THE PREDICTION OF FUNCTIONAL CAPACITY IN ACTIVE CORONARY ARTERY DISEASE PATIENTS USING A PHYSICAL ACTIVITY QUESTIONNAIRE

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(ABSTRACT)

This investigation examined the ability of the Veterans Specific Activity Questionnaire (VSAQ) to predict the functional capacities (expressed in metabolic equivalents or METs) of twenty male participants previously diagnosed with CAD who were referred for exercise testing as part of their participation in a community based exercise program. On the morning of their normally scheduled GXT, each individual completed the VSAQ and was administered a maximal exercise test on a treadmill utilizing a ramp style protocol based on their self estimation of functional capacity. Respiratory gas exchange values were recorded throughout and analyzed via stepwise linear regression with respect to several experimental and demographic variables such as age, BMI, percent body fat and time since entering a cardiac maintenance exercise program. The only variable to contribute significantly to the prediction of FC with regard to exercise capacity as measured by respiratory gas analysis was the VSAQ. The VSAQ explained 22.% of the variance in actual performance and this variable only showed a modest association with the criterion measure ($r = 0.47$ SEE 2.25, $p < 0.05$). A similar finding was noted when this criterion of exercise performance was estimated from treadmill speed and grade equations. In this case, the VSAQ accounted for 34% of the variance in exercise performance, i.e., $r = 0.58$ (SEE 2.16, $p < 0.05$). The final regression equation by which the VSAQ might be used to predict exercise capacity by the gas exchange criterion was: METs = 4.21 + 0.50(VSAQ). The final regression equation for prediction of MET exercise capacity by speed/grade at peak exercise was: METs = 4.60 + 0.65(VSAQ).

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Chapter I

Introduction

The assessment of physical activity by questionnaire has been the most popular and practical method of estimating physical activity patterns in both healthy and diseased persons for several years. Early systems traced their genesis to epidemiological research involving the recall of habitual physical activities over a predetermined period of time in large populations of individuals (Washburn & Montoye, 1986). While these assessments provided an immense quantity of data for the investigator to examine, accurate interpretation for specific populations was often difficult due to an excessive generality in the focus of the questions and the fact that patient self record keeping could potentially influence activity patterns.

Coronary artery disease (CAD) is a subgroup often studied by the epidemiological teams primarily due to the fact that it is the leading cause of mortality in the United States on an annual basis, with an average of 700,000 deaths each year directly attributable to it's origins (McGinnis & Foege, 1993). Evidence has accumulated that directly links the incidence of CAD with levels of physical activity and the resulting disability in those afflicted with the disease (McGinnis & Foege 1993). The NYHA functional classification was developed in 1939 as a quick, simple reference for physicians to use when attempting to estimate the maximal physical exercise ability of their patients, also known as functional capacity, in relation to the degree of symptoms experienced (Cox and Naylor, 1992).

Functional capacity is a general term most closely associated with maximal oxygen uptake expressed in metabolic equivalents or METs. Maximal oxygen uptake is the maximal rate at which oxygen can be taken up, distributed and used by the body in the performance of exercise that utilizes large muscle groups (Glassford, Baycroft, Sedgewick & Macnab, 1965; Foster, Jackson, Pollock, Taylor, Hare, Sennet, Rod, Sarwar, & Schmidt, 1984). The most accepted method for estimating VO_2 max is to derive it through prediction equations relating performance on a treadmill based exercise test to oxygen uptake (Foster, et al.,1984). It is often used as an indicator of the progression of CAD in those diagnosed with the disease.

Graded exercise testing has been used as a diagnostic procedure for the prediction of functional capacity (FC) in both healthy individuals and patients diagnosed with coronary artery disease (CAD) for several years (Foster, Hare, Taylor, Goldstein, Anholm & Pollock, 1984; Sullivan & McKirnan, 1982; Jackson, Blair, Mahar, Wier, Ross & Stuteville, 1990). Serial exercise testing is preferred by many physicians as the method of choice for tracking and documenting the progression of CAD in their patients on a semiannual or annual basis. While measurement of maximal oxygen uptake is the most accurate method of assessing functional capacity, tables, nomograms and formulae are often used as substitutes in the absence of metabolic measurement equipment. Advances in medical technology have introduced specialized GXT's such as thallium and dobutamine which have greatly enhanced the value and accuracy of such testing in the analysis of CAD.

While beneficial and in many instances lifesaving, these advances have undoubtedly contributed to the dramatic rise of health care costs and the questions regarding the necessity of serial exercise testing by financial providers such as the federal government. The recent focus on health care reform has highlighted this issue and emphasized the fact that GXT's are quite cumbersome as they require significant staffing, facility and personnel commitments by the sponsoring institution.

These factors have led to the renewed interest in the development of specific activity questionnaires that can accurately predict functional capacity in individuals diagnosed with CAD. The most recent of these is a study which entailed the creation of a Veterans Specific Activity Questionnaire (VSAQ) that contains activities listed according to sequential MET values (Myers, Do, Herbert, Ribisl & Froelicher, 1994). While the study was found to be more accurate than it's predecessors, several shortcomings may preclude it's usage among larger groups, the first of which is the comparison versus prediction equations for maximal oxygen uptake. Further research is clearly needed to assess the VSAQ's usefulness as an indicator of functional aerobic capacity in diseased individuals. This information would be invaluable in determining if the VSAQ may eventually be able to be applied across a wider segment of the CAD population.

Statement of The Problem

The current literature contains various methods of predicting functional capacity in those individuals diagnosed with CAD. Each system possesses specific limitations which may preclude their usage throughout a wide range of capacities. The most recent attempt is a study by Myers, et al (1994) in which a nomogram is utilized to predict maximal oxygen uptake (in METs) based on the subject's questionnaire estimation of their highest level of activity in the absence of angina, fatigue or shortness of breath. It then examines the value predicted by the VSAQ versus a MET value estimated on the subject's speed and grade at the maximal stage of their GXT. The subjects in this study possessed an average maximal oxygen uptake of 7.1 METs with a correlation of $r = 0.82$ noted between VSAQ and predicted METs based on equations of treadmill speed and grade (Myers, Do, et al., 1994)

Individuals diagnosed with CAD who have high FC's due to consistent training or other reasons such as relatively young age also require a means of accurate estimation of their functional capacity. This study will examine the predictive ability of the VSAQ in a population of individuals diagnosed with CAD who possess higher FC's than those used in the Myers (1994) study. It will also examine the issue of predicting maximal oxygen uptake by involving the utilization of a metabolic measurement cart.

