test technician positioned the dynamometer
at the midpoint of the forearm. The test was then executed by the subjects contracting their elbow flexors.

Knee extension strength was measured by having the subjects sit at the edge of a bed with their knee bent to a 90-degree angle. The test technician then positioned the dynamometer at the midpoint of the subject’s right lower limb. The subjects were asked to extend their leg as forcefully as they could. Subjects were advised not to hold their breath for the strength measurements. The elbow and knee strength assessments utilized a Chantillon CSV200 Strength Dynamometer; grip strength was measured with a Baseline Hydraulic Hand Dynamometer, Country Technology Inc.

Body composition was assessed by measurements of skinfold. Three standardized sites were measured. Skinfold measurements (+/-1 mm) were taken on the chest, abdomen and thigh for males, and on the triceps, suprailium, and thigh for females. Subjects were asked to stand for these measures. All skinfolds were taken on the subject’s right side with a Harpenden Skinfold Calipers, British Indicators LTD. The chest measurement was taken with a diagonal fold half of the distance between the anterior axillary line and the nipple. The abdominal skinfold was a vertical fold taken at a distance of approximately 2 cm lateral to the umbilicus. The thigh skinfold was a vertical fold on the anterior aspect of the thigh midway between hip and knee joints. The triceps skinfold was taken as a vertical fold on the posterior midline of the upper arm, halfway between the acromion and olecranon processes. The suprailium was taken as a diagonal fold above the crest of the ilium at the spot where an imaginary line would come down from the anterior axillary line. Body composition measures were taken and then repeated at least once in order to assure accuracy. For a measure to be accepted, it must have had less than a 5% variation with its repeated measurement. The highest skinfold measurement was the score recorded. Height and weight were also measured and body mass index (BMI) (kg/m$^2$) was calculated from these measurements.

The Veterans Specific Activity Questionnaire (VSAQ) was used to evaluate the patients’ perceptions of their peak exercise tolerance. To complete the
questionnaire, the patient scanned a list of common outdoor, social, recreational, and sports activities, which were paired with estimates of metabolic demand. The patients were then asked to identify the highest level they would be able to perform and maintain without being limited by symptoms such as shortness of breath or pain. Since some of the activities listed on the questionnaire were unfamiliar to certain patients, the technician was prepared to provide patients with equivalent examples more familiar to the patients. (Ainsworth, 1993). The VSAQ scores recorded were the pre-surgery VSAQ, what patients would be able to accomplish that day, and the VSAQ prior to any reduced activity due to health decline that precipitated their CABG surgery decision.

In addition to the previously described tests and questionnaire, medical data, including clinical, descriptive, demographic and health status data, were collected from the STS database by Sanger Clinic nurses and physicians. These data included: age, height, weight, BMI, ejection fraction, family history, gender, presence of hypercholesterolemia, current medications, incidence of MI, orthopedic limitations, smoking history, PVD, COPD, presence of diabetes mellitus, CHF, and cardiomegaly.

Post-Surgical Testing

Three months following bypass surgery, subjects returned to the Sanger Clinic to repeat the strength, body composition, and anthropometric testing, and repeat the VSAQ. In addition the subjects underwent a maximal VO₂ test on a treadmill.

Treadmill Instrumentation and Protocol

The Vmax 29c CardioPulmonary Exercise Module, manufactured by the SensorMedics Corporation, Yorba Linda, California, was used to measure the maximal VO₂. The test technician immediately prior to administration of the treadmill test calibrated this instrument. The Vmax 29 was able to give a breath by breath gas analysis. A head apparatus was fitted for each subject and a mouthpiece
and pneumotech was assembled to fit for each subject. The mouthpiece was placed in the subject’s mouth and a nose clip was used to block off the nasal passage. A Quinton 5000 treadmill was utilized for the maximal test.

The subject was instructed to breathe as normal as possible through the pneumotech. Breath analysis measures were checked to confirm that the subject was in the normal range before commencing the test. VO\textsubscript{2}pk was calculated as an average breath by breath oxygen consumption over the last 30 seconds of the test. The protocol for the treadmill test was to have the subjects walk at a comfortable treadmill speed, between 1.5 to 4 mphs with a 0% grade. This speed remained constant throughout the test while the grade increased 1/2 of 1% every 30 seconds. The test continued until the patient asked to terminate the test or until the physician assistant determined to terminate the test due to the patient’s negative response to exercise.