The purpose of this study is twofold: (1) to examine the predictive ability of the VSAQ in a population of males diagnosed with CAD who are asymptomatic at rest and participate regularly in a cardiovascular maintenance and exercise program; (2) to measure directly the maximal oxygen uptake of the individuals and compare these results with predicted MET peak values derived from the VSAQ method.

Research Hypothesis

HO1: The MET peak for physically active CAD patients cannot be predicted by use of the VSAQ questionnaire.

HO2: The VSAQ does not differ in prediction of the MET peak when compared with either direct measurement of oxygen uptake or prediction based on maximal workload.

Significance of the Study

Graded exercise testing (GXT) is a frequently utilized method of evaluating functional capacity in those individuals with coronary artery disease and also as a screening test for the diagnosis of CAD in those with suspicious symptoms. Due to it's financial, time, staffing and facility requirements, however, it is not necessarily a practical consideration for all patients and situations. Recent discussions on impending health care reform measures have initiated the examination of the necessity of serial GXT's in persons with relatively stable CAD. A need therefore exists for a reliable, simple, quick and accurate indices of functional aerobic capacity in this population. Various interview and questionnaire inventories of physical functional ability have been developed to satisfy this need, e.g., the New York Heart Association functional classification, the Canadian Cardiovascular Society (CCS), the Goldman Specific Activity Scale (SAS) and the Duke Activity Status Index (DASI) (Criteria Committee of the NYHA, 1964; Goldman, Hashimoto, Cook, & Loscalzo, 1981; Campeau, 1976; Hlatkey, Boineau, Higginbotham, Lee, Mark, Califf, Cobb & Pryor, 1989) .

The most recent is a Veterans Specific Activity Questionnaire (VSAQ) developed by Myers and co - workers (!994) in a study which involves the use of a nomogram to predict maximal oxygen uptake (in METs) based on the subject's questionnaire estimation of their highest level of activity in the absence of angina, fatigue or shortness of breath (Myers, Do., et al., 1994). It then examines the value predicted by the VSAQ versus a prediction based upon the subject's speed and grade at the maximal stage of the GXT (Myers, Do, et al., 1994). Should the VSAQ be demonstrated to be an accurate predictor of functional capacity in individuals with relatively high FC's who are diagnosed with CAD when examined versus measured oxygen uptake, positive implications would exist for it's usage as a potential replacement of the serial GXT in certain situations. In addition, the results of this study may spawn further development and modification of the VSAQ to include a wider realm of patients with varying degrees of the disease.

Delimitations

1. Subjects were 20 patients currently enrolled in the Virginia Tech Cardiac Therapy and Intervention Center morning exercise program with a status of post myocardial infarction or coronary artery bypass surgery.
2. Independent variables were age, percent body fat, BMI and time

spent in a cardiac exercise maintenance exercise program.

3. Dependent variables were measured oxygen uptake and estimated oxygen uptake based on peak treadmill speed and grade.

Limitations

1. Sampling procedures may limit the generalizability of the study.

Basic Assumptions:

1. Subjects correctly assessed their maximum functional capacity in the VSAQ.
2. Subjects exhibited a maximal performance on the GXT.
3. Subjects accurately reported their RPE.
4. RER, HR, RPE are accurate variables for measuring maximum performance on a GXT.

Summary

The chronic prevalence of CAD has necessitated the accurate determination of FC in a wide range of patients for several years. Early attempts to address this need, e.g., the New York Heart Association functional classification and the Canadian Cardiovascular Society functional classification were simple, rapid and somewhat accurate systems often utilized almost exclusively until quite recently. Further study of these classifications and the advent of exercise testing as a highly accurate method of determining functional capacity have revealed shortcomings in their design. In fact, exercise testing gradually became the preferred method of determining functional capacity in those with CAD and was used wherever possible.

Concerns over the significant facility and equipment requirements of exercise testing coupled with the recent emphasis on lowering the costs of health care services have brought about renewed interest in the questionnaire as a predictor of FC. The most recent development to examine this issue is the Veterans Specific Activity Questionnaire developed by Myers and co-workers (1994) in which activities are listed according to their MET values. While the results of the study found the VSAQ to be the most accurate non physical assessment of FC yet developed, several shortcomings existed. The most significant of these was the absence of respiratory gas exchange analysis as a basis of comparison for the VSAQ.

This study compared the results of measured maximal oxygen uptake to those predicted by the VSAQ and estimated by peak exercise workload. It also examined the predictive ability of the VSAQ in a population of males who were aysmptomatic at rest , possessed higher functional capacities than those examined by Myers, et al and who were involved in a community based exercise program for several years after their diagnosis or event.

Chapter II

Review of Related Literature

Introduction

The literature pertinent to this investigation is presented in three major sections. The initial section contains a review of various non physical methods of predicting functional capacity including questionnaires, interviews and their generalizability to the physical activity capabilities for general living. The second section examines the laboratory assessment of functional capacity and it's clinical applicability for diagnosis and therapeutic evaluations of patients and healthy individuals. The final section will trace the development of the SAQ line of research and examine the strengths and weaknesses of previous studies.

Prediction of FC based on Non-Physical Means

Questionnaires

The quest for a quick, reliable and accurate indices of maximal functional capacity via daily activity assessment has evolved over several years (Myers, Do, Herbert, Ribisl & Froelicher ,1994; Selzer & Cohn, 1972; Goldman, Hashimoto, Cook & Loscalzo, 1981; Hlatkey, Boineau, Higginbotham, Lee, Mark, Califf, Cobb & Pryor, 1989; Sullivan, & McKirnan, 1984). The first attempt was that developed by the New York Heart Association when it established it's functional classification which organized patients into one of four categories according to degree of symptoms (angina, shortness of breath, fatigue, palpitations) experienced while engaged in “ordinary” and “less than ordinary" activity (Criteria Committee of the NYHA, 1964). The four functional classes range from completely asymptomatic regardless of activity (Class I) to symptomatic at rest and worsening with activity (Class IV). Physicians commonly indicated that a certain MET level attained on a GXT is associated with each NYHA criteria as follows: Class I > 7 METs, Class II = 5-6 METs, Class III = 2-4

METs and Class IV = 1- 2 METs.

This classification system remained in use for a long period, primarily due to the fact that it was the first of it's kind to provide physicians with a rapid method of classifying their patients with CAD. Countless studies have examined a variety of therapies for virtually every type of cardiac disease based on the serial assessment of patient's functional status as measured by the NYHA criteria (Criteria Committee of the NYHA, 1964). Advances in the field of medicine since that time have wrought vast changes in the treatment of cardiac disease so that it bears little resemblance to that which the NYHA classification was designed to serve.

The classification developed by the Canadian Cardiovascular Society in 1974 is a followup to the NYHA scale, designed to improve the reproducibility of classification by independent observers and establish a consistent grading scale for angina pectoris (Circulation, 1976). While structurally similar to it's predecessor, the CCS system is slightly modified through the usage of somewhat more precise terminology in the four functional classifications (See Appendix D). Each class contains uniform references of physical activity (walking, climbing stairs, walking uphill), environment and emotions which enable the physician to more accurately estimate the patient's activity levels.

The next classification that attempted to address this issue was a study by Goldman, et al (1981) who developed a Specific Activity Scale (SAS) which classifies patients according to cardiac functional class, noted in metabolic equivalents or METs. This scale was specifically intended to improve the reproducibility and validity of the NYHA and CCS systems as they lacked the systematic testing necessary for clinical evaluation.

The initial development phase consisted of the estimation of metabolic costs of a variety of occupational, housework, personal care and recreational activities based on available data (Goldman, et al., 1981). A one month pretesting phase followed which entailed the identification of particular questions that referred to activities relevant to the patient population being studied. Those activities and their corresponding MET values were then organized into a patient's self administered questionnaire and a separate set of criteria that defined each of the four functional classifications.

The patient was considered to be able to perform the metabolic equivalents of a functional class if any activity listed on the questionnaire could be completed regardless of the emergence of symptoms. However, if none of the physical activities in a particular MET range on the questionnaire could be undertaken due to symptoms, fear of symptoms, habits or other limiting factors, the individual was considered unable to work at that level and the functional classification reexamined until the proper one was established.

Validity of the SAS as a predictor of functional capacity was examined against treadmill test performance of the Bruce protocol. While the correlation (r=0.66) between the METs derived by the SAS and that predicted from the maximal speed and grade formula was somewhat modest, it was greater than that of either the NYHA (r=0.51) or CCS (r=0.59) (Goldman, et al., 1981) The improved validity is primarily due to the fact that the SAS asks standardized questions related to individual activities that the individual can perform and then compares those responses with the actual ability to exercise (Goldman, et al., 1981).

This method was a significant departure from the previous classification systems as it reduced dependence upon accurate physician diagnosis and increased the patient's perspective on the ability to engage in physical activity. Virtually all of the subsequent research in the classification of functional capacity in patients with CAD would utilize a system based on a variation of this format.

The Duke Activity Status Index (DASI) was created as a brief, self administered questionnaire designed to improve upon the SAS by predicting functional capacity in any individual regardless of cardiac status (Hlatkey, et al., 1989). The Index contains an expanded version of the Goldman scale and includes such activities as personal care, household tasks, sexual function, ambulation and a wide variety of recreational interests. It was constructed primarily by taking into account the relationship of questionnaire items with maximal oxygen uptake and data from previous studies (Sullivan, et al., 1984, Goldman, et al., 1981) indicating those activities best representing different areas of physical movement. Stepwise multiple regression analyses were then used to determine which activities best correlated with maximal oxygen uptake.

The first phase of the study entailed the administration of the questionnaire via a structured interview to determine the subject's ability to engage in a variety of common daily activities followed by a maximal cycle ergometer GXT. The results indicated that the correlation of the DASI with maximal oxygen uptake was significantly greater than those of previous functional classification systems ($r=0.80$, $p<0.0001$) (Hlatkey, et al., 1989).

The most recent attempt to enhance the prediction of functional capacity from a questionnaire is a study by Myers, et al (1994) which centers around the creation of a questionnaire specific to the veteran population i.e. the Veterans Specific Activity Questionnaire (VSAQ). This self administered questionnaire consists of a list of activities compiled in an increasing list according to MET values from 1 to 13. The MET values listed on the VSAQ were derived from various sources and are generally similar to those found in the recently published Compendium of Physical Activities (Ainsworth, Haskell, Leon, Jacobs, Montoye, Sallis & Paffenbarger, 1993).

The 212 subjects were instructed to determine which activities might typically cause fatigue, angina or shortness of breath and the results obtained were plotted on a nomogram developed by the authors which was constructed via the utilization of GXT results of 1,388 apparently healthy subjects and equations for predicted MET values (Myers, Do, et al., 1994). Maximal oxygen uptake was estimated from the VSAQ and an individualized ramp style protocol controlled electronically via a Mortara treadmill software system established. Maximal functional capacity was determined by estimation based on standard equation from treadmill speed and grade values at the highest exercise stage.

The mean maximal MET value predicted by the VSAQ was 6.3 $\pm$ 2.3 METs while the actual achieved value was 7.1 $\pm$ 3.0 METs (Myers, Do, et al., 1994). A correlation coefficient of 0.79 ($p < 0.001$) was noted between these two variables and the only other variable which added significantly to the prediction of FC was age, providing an $R = 0.82$ ($p < 0.001$) (Myers, Do, et al., 1994). This finding is in contrast to prior investigations, which had determined age, body composition and gender to be key variables in the estimation of FC (Milesis, 1987, Froelicher, Allen & Lancaster, 1974, Bruce, Kusumi & Hosmer, 1973). The investigators used this data to develop a regression equation reflecting the relationship between these three variables : METs = 4.7 + 0.97 (VSAQ) - 0.06 (age) (Myers, Do, et al., 1994). A nomogram utilizing VSAQ and age was then created to predict FC.

Interviews

The use of interviews improves the accuracy of predicting functional capacity in both healthy and diseased individuals (Hlatkey, et al.,1989, Goldman et al., 1981). One reason appears to be an improved specificity of questions regarding the patient's activities. Another is that the interview provides a structured environment for the individual; encouraging concentration and thought regarding the questions and minimizing distractions which enable the physician to possess a more accurate and thorough indices of the individual's FC. Some limitations of the interview technique include the time requirements inherent in the process, the reproducibility of results among two or more interviewers, and the hesitation of the patient to accurately describe symptoms experienced while exercising. Another is the fact that a physician may not be present at all times to administer the SAQ, raising doubts regarding the accuracy of an interview administered with the same questionnaire by an untrained observer.