**Heart Rate and Blood Pressure**

During each maximal treadmill test, heart rate was recorded electrocardiographically. A standard 12-lead clinical ECG system was employed and provided the basis of clinical monitoring by the physician’s assistant. ECG recordings were printed out every two minutes and when the physician assistant asked for a recording. Blood pressure was taken manually before, during and after the treadmill test. Prior to the treadmill test, blood pressure was taken in supine and standing positions. During the test, blood pressure was taken every two minutes throughout exercise. Following the test, blood pressure was taken every two minutes for a maximum of eight minutes with the patients in a supine position.

**Perceived Exertion**

Rate of perceived exertion (RPE) was measured every two minutes during the test. The RPE scale was shown and explained to the subjects prior to starting the test. As seen in Appendix F, this scale ranges between “very,
“very, very hard.”

Similarly, Appendix G contains the dyspnea scale that was also shown and explained to the subjects. This scale was used to help determined the subjects’ shortness of breath. The scale ranged from “1-4”, one being “mild, no sign”, to 4 being, “severe difficulty.” It was used during the treadmill test when deemed necessary by the physician’s assistant.

Finally, Appendix H contains the angina scale which was also shown and explained to the subjects. This scale was used to help determine chest pain. The scale ranged from “1-4”, one being “light”, to four being “severe.” It was used during the treadmill test when deemed necessary by the physician’s assistant.

**Statistical Procedures**

Standard statistical methods were used. All statistical analyses were run with JMP, a product of the Statistical Analysis System (SAS) Cary, NC. Physical and clinical descriptive statistics were run on all pre-surgical variables. These variables included: age in years, height in centimeters, weight in kilograms, body mass index (kg/m^2), ejection fraction measured in percentage, grip strength measured in relation to subjects weight, elbow strength measured in relation to subjects weight, knee extension strength measured in relation to subjects weight, VSAQ at time of surgery, VSAQ prior to the point in time just before the health decline that precipitated the subjects CABG surgery decision, and sum of three skinfold. Skinfold measures are able to determined body density.

Descriptive data were collected on all patients undergoing CABG at Carolinas Medical Center during the time frame the study, data were also collected on all subjects who finished the 3 mo VO_{2pk} treadmill test. A one-way t-test analysis was used to determine significant differences between the subjects that entered the study and the subjects that finished the 3 mo VO_{2pk} treadmill test.

Paired t-test analyses were used to compare the pre-surgical and post-surgical physical and clinical descriptive statistics. These variables included: age in
years, height in pounds, weight in inches, Body Mass index (kg/m$^2$), Ejection Fraction measured in percentage, grip strength measured in relation to subjects weight, elbow measured in relation to subjects weight, knee extension measured in relation to subjects weight, VSAQ at time of surgery, VSAQ prior to the point in time just before the health decline that precipitated the subjects CABG decision, and sum of three skinfold.

In order to test the first hypothesis, step-wise multiple linear regression, with the probability to enter and leave the model established at 0.15 and 0.05, was used to compare the fitness measures which included muscular strength as derived from grip strength (kg/kg body weight), elbow flexion (kg/kg body weight) and knee extension (kg/kg body weight); body composition as derived from BMI (Kg/m$^2$) and sum of three skinfolds; and the Veterans Specific Activity Questionnaire (VSAQ) at time of surgery and at the time prior to the point in time just before the health decline that precipitated the subjects CABG decision to the VO$_2$max which was taken as an average of the breath by breath measures during the last 30 seconds of the maximal treadmill test which was conducted 3 mo post-bypass grafting. The statistical model was constructed and analyzed in two ways. The first model included all subjects that attempted a 3 mo maximal treadmill test. The second model included subjects that met the criteria of an RER of at least 1.1.