The initial study which examined the viability of the interview technique as an accurate method of serially assessing cardiac functional status was that by Goldman and coworkers in 1981. Estimation of FC was accomplished via the administration of both the SAS and CCS functional classifications prior to the GXT by two independent interviewers who had no knowledge of the patient's current functional status. If one of the interviews was not conducted prior to the GXT, it was given at a later time by an individual blinded to the results of both the first interview and the GXT. While one of the two interviews was always conducted by a physician, the identity of the second interviewer varied somewhat. Approximately 55% of the subjects had their second interview performed by a medical school librarian who had never interviewed a patient and had no background on cardiovascular diseases. The remaining 45% had their interviews conducted by a board certified cardiologist. who had no prior knowledge of the patient's functional status (Goldman, et al., 1981) All subjects' NYHA functional classifications were estimated before their GXT by the referring physician who were cognizant of their cardiac status .

The results of the study indicated that both the SAS and CCS functional classifications possessed reproducibilities of 73% among the two interviewers while the NYHA recorded a value of 56% (Goldman, et al., 1981). The reproducibilities of the SAS and CCS were not dependent upon the identity of the interviewer (Goldman,et al., 1981). Interestingly, the reproducibility and validity rates of both the CCS and SAS classifications did not increase over the course of the study, possible suggesting that further experience of the interviewers with the systems was not an important factor in the outcome. A conclusion reached by the authors was that the greater validity of the SAS scale in comparison to the NYHA and CCS was primarily due to the fact that the interviewers asked a predetermined series of questions in regards to the activities which the patient could perform.

The low reproducibility of the NYHA (56%) clearly indicates that knowledge of the interviewer in regards to the patient's condition is not as crucial in the estimation of functional capacity as the structure of the questionnaire itself. This is reinforced by the lack of significant difference among the interviewers who utilized the CCS and SAS classifications and thus the decisive factor seemed to be the structure of the questionnaire itself.

Goldman and coworkers followed up this concept in a study which examined the limitations inherent in the serial assessment of functional capacity. (Goldman, Cook, Mitchell, Flatley, Sherman & Cohn, 1982). All of the patients were interviewed and classified according to the NYHA and SAS functional classifications, with the SAS involving the aforementioned questions and the NYHA being based upon the terms "ordinary" and "less than ordinary" , whose limitations will be discussed in another section. The patients were divided into three groups according to the manner of interview technique. Group I consisted of 58 patients whose NYHA classification was determined in an interview prior to the GXT by the referring physician. The second blinded interview was conducted on the day of the test by one of five board certified cardiologists who routinely supervised GXT's . Estimates of FC using the SAS classification were also generated by two observers: the first by a physician and the second by a medical school librarian with no previous interview or medical training. All estimates were made without any knowledge of the GXT or the other interview. Group II included 71 patients admitted for catheterizations and Group III included those scheduled for follow - up interviews after the catheterizations. All interviews in Groups I and II were conducted solely by trained physicians.

The results in Group I indicate that the NYHA and SAS gave identical classifications in 58% of the interviews (Goldman, et al., 1982). In those cases where the two classifications disagreed, the NYHA was higher in 28% of the cases and the SAS in 14%. The tendency of the NYHA to be higher may have been attributable to the cardiologists who were more likely to assign higher NYHA estimates than the referring general practice physicians. Group II saw agreement between the two classifications in 60% of the cases, possibly indicating that the NYHA was more likely to assign the patient to a lower FC than the SAS (Goldman, et al., 1982).

Lee, Shammas, Ribeiro, Hartley, Sherwood & Goldman (1988) examined the SAS in combination with an interview as a method of predicting functional capacity in those with CAD. This two phase study focused upon the correlation of the classification and maximal oxygen uptake. The first phase consisted of ten patients while the second had a total of 26. All patients in both phases were placed into one of the four SAS classes on the day of the GXT by two independent interviewers who were not involved in the patient's care and who were blinded to the results of both the GXT and the other interview. Each of the first phase's (1984) two interviews were conducted by physicians while those of the second phase (1986) were administered by individuals with no prior medical experience. All questions were administered in a structured flow chart manner which led to the classification of the patient's SAS FC within one minute (Lee, et al., 1988).

The results demonstrated that the two interviewers agreed on the patients SAS functional classification in 29 out of the 36 patients or 81% of the cases. The rate of agreement among the physicians (90%) was not significantly different from that of the untrained interviewers (77%) (Lee, et al., 1988). A regression analysis demonstrated a strong correlation of the SAS with maximal oxygen uptake ($r = 0.75$ $p<0.0001$) (Lee, et al., 1988). This led the authors to conclude that individually reported information on the ability to perform daily activities via the SAS classification is highly reproducible when the scale is utilized by both trained and untrained observers who are not familiar with the patient (Lee, et al., 1988). These findings are similar to those of Goldman, et al (1981, Goldman, et. al., 1982) in their two previous studies, clearly supporting the concept that while an interview is a powerful tool for assessing FC, the specificity of the questionnaire is also a key factor and must be as specific as possible to ensure accurate estimation of FC.

The next study that examined the effectiveness of the interview based prediction of functional capacity against the self administered questionnaire was that of Hlatkey, et al., (1989) who developed the Duke Activity Status Index (DASI). The initial section of this two phase study consisted of the development of the self administered questionnaire in a group of subjects undergoing maximal bicycle exercise tests. Each patient was interviewed immediately after the GXT by an exercise physiologist who was blinded to the results of the test. The interview consisted of a structured series of questions designed to assess the subject's ability to perform a wide range of daily activities. A broad spectrum of activities which represented various cardiovascular exercises and dimensions of personal health were selected from previously published studies such as those by Goldman in the attempt to improve specificity of the questionnaire.

The second phase entailed the validation of the DASI in independent sample of fifty subjects . All subjects undergoing maximal cycle ergometer testing were asked to complete a self administered questionnaire without an interview and the responses were used to calculate the DASI, the CCS and the SAS functional classification levels.

The results demonstrated clear improvements in the correlation between the DASI and maximal oxygen uptake as more activities were included in the classification. However, the improvements were significantly reduced after 12 activities were included. The highest amount of information was given by the ability to perform activities easily and no significant improvements in accuracy were noted upon the inclusion of those activities which were difficult to perform. (Hlatkey, et al., 1989). The correlation between the DASI and maximal oxygen uptake was quite high in the initial phase ($r = 0.81$, $p,0.0001$) while the CCS and SAS received significant albeit lower values of $r = 0.58$, $p<0.0001$ and $r = 0.67$, $p<0.0001$ respectively (Hlatkey, et al., 1989).