The second hypothesis was also tested with the use of stepwise multiple linear regression with the probability to enter and leave the model established at 0.15 and 0.05. In this hypothesis, the fitness measures which included muscular strength, as derived from grip strength (kg/kg body weight), elbow flexion (kg/kg body weight) and knee extension (kg/kg body weight); body composition as derived from BMI (Kg/m$^2$) and sum of three skinfolds; and the Veterans Specific Activity Questionnaire (VSAQ) at time of surgery and at the time prior to the point in time just before the health decline that precipitated the subjects CABG decision. This hypothesis also included confounding variables: ejection fraction, family history, gender, hypercholesteroolemia, medications, MI-when, orthopedic limitations, smoking pack years, PVD, diabetes mellitus, CHF, COPD, CVA,
cardiomegaly, and age. All of the above variables were compared to the peak VO$_2$ which was taken as an average of the breath by breath measures during the last 30 seconds of the maximal treadmill test which was conducted three month post bypass graph. The statistical model was constructed and analyzed in two ways. The first model included all subjects that attempted a 3 mo maximal treadmill test. The second model included subjects that meet the criteria of an RER of at least 1.1.

The mean caloric expenditure for the physical activity that the subjects participated in was calculated for subjects between the time of their surgery and three months later post-surgery. The Spearman-Rho correlation analysis was computed to determine any relationship between the VSAQ that was administered 3 mo post-surgery and the VO$_2$ outcomes from the maximal treadmill test. The level for significance was established at 0.05.
APPENDIX B
**Table 5:**
Multiple Linear Regression: Pre-surgical physical fitness measure as predictor variables for functional capacity*

N = 55

<table>
<thead>
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<th>Variable</th>
<th>Estimates</th>
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<tr>
<td>Intercept</td>
<td>8.59</td>
<td>3.28</td>
<td>&lt;0.002</td>
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<tr>
<td>Grip Strength (kg/kg body weight)</td>
<td>10.91</td>
<td>2.14</td>
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<td>Prior VSAQ</td>
<td>0.867</td>
<td>2.92</td>
<td>&lt;0.005</td>
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</table>

Analysis of Variance  <0.0004

$R^2 = 0.26$

$R^2$ Adjusted = 0.23

Regression Equation

$VO^2_{peak} = 8.59 + 10.91 \times \text{(Grip Strength)} + 0.867 \times \text{(Prior VSAQ)}$

* This model is a step-wise regression with the probability to enter and leave established at 0.15
Table 6:
Multiple Linear Regression: Pre-surgical physical fitness measure as predictor variables for functional capacity when RER of 1.1 or greater is achieved*

N = 25

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<td>Grip Strength (kg/kg body weight)</td>
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<td>Pre-surgery VSAQ</td>
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<td>Prior VSAQ</td>
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<td>3.05</td>
<td>&lt;0.006</td>
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</table>

Analysis of Variance <0.03

$R^2 = 0.356$

$R^2$ Adjusted = 0.264

Regression Equation

$VO^2_{peak} = 7.38 + 17.26 \text{ (Grip Strength)} - 0.1 \text{ (VSAQ)} + 1.22 \text{ (Prior VSAQ)}$

*This model is a step-wise regression with the probability to enter and leave the model established at 0.15
Table 7:
Multiple Linear Regression: Pre-surgical physical fitness measures and health and clinical status variables as outcomes for functional capacity*

N = 63

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<tr>
<td>Intercept</td>
<td>9.25</td>
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<td>&lt;0.0001</td>
</tr>
<tr>
<td>Pre-surgery VSAQ</td>
<td>1.11</td>
<td>0.21</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>ACE Inhibitor drugs</td>
<td>1.35</td>
<td>0.51</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Orthopedic Limitations</td>
<td>2.19</td>
<td>0.63</td>
<td>&lt;0.0009</td>
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</table>

Analysis of Variance <0.0001

$R^2 = 0.50$

$R^2$ Adjusted = 0.48

Regression Equation
$VO_2^p k = 9.25 + 1.11 \text{(Pre-surgery VSAQ)} + 1.35 \text{(ACE Inhibitor Drugs)} + 2.19 \text{(Orthopedic Limitations)}$

* This model is obtained with step-wise regression with the probability to enter and to leave the model established at 0.05
Table 8:
Multiple Linear Regression: Pre-surgical physical fitness measures and health and clinical status variables as outcomes for functional capacity*