The results of the validation phase demonstrated a lower correlation of FC measures via the DASI with maximal oxygen uptake ($r = 0.58$, $p< 0.0001$) than in the developmental sample which utilized an interview (Hlatkey, et al., 1989). This may be due to the fact that a trained interviewer collected data from the first group while a self administered questionnaire was given to the second. The marked difference in the SAS was most likely due to the fact that it was given as a self administered questionnaire when in reality it is designed as a tool for an interviewer. These results clearly demonstrate that an interview is still the most accurate method of assessing FC and that questionnaires must be designed specifically for use by the patient and contain items that are relevant to daily patient activities (Hlatkey, et al., 1989, Goldman, et al., 1982).

Generalizability to Physical Activity Capabilities of Daily Living

One particular area of interest regarding the SAQ is the potential for application to physical activity capabilities for daily living in the general public. While several studies have examined the viability of such an approach through general physical activity and leisure time questionnaires (Folsom, Caspersen, Taylor, Jacobs, Luepker, Gomez-Marin, Gillum & Blackburn, 1985; Blair, Haskell, Ho, Paffenbarger, Vranzin, Farquhar & Wood, 1985; Siconolfi, Lasater, Snow & Carleton, 1984; Montoye & Washburn, 1986), few have examined the potential of a population specific questionnaire. Some factors to consider when attempting to generalize the SAQ to activities of daily living are 1: matching the FC of the individual to the metabolic cost of work, 2: the wording of the SAQ itself; and 3: environmental considerations.

The SAQ is based upon the concept that certain activities require a certain amount of energy, (usually expressed in METs) to complete. Several studies have examined the metabolic cost of various household and vocational activities for healthy individuals via direct measurement (Bannister & Brown, 1968; Passmore & Durnin, 1955). This data was then published in the form of tables and often utilized by subsequent investigators in their research (Folsom, et al., 1985; Blair, et al., 1985; Siconolfi, et al., 1984; Montoye & Washburn, 1986). These tables posses two inherent limitations which may preclude their usage in both the diseased and healthy populations. First, they are somewhat old and need reevaluation based on today's improved standards of measurement. Advances in technology have immensely enhanced the accuracy of gas analysis and thus present the investigator with the option of assessing the accuracy of the initial measures. Secondly, individuals who are healthy and those with CAD of different functional classes differ in the amount of energy expenditure when performing identical activities (Aronov & Rosykhodzhajeva, 1992).

These differences were examined in a study by Aronov, et al,. (1992) who viewed the energy expenditure and energy responses of patients with different functional classifications of CAD to various daily activities. The seventy male subjects possessed varying degrees of CAD and were placed into one of three functional classes based on the results of a symptom limited maximal cycle ergometer GXT utilizing gas analysis. Functional Class 1 consisted of those with FC > 7 METs, Functional Class 2 of those with FC 4.0 - 6.9 METs and Functional Class 3 for those with FC 2.0 - 3.9 METs (Aronov & Rosykhodzhajeva, 1992). All patients were tested for common daily exercise capacity in ten minute intervals in the following activities: hand sawing, shoveling, gravel, vacuuming, cleaning with a sponge, hand drilling and carrying weights in a suitcase on level ground. Job difficulty was measured by the amount of energy spent for a certain activity in relation to individual energy expenditure measured directly during exercise.

The results demonstrated a decrease in CV function in patients with respect to the severity of their FC, with the amount of relative energy demands of the activities rising progressively as the severity of the FC scale rose. FC1 recorded a demand level of 33-60%, FC2 47 - 81% and FC3 78 - 111%(Aronov, & Rosykhodzhajeva, 1992). Thus, while patients with varying levels of CAD and healthy individuals who engage in similar activities may be working at similar absolute MET levels, their VO_2 and oxygen consumption responses in relation to their individual maximal oxygen uptake may be quite different due to the unequal levels of energy costs in relation to that measured by the GXT. An SAQ whose MET levels and functional classes are based upon the responses of patients with CAD will not be applicable to healthy individuals. One interesting note is that many of the SAQ's are in fact based upon the MET levels noted in the aforementioned older studies involving healthy persons, indicating a lack of studies such as Aronov's which directly measure the energy expenditure levels of persons with CAD. Recent investigations such as those which involve the direct measurement of household and vocational activities (winter activities such as snow shoveling) in those with CAD are especially helpful in this regard (Sheldahl, Wilke, Tristani & Kalbfleisch, 1985; Sheldahl, Wilke, Dougherty & Tristani, 1992; Dougherty, Sheldahl, Wilke, Levandoski, Hoffman & Tristani, 1993).

Another factor which may limit the application of the SAQ's to common daily activities of healthy persons is the wording of the questionnaires themselves. Research has indicated that increased specificity of the SAQ with regards to activities of patients with CAD enhances their accuracy and reliability (Goldman, et al., 1982, Lee, et al., 1986, Hlatkey, et al., 1989, Cox, et.al., 1992). This has led to a focus upon household and vocational tasks specific to that population and a lack of activities which healthy individuals may engage in. For example, questionnaire such as the DASI tends to avoid the use of isometric activities such as weight carrying due to the fact that many older CAD patients may not do those activities or may not be able to accurately estimate the weight that they can carry. This may prove to be a limitation for those individuals whose occupation involves frequent carrying and lifting of heavy objects.

The final factor to be examined is that of the environment and the resulting physiological changes brought about by seasonal fluctuations. Many occupational and home activities requiring significant amounts of isometric effort performed in a variety of locations(e.g. construction, yard work). Such activities will inevitably lead to exposure to temperature and weather extremes during winter and summer months, altering the demand placed upon the cardiovascular system.

Cold environments induce vasoconstriction of coronary arteries and thus decreased oxygen supply to the myocardium, leading to increased oxygen uptake at lower levels of activity (Emmett & Hodgson, 1993). Many patients have reported that angina occurs more frequently and with less exertion in a cold environment than a warmer one (Brown & Oldridge,1985). A self administered questionnaire which does not adjust for these differences by including cold weather activities (such as snow shoveling) or listing activities in both the summer and winter months may be inaccurate. A patient who cannot perform winter snow shoveling (about 7 METs) without the emergence of symptoms and yet who can engage in all the activities listed in the 7 MET range on the SAQ will be incorrectly classified.

Section II: Laboratory Assessment of Functional Capacity:

This section of the literature review will examine the laboratory assessment of FC via the GXT, it's clinical applications and generalizability to general physical activity capabilities of daily living.

Laboratory Assessment of Functional Capacity via the GXT

Graded exercise testing is the most accurate and useful method of assessing the FC of patients diagnosed with CAD. One of the measures obtained from such tests, maximal oxygen uptake, is generally recognized as the best indicator of aerobic capacity and cardiorespiratory function (Froelicher, et al., 1993). Maximal oxygen uptake is defined as the capacity of the cardiovascular and respiratory systems to take up, transport and give off oxygen to active tissues and the ability of those tissues to use that oxygen (Glassford, et al., 1965; Foster, et al., 1984). It represents the integrated product of cardiac output and arteriovenous oxygen difference and is often expressed in metabolic equivalents or METs (Jette & Blumchen, 1990). VO_2 max is reached when the oxygen uptake has achieved it's maximal limit and remains constant at this plateau due to the limitations of the circulatory and respiratory systems.

Several factors should be considered when attempting to optimize assessment of FC via exercise testing: selection of a mode of testing, e.g., treadmill or cycle ergometer, type of protocol, test duration and indirect estimation versus direct measurement of oxygen uptake. The use of a treadmill during clinical exercise testing consistently generates higher VO_2 max values in both healthy and diseased individuals when compared directly to maximal oxygen uptake values recorded during a cycle ergometer GXT (Buchfuhrer, Hansen, Robinson, Sue, Wasserman & Whipp, 1983, Guidelines for Graded Exercise Testing and Prescription, 1994). Various studies comparing upright cycle ergometer versus treadmill exercise demonstrated VO_2 max values to be 6 - 25% higher during treadmill work (Froelicher, Myers, Follansbee & Labovitz, Exercise and the Heart, 3rd edition,1993). Treadmill GXT's frequently involve the use of protocols containing fixed incremental changes in speed, grade and stage duration, the Bruce being by far the most common (Foster, Jackson, Pollock, Taylor, Hare, Sennet, Rod, Sarwar & Schmidy, 1984; Myers, Buchanan, Smith, Neutel, Bowes, Walsh, & Froelicher, 1991).

Such discrepancies often lead to premature ending of the GXT, causing inaccurate prediction of VO_2 max based on treadmill speed and grade and thus a poor assessment of FC. Buchfuhrer, et al (1983) compared the maximal oxygen uptake values of normal subjects undergoing treadmill and cycle GXT's containing various incremental stage changes and found that the highest VO_2 max values achieved were those tests utilizing intermediate increments as opposed to small or large changes in workload.

Recent investigations have examined the potential of individualizing test rather than using a standard protocol for every subject (Myers, et al., 1993, Myers, et al., 1991; Panza, Quyumi, Diodati, Callahan & Epstein, 1991). The central focus was the creation of treadmill GXT protocols which minimized the aforementioned difficulties with large incremental changes between the stages (< 1 MET per stage as opposed to 2-3 METs in standard protocols). A test that utilizes this concept is the ramp test in which changes in work can be customized according to the patient's age, fitness level, mechanical efficiency and disease status. Myers and co-workers (1991) recently compared ramp treadmill GXT's versus standard protocols in patients with CAD and CHF. The results demonstrated oxygen uptake to be overestimated in GXT's involving large incremental changes in work and that the variability in estimating oxygen uptake from treadmill speed and grade was much higher in these test than the ramp style (Myers, et al., 1991).

Another factor to be considered in devising an optimal assessment of FC in the laboratory is GXT duration. Buchfuhrer and co - workers (1983) examined the effect of test duration on the maximal oxygen uptake values of healthy subjects undergoing treadmill and cycle GXT's and determined that the VO_2 max was highest for tests lasting 8-17 minutes. Longer tests (>17 minutes) were found to incur back discomfort and boredom while shorter tests (<8 minutes) often required large incremental changes resulting in lower VO2 max values. The optimal test length recommended by the authors was 10 $\pm$ 2 minutes (Buchfuhrer, et al.,1983). Myers and co-workers (1994) found that the associaton between age, VSAQ and FC suggested that for a test of this (10 minutes) length, 90% of the GXT's would last approximately 8 to 12 minutes. The American Heart Association's recently published Exercise Standards agree with these findings (Fletcher, Froelicher, Hartley, Haskell & Pollock, 1990).

A popular method of estimating FC which has gained wide clinical acceptance due to it's ease of application is to derive it from maximal exercise time and/or workload. Such techniques involve estimation through linear regression equations relating treadmill performance to maximal oxygen uptake.

This concept has been heavily developed by Bruce, Kusumi & Hosmer (1973) who derived population specific equations relating performance on a multi stage GXT to maximal oxygen uptake as measured by open circuit spirometry (Bruce, Kusumi & Hosmer, 1973). Some shortcomings inherent to this method are that there are multiple equations involved, the clinical and activity indexes of the patients can vary and also that some equations are based upon the responses of individuals who are not part of the target population (Foster, et al., 1984). Other problems inherent to this method in the CAD population such as the potential effects of angina or exercise induced ischemia upon the prediction of VO_2 max have been well documented (Foster, et al.,1984, Sullivan & McKirnan,1984, Froelicher, et al.,1993).

The most accurate method of assessing FC in the CAD population is direct measurement of oxygen uptake involving the use of open circuit spirometry, the benefits of which have been well documented (Foster,et al., 1984, Buchfuhrer, et al.,1983, Froelicher,et al.,1993). Since it is considerately more expensive and facility intensive than indirect estimation, the purpose of the test must be thoroughly scrutinized. If the intent is to examine the effects of various interventions upon the FC of the patient as in research, then the procedure is essential. This method can provide the investigator with a wealth of variables to examine in regards to the functional ability of the cardiovascular system to deliver oxygen to the working muscles.

Clinical Applications

The laboratory assessment of FC via direct measurement possesses a wide range of applications in the clinical setting, the first of which is that it allows the prediction of the severity of disease in those individuals with known or suspected CAD (Froelicher, et al., 1993). More sophisticated tests such as pharmacological testing can be utilized if necessary as exercise testing cannot predict a poor prognosis with compete confidence. The knowledge of the patient's exercise capacity is a useful tool for the clinician to use when designing a safe, effective activity program for that particular individual. Activities can be suggested and/or chosen that fall within acceptable guidelines based on test responses and minimize the onset of potentially dangerous symptoms.

Another benefit to maximal exercise testing is that it gives practical and valuable information regarding the efficacy of various forms of pharmacological therapy. The diagnostic GXT provides the physician with valuable information concerning the fitness and disease status of patients of various ages and an accurate indication of any changes in FC and possibly disease status since the last GXT.

Generalizability to Physical Activity Capabilities for Daily Living

The results of the laboratory assessment of FC are generalizable to quite a few situations and activities that the patient will engage in away from the supervised program. Through staff led education sessions, patients can become familiar with activities which they will be able to enjoy without the onset of symptoms and those which may be slightly more demanding. One type of activity where the results may not be very useful is that containing a significant amount of isometric movements, such as lifting boxes or moderately heavy gardening. The GXT involves rhythmic movements involving large muscle groups and does not contain a large element of heavy movements involving small or large muscle groups. Such activities must be viewed with caution and programmed accordingly.