<table>
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<th>t-Ratio</th>
<th>P</th>
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<td>Intercept</td>
<td>16.73</td>
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<td>&lt;0.002</td>
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<td>Elbow Strength (kg/kg body weight)</td>
<td>13</td>
<td>3.25</td>
<td>&lt;0.002</td>
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<tr>
<td>COPD</td>
<td>1.56</td>
<td>1.89</td>
<td>&lt;0.002</td>
</tr>
<tr>
<td>PVD</td>
<td>-1.91</td>
<td>-2.03</td>
<td>&lt;0.07</td>
</tr>
<tr>
<td>MI when</td>
<td>-0.89</td>
<td>-2.59</td>
<td>&lt;0.05</td>
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<td>Prior VSAQ</td>
<td>0.82</td>
<td>3.04</td>
<td>&lt;0.01</td>
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<tr>
<td>Age</td>
<td>-0.18</td>
<td>-2.62</td>
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<td>Orthopedic Limitations</td>
<td>3.06</td>
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<tr>
<td>ACE Inhibitors</td>
<td>1.26</td>
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<td>Platelet Inhibitor Drugs</td>
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<td>Lipid Lowering</td>
<td>1.25</td>
<td>2.08</td>
<td>&lt;0.04</td>
</tr>
<tr>
<td>Potassium</td>
<td>2.52</td>
<td>3.71</td>
<td>&lt;0.0006</td>
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</table>

Analysis of Variance
\( R^2 = 0.62 \)
\( R^2 \text{ Adjusted} = 0.52 \)

Regression Equation
\[
VO^{2}\text{pk} = 16.73 + 13 \text{ (elbow strength)} + 1.56 \text{ (COPD)} - 1.91 \\
\text{ (PVD)} - 0.89 \text{ (MI When)} + 0.82 \text{ (pre-surgery VSAQ)} - 0.18 \text{ (Age)} + 3.06 \\
\text{(Orthopedic Limitations)} +1.26 \text{ (ACE Inhibitors)} - 0.9 \text{ (platelet inhibitor drugs)} \\
+ 1.25 \text{ (lipid lowering)} + 2.52 \text{ (Potassium)}
\]

* This model was obtained with step-wise regression with the probability to enter and to leave the model established at 0.15
Table 9:
Multiple Linear Regression: Pre-surgical physical fitness measures along with health and clinical status variables as predictor variables for functional capacity when RER of 1.1 or greater is achieved*

<table>
<thead>
<tr>
<th>Variable</th>
<th>Estimates</th>
<th>Ratio</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>15.27</td>
<td>8.13</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>VSAQ</td>
<td>-0.86</td>
<td>-3.9</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Prior VSAQ</td>
<td>0.44</td>
<td>1.65</td>
<td>&lt;0.12</td>
</tr>
<tr>
<td>Family history</td>
<td>0.8</td>
<td>1.85</td>
<td>&lt;0.082</td>
</tr>
<tr>
<td>MI When</td>
<td>-0.82</td>
<td>-3.01</td>
<td>&lt;0.008</td>
</tr>
<tr>
<td>CHF</td>
<td>4.66</td>
<td>4.79</td>
<td>&lt;0.0002</td>
</tr>
<tr>
<td>Anti-arrhythmic Drugs</td>
<td>-1.933</td>
<td>-3.49</td>
<td>&lt;0.003</td>
</tr>
<tr>
<td>Lipid Lowering drugs</td>
<td>0.879</td>
<td>2.09</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Orthopedic Limitations</td>
<td>4.15</td>
<td>5.07</td>
<td>&lt;0.0001</td>
</tr>
</tbody>
</table>

Analysis of Variance <0.0001
R² = 0.87
R² Adjusted = 0.82

Regression Equation
VO²pk = 15.27 – 0.26 (VSAQ) + 0.44 (Prior VSAQ) + 0.8 (Family history) - 0.82 (MI When) + 4.66 (CHF) - 1.933 (anti-arrhythmic drugs) + 0.879 (lipid lowering drugs) + 4.15 (Orthopedic Limitations)

* This model is obtained with step-wise regression with the probability to enter and leave the model established at 0.15
Table 10:  
**Clinical Characteristics in Research Patients versus Non-Research Patients**

<table>
<thead>
<tr>
<th>Risk Factors</th>
<th>Research Patients in percent (N=55)</th>
<th>Non-Research Patients in percent (N=904)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>82</td>
<td>67</td>
</tr>
<tr>
<td>Female</td>
<td>18</td>
<td>33</td>
</tr>
<tr>
<td>Family History</td>
<td>64</td>
<td>64</td>
</tr>
<tr>
<td>Hypercholesterolemia</td>
<td>65</td>
<td>65</td>
</tr>
<tr>
<td>PVD(^a)</td>
<td>9</td>
<td>17</td>
</tr>
<tr>
<td>Diabetes</td>
<td>35</td>
<td>35</td>
</tr>
<tr>
<td>COPD(^b)</td>
<td>5</td>
<td>15</td>
</tr>
<tr>
<td>Myocardial Infarction</td>
<td>42</td>
<td>49</td>
</tr>
<tr>
<td>Recovery of MI, days(^c)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1-7 days</td>
<td>11</td>
<td>24</td>
</tr>
<tr>
<td>7-21 days</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>&gt;21 days</td>
<td>27</td>
<td>19</td>
</tr>
<tr>
<td>CHF(^d)</td>
<td>5</td>
<td>12</td>
</tr>
<tr>
<td>Smoking History</td>
<td>67</td>
<td>65</td>
</tr>
<tr>
<td>Current Smoker</td>
<td>25</td>
<td>18</td>
</tr>
</tbody>
</table>

\(^a\) PVD - Peripheral Vascular Disease  
\(^b\) COPD - Cardiopulmonary Disease  
\(^c\) The number of days myocardial infarction took place prior to CABG  
\(^d\) CHF - Congestive Heart Failure
Predicted VO$_2$pk plotted against actual VO$_2$pk when physical fitness measures were considered and RER of 1.1 was achieved (alpha: 0.15)

Figure 2:
Predicted VO$_2$pk plotted against actual VO$_2$pk when physical fitness measures and health and clinical measures were considered (alpha: 0.15)

Figure 3:
Predicted VO$_2$pk plotted against actual VO$_2$pk when physical fitness measures and health and clinical measures were considered (alpha: 0.05)

Figure 4
APPENDIX C
Consent to Participate in Research Study
Clinical, Physical, and Quality of Life Variables in Patients after Coronary Artery Bypass Graft Surgery—Part I

Introduction
You are being asked to participate in a research study to be conducted by Joseph Cook, M.D. at the Carolinas Heart Institute (CHI). The purpose of this study is to determine if physical, psychological, and nutritional status are important factors in determining how well patients do after coronary artery bypass surgery. This will involve completing questionnaires and having approximately 200 people involved in this research at CHI, and your participation will last for approximately 1 year.

Procedure
Two types of test will be used. Some will involve answering questions about yourself and will include evaluation of how you feel about your ability to tolerate activities involving exercise, your ability to perform self care, and daily living activities at home, your feeling of well being, your health, your quality of life, and your diet. Other non-invasive tests will include determining your body composition by measuring the thickness of a skin fold, grip strength by squeezing a hand-held device, and upper body strength by pushing against or pulling on a small machine with your hands.

These tests will be done at the time of your surgery and/or at 3 and 12 months after surgery. Also at three months after you surgery and again at 12 months, you will be tested to maximum effort in a treadmill, and your ECG, heart rate and blood pressure will be evaluated by a physician. In addition, at surgery and at 12 months, you will receive a non-invasive, low-energy x-ray scan (DEXA) to determine the percentage of your body that is fat or muscle and to determine the quality of your bones.
Risks
None of the tests should cause any foreseeable risk or discomfort. The strength tests are of low intensity and the treadmill test will be the same maximal effort evaluation you took before your surgery. These tests will be closely monitored during their administration. The amount of x-ray exposure from the DEXA scan will be very low.

Exclusion Criteria
You should not participate in this study if:

You have any circulatory, joint, nerve, or emotional disorders that would not allow completion of the items being tested.

You are taller than 6’ or weight more than 220lbs.

Benefits
There may be no direct benefit to you for participating in this study, but the information gained may benefit others with your condition. Being able to better predict who will benefit most from coronary artery bypass surgery would result in better treatment and rehabilitation planning for future patients. At the conclusion of participation in the study, your results will be forwarded to your personal physician and may be used in planning your future health care.

Additional Cost
There will be no additional cost to you for participating in this study.