Section III: Development of The SAQ Line of Research

In the preceding section, the development of the self administered questionnaire for the classification of CAD has been examined in detail. Each of these classifications possesses strengths and weaknesses which have aided concurrent investigators in the quest to design a highly accurate method of estimating FC.

The first to be critiqued will be the NYHA functional classification. Selzer & Cohn (1972) examined the limitations of the general functional classification and applied a critique to the NYHA system in a series of questions. The first addressed the reliability of symptoms and how they are interpreted by the patient. While dyspnea and shortness of breath are key physiological signs of the subject's impending maximal limit of exercise, the individual may experience or believe that he is experiencing dyspnea well before maximal exercise capacity is reached. Thus, a psychosomatic patient with a normal functional capacity may present with symptoms of a NYHA Class III or Class IV disability and result in subsequent misclassification by the physician (Selzer & Cohn, 1972).

Fatigue is another symptom which is difficult to interpret by a second party and can be thus quite vague to classify. For example, patients who possess ventricular failure are less subject to dyspnea and are frequently limited by muscular fatigue before the onset of other symptoms. These patients will often tailor their activities to those which do not elicit symptoms consistent with cardiac failure and thus have the potential to be classified as a NYHA Class I or healthy individual.

Another limitation examined by the authors was the NYHA's lack of definition to the terms "ordinary" and "less than ordinary" activity and the apparent inability to standardize these activities so that they can be applied to individuals across a greater range of functional abilities (Selzer & Cohn, 1972; Goldman, Cook, Mitchell, Flatley, Sherman & Cohn, 1982). Physical conditioning can dramatically affect exercise capacity in all types of individuals, especially those with CAD (Selzer & Cohn, 1972). Patients with CAD who engage in regular physical exercise are usually able to account for any symptoms inherent with their disease which arise as result of certain activities. They will recognize these symptoms if they begin to occur during activities which are less strenuous than those in which they normally occur and tailor the exercise routine as such.

A sedentary patient whose major activity is watching television may be unaware of any changes in his functional capacity due to detraining. This is also true for the "weekend warrior" whose physical exercise consists solely of annual hunting expeditions and who thus cannot accurately account for the occurrence of symptoms which limit his exercise capacity in comparison to the previous year. His anxiety over these changes may provoke an overcautious physician who does not realize that these trips are not included in the individual's everyday activity into believing that a serious decline in physical capacity has occurred when it actually has not. This will possibly result in a misclassification of the patient into a higher NYHA functional class which will cause an unnecessary decline in present physical activity and conditioning levels and eventually bring about serious disability.

A third concern for the NYHA classification is in regards to patients with temporary disability as it assumes that there will be a standard progression from Class I to Class IV disability. Episodic changes in patient status can create challenges for the physician attempting to select the proper classification. For example, a Class I patient may experience severe coronary insufficiency as a result of a burst of tachycardia (Class IV) but may return to Class I after the attack subsides. Where should the individual be classified?

The NYHA system also does not recognize the existence of symptoms which occur at rest, especially when they are not noted during typical daily activity. There are forms of ischemic heart disease which elicit chest pain at rest only and these patients can be asymptomatic in daily activity and yet have nocturnal ischemic episodes (Feinstein & Wells, 1977).

While the NYHA system has proved to be somewhat useful for many years, the advent of modern surgical and therapeutic techniques has rendered the classification virtually outdated (Selzer, et al., 1972). Cardiac surgery and therapy were virtually nonexistent at the time of it's inception, with the major method of primary treatment being 6 to 8 weeks of bed rest (Selzer, et al, 1972). Advances in technology have led to the availability of medical and surgical tools that can dramatically improve the status of a previously irreversible classification. For example, coronary artery bypass grafting can lower the classification of patients with Class IV heart disability to Class I activity levels indefinitely. In addition, pharmacological therapy can successfully allow patients who would previously have been bedridden to enjoy daily activities via the control of hemodynamic responses to exercise.

The final criticism mentioned by the authors is that functional classifications in general may lead to bias due to their subjective nature. Reproducibility by independent observers is crucial if these classifications are to be viewed with confidence, the key being detailed descriptions of the physical activities in each of the levels established by that system (Selzer, et al., 1972). They concluded that the NYHA system must be examined thoroughly by outside observers and that future classifications should possess a wider range of physical activities in the place of the term " ordinary".

A scale that contains greater specificity in disease description over it's predecessors has been demonstrated to improve the clinical applicability of that type of scale (Cox & Naylor, 1992). The CCS is therefore more accurate as it removes such vague terms as "dyspnea" and "fatigue" that are present in the older NYHA scale. Another example of this increased specificity is demonstrated by the fact that Class I of the CCS includes patients in whom angina is provoked by strenuous exertion whereas the NYHA definition is unclear (see figure 1). The CCS scale also denotes specific activity thresholds for symptoms at Classes II and III, a factor which is left vague by the NYHA classification.

Despite these improvements, a thorough scrutiny by Cox & Naylor (1992) yielded some serious shortcomings that may limit the effectiveness of this improved scale. One of these is that the CCS's notation of symptoms is limited to those which occur solely during walking or stair climbing activities. Patients who engage in other forms of exercise may encounter difficulties when attempting to quantify their symptoms in relation to those listed, leading to possible misclassification (Cox & Naylor, 1992).

Secondly, the term "angina syndrome may be present at rest" is a confusing addition to CCS Class IV in both the wording and the fact that some patients in Classes I to III may experience occasional symptoms at rest. Persons whose symptoms are episodic or variable in response to activity (such as unstable angina) do not fit well in the CCS, a finding similar to that of the NYHA scale (Cox & Naylor, 1992).

Another finding was that the both the CCS and scales in general do not accurately account for the patient's perspective of their disease and the accompanying symptoms. A sedentary 70 year old's class II symptoms may be quite tolerable on a daily basis while those of an active 45 year old may lead to disability due to discouragement, depression and a subsequent decline in activity. Feinstein & Wells (1977) examined these concerns and concluded that the development of further functional classification systems must include a wider selection of patient oriented activities if any improvement in accuracy were to be promoted.

Lee, et al (1986) examined the correlation between the SAS and maximal oxygen uptake in a two phase study involving 36 patients and a maximal bicycle ergometer GXT. Patients were set into one of the four SAS classes on the day of the test by two independent interviewers who were not involved in any aspect of patient care and were blinded to the results of the tests. The initial section (1984) consisted of physician led interviews while the second (1986) was staffed by individuals with no prior medical training. Questions were administered in the form of a flow chart and the individuals asked whether they could perform the activities listed " at a normal rate". The patient was classified according to the highest level of activity they could complete regardless of symptoms. Regression analysis demonstrated a strong correlation of VO_2 max with the SAS ($r = 0.75$, $p < 0.0001$) (Lee, et al., 1986). The authors concluded that the self reported information on the ability to engage in daily activities via the SAS is highly reproducible when the scale is used by both physicians and non physicians who are not familiar with the patient. The SAS and CCS systems had reproducibilities of 73%, significantly higher that the 56% reproducibility of the NYHA functional classification (Lee, et al., 1986).

Criticisms of the SAS include the fact that the activities listed are still somewhat restricted in scope and that a more comprehensive list should be developed. In fact, there is a complete omission of those activities which require an oxygen uptake of 10 METs or higher. In addition, the cross validation study by Lee, et. al. (1986) utilized a cycle ergometer for their GXT, a protocol which is not as accurate as the treadmill GXT (Froelicher, et al., 1993).

The next classification system, the DASI, was determined to be superior to the NYHA, CCS and SAS systems due to the fact that the Index abandons the four level classification concept in favor of a more continual system that allows smaller differences in functional capacity to be recognized. The correlation postulated by Feinstein and Wells (1977) between enhanced patient involvement and accuracy of a questionnaire can clearly be demonstrated upon comparing the NYHA, CCS, SAS and DASI functional classifications.

Major limitations of the DASI include the lack of discrimination at < 5 METs and > 10 METs, thus indicating a need for further study of the instrument. The usage of a cycle ergometer test is questionable due to it's lack of relevance in the U.S., where treadmill testing is preferred by clinicians and has a greater specificity as a mode of exercise for the CAD population. There is also significant lack of clarity in the definition of subject demographic and clinical characteristics which makes interpretation and general application difficult. Another criticism of the DASI is the low (r=0.58) correlation between the questionnaire and maximal oxygen uptake in the independent sample tested in the second phase of the study (Lee, et al., 1986). This finding led the authors to conclude that although the correlation was significantly lower than the original tests, more thorough testing involving a wider sample of patients would provide a more accurate analysis of the DASI's capabilities.

The VSAQ, created by Myers, et al (1994) is the most comprehensive and accurate classification system yet developed. It's benefits include: a wide range of well phrased activities for the patient to choose from; clear, concise instructions which reduce it's dependence upon staff supervision and a simple, one page format which undoubtedly increases patient compliance. The study does contain some shortcomings which must be addressed, the first of which is the lack of measurement of oxygen uptake during the maximal GXT, limitations of which have already been discussed. Also, while the ramping treadmill protocol seems to improve the accuracy of the estimation of oxygen uptake when compared to standardized protocols, a significant degree of variability has been observed (Myers et al., 1991). Lastly, individual differences in perceptions of certain activities must be accounted for if accuracy is to be optimized. This can be seen in the fact that those in the < 54 age group underestimated their FC by 10% and those individuals in the 57 and over age group underestimated their FC by 30% (Myers, et al., 1994). This is a significant finding due to the fact that a majority of patients with CAD are near 54 and that quite a few are 57 and older.

Summary

In summary, an investigation of the literature on the topic of the SAQ provides an in depth view of it's development, strengths, weaknesses and possibilities for improvement. Various investigators have attempted to address this issue through increasing the specificity of the activities listed and analysis of their energy requirements, with varying results. One trend that seems to be emerging is that it is difficult to design a questionnaire which will provide suitable activities for all manner of patients. The usage of an accurate questionnaire will undoubtedly be very useful for physicians attempting to rapidly and easily classify their patient's CAD status.

CHAPTER III

JOURNAL MANUSCRIPT

THE PREDICTION OF FUNCTIONAL CAPACITY IN ACTIVE CORONARY ARTERY DISEASE PATIENTS USING A PHYSICAL ACTIVITY QUESTIONNAIRE

(ABSTRACT)

This investigation examined the ability of the Veterans Specific Activity Questionnaire (VSAQ) to predict the functional capacities (expressed in metabolic equivalents or METs) of twenty male participants previously diagnosed with CAD who were referred for exercise testing as part of their participation in a community based exercise program. On the morning of their normally scheduled GXT, each individual completed the VSAQ and was administered a maximal exercise test on a treadmill utilizing a ramp style protocol based on their self-estimation of functional capacity. Respiratory gas exchange values were recorded throughout and analyzed via forward multiple stepwise linear regression with respect to several experimental and demographic variables such as age, BMI, skinfold fat and time since entering a cardiac maintenance exercise program. The only variable to contribute significantly to the prediction of FC with regard to exercise capacity as measured by respiratory gas analysis was the VSAQ. The VSAQ explained 22% of the variance in actual performance and this variable only showed a modest association with the criterion measure ($r = 0.47$ SEE 2.25, $p < 0.05$). A similar finding was noted when this criterion of exercise performance was estimated from treadmill speed and grade equations. In this case, the VSAQ accounted for 34% of the variance in exercise performance (i.e., $r = 0.58$ SEE 2.16, $p < 0.05$). The final regression equation by which the VSAQ might be used to predict exercise capacity by the gas exchange criterion was: $\text{METs} = 4.21 + 0.50(\text{VSAQ})$. The final regression equation for prediction of MET exercise capacity by speed/grade at peak exercise was: $\text{METs} = 4.60 + 0.65(\text{VSAQ})$.

INTRODUCTION

Graded exercise testing is used frequently to evaluate functional capacity (FC) in those individuals with coronary artery disease (CAD) and also as a screening test to guide diagnosis of CAD in those with suspicious symptoms. Although there are several factors which must be considered during such testing, one of the most crucial is the proper matching of the patient to a protocol which will optimize the progression of effort toward a symptom limited exercise endpoint. For an optimal clinical result, the selection of an accurate protocol should result in a GXT that is terminated due to one or more of the following endpoints: (1) a test duration of 8 to 12 minutes; (2) an end stage RPE of 17 or higher; and (3) a maximal heart rate of > 85% of age•predicted maximum (1,2). Unfortunately, the conduct of GXT's in the clinical setting is often subject to constraints of time, financial and staffing limitations and thus may be performed with an emphasis upon expediency rather than accuracy. Such tests frequently involve reliance upon fixed stage protocols and the absence of gas exchange measures, both characteristics which carry significant