Compensation
In the event that physical injury occurs as a result of this research project, medical treatment will be available. This treatment, as well as other medical care expenses, will be your responsibility or, may, in some instances, be paid for you by your health insurance. No compensation or reimbursement will be available from the
Withdrawal
Participation in this study is voluntary. You may refuse to participate or you may withdraw from the study at any time. This will result in no penalty or loss of benefits to which you are otherwise entitled. You will be notified of significant new findings that may affect your treatment or your willingness to continue in the study.

Confidentiality
The record or your visits will be in your medical record and is accordingly confidential. Other study records will be maintained by the investigator in a likewise confidential manner. Records pertaining to the study may be examined and/or copied by Joseph Cook, M.D. This research may result in scientific presentations and publications, but precautions will be taken to make sure that you are not identified by name.

Financial Interest of the Investigator
As the principal investigator, I (Joseph Cook, M.D.), as well as the co-investigators (John Fedor, M.D., Parks Griffith, M.A., William Herbert, PhD., Warren Ramp, PhD., Gary Kiebzak, PhD., or James Norton, PhD), will not receive compensation for your involvement in this study.

Questions

For more information concerning the research and research-related risks or injuries, you may contact the principal investigator, Dr. Joseph Cook at (704) 373-1500. In addition, you may contact the chairman of the Institutional Review
Board of the Carolina HealthCare System for information regarding patient rights in a research study. You can obtain the name and number of this person by calling (704) 355-3158.

**Consent**

I hereby give my consent to participate in this study. I have read all of the above or have heard it read to me. I have had the opportunity to ask questions about this study, and my questions have been answered. A copy of this consent form has been provided to me.

| ______________________________ | ___________ |
| Patients printed name | |
| ______________________________ | ___________ |
| Patients/Guardian Signature | Date |
| ______________________________ | ___________ |
| Witness Signature | Date |
| ______________________________ | ___________ |
| Investigators Signature | Date |
The Veterans Specific Activity Questionnaire

Draw a line below the activities you are able to do routinely with minimal or no symptoms, such as shortness of breath, chest discomfort, fatigue

**METs**

1. Eating, getting dressed, working at a desk.
2. Taking a shower.
   Walking down eight steps.
3. Walking slowly on a flat surface for one or two blocks.
   A moderate amount of work around the house, like vacuuming, sweeping the floors or carrying groceries.
4. Light yard work, i.e., raking leaves, weeding or pushing a power mower.
   Painting or light carpentry.
5. Walking briskly, i.e., four miles in one hour.
   Social dancing, washing the car.
6. Play nine holes of golf carrying your own clubs. Heavy carpentry, mow lawn with push mower.
7. Perform heavy outdoor work, i.e., digging, spading soil, etc.
   Play tennis (singles), carry 60 pounds.
8. Jog slowly, climb stairs quickly, carry 20 pounds upstairs.
10. Brisk swimming, bicycle up a hill, walking briskly up a hill, jog six miles per hour.
11. Cross country ski.
    Play basketball (full court).
12. Any competitive activity, including those which involve intermittent sprinting.
    Running competitively, rowing, backpacking.
13. Running briskly, continuously (level ground, eight minutes per mile).
APPENDIX E
Rate of Perceived Exertion (RPE)

15 Point Scale

6
7
8
9
10
11
12
13
14
15
16
17
18
19
20

VERY,VERY LIGHT

VERY LIGHT

FAIRLY LIGHT

SOMEWHA AT HARD

HARD

VERY HARD

VERY, VERY HARD
APPENDIX F
ANGINA

+1     LIGHT
+2     MODERATE
+3     SEVERE
+4     MOST SEVERE EVER
DYSPNEA

+1  MILD NO SIGNS
+2  MILD WITH SIGNS
+3  MODERATE DIFFICULTY
+4  SEVERE DIFFICULTY
APPENDIX H
The following is a reference to help identify and quantify the analysis of the variables located in the raw data. When appropriate, definitions have been included to explain how the data was quantified for analysis.

ID: Identification number

VO$_2$pk: Maximal oxygen intake (ml/kg)

RER: Respiratory equivalence ratio:

The Veterans specific activity questionnaire:
- VSAQ: Taken at the time of surgery
- PrCVSAQ: Taken at the time prior to a reduction of activity
- 3VSAQ: Taken at three months post-surgery

GRIP: Pre-surgical grip strength (kg)

3GRIP: Post-surgical grip strength (kg)

ELBOW: Pre-surgical elbow flexion strength (kg)

3ELBOW: Post-surgical elbow flexion strength (kg)

KNEE: Pre-surgical knee extension strength (kg)

3KNEE: Post-surgical knee extension strength (kg)

HT: Height (inches)

WT: Weight (pounds)

BMI: Pre-surgical Body Mass Index (kg/m$^2$)

3BMI: Post-surgical Body Mass Index (kg/m$^2$)

M/F: Gender

SUM: Pre-surgical sum of three sites (mm)

2SUM: Post-surgical sum of three sites (mm)

This measure is the sum of the chest, abdominal and thigh for males and the sum of the triceps, suprailium and thigh for females.

Medications: Subjects received a “1” for any drug that fit into the category and a “0” if they did not take any of these medications.

BB: Beta-blockers drugs
CA: Calcium channel blockers drugs
AB: Alpha blockers drugs
DIG: Digitalis
DIU: Diuretic drugs
ACE: ACE inhibitors
AN-A: Anti-arrhythmia drugs
PI: Platelet inhibitor drugs
LL: Lipid lowering drugs
AC: Anti-coagulant
EST: Estrogen
GLU: Glucose
K: Potassium

SMKR: Smoker
Any past or current smoking habits as an estimate of the number packs the patient had smoked per year.

FHX: Family History
Patients with family history were scored “1” and “0” if they had not been diagnosed with family history.

DM: Diabetes Mellitus
Patients with diabetes were scored “1” and “0” if they had not been diagnosed with diabetes mellitus.

HCL: Hypercholesterolemia
Patients were scored a “1” score if his/her total serum cholesterol level greater than 200 mg/dl. Patients were scored as a “0” if their cholesterol level are in the normal range.

CVA: Cerebrovascular Accident
Patients with such an accident were scored “1” or “0” if not,

CARD: Cardiomegaly
This variable was scored “1” if the enlargement was present and “0” if not.

COPD: Chronic Obstructive Pulmonary Disease
Patients with this disease were scored “1” or “0” if they had not been diagnosed with COPD.

PVD: Peripheral Vascular Disease
Abnormalities of the arteries and veins located in the extremities. Patients with this disease were be scored “1”; if the disease was not present a score of “0” was recorded.
MI: Myocardial Infarction
A “1” is given to patients that have had a MI more than 21 days before surgery. A “2” is given to patients that have had a MI between 15 to 21 days prior to surgery. A “3” was given to patients that had an MI between 7 and 14 days prior to surgery. A “3” is given to patients that have had a MI less than 7 days prior to surgery. A “0” was given to patients that have not had a MI.

CHF: Congestive Heart Failure
Patients with this failure were be scored “1” or “0” if they had not been diagnosed with CHF.

EF: Ejection Fraction

OL: Orthopedic Limitations
Patients that reported any orthopedic limitations were be scored “1” or “0” if they did not report any.

The following measurements were taken between the time of surgery and three months post surgery:
FREQ: Frequency- the frequency (times/week) in which the subjects participated in physical activity
DUR: Duration- the duration (minutes/session) in which the subjects participated in physical activity

VT: Ventilatory threshold
VITA

Amy Ann Strickler was born July 3, 1974 in Fairfax, Virginia. In elementary school, Amy participated in several sporting activities including gymnastics and softball. In high school, Amy spent much of her time as a Cheerleader and running track. Amy’s love for exercise physiology started in high school with the help of her Cheerleading coach. High school also started her interest in Cardiac Rehabilitation. Amy began to volunteer at a local nursing home, she visited and gave manicures to the patients. For this project, Amy was awarded Fairfax City Service Participant of the year. Amy graduated high school in June 1992.

Amy attended Virginia Tech and received a degree in Communication Studies with a minor in Nutrition. Upon graduation, Amy decide to continue her studies and work towards a degree in Exercise Physiology, specializing in Cardiac Rehabilitation. Working towards this degree has given Amy the opportunity to work with the Virginia Tech Cardiac Therapy and Intervention Center and to work at the Carolinas Medical Center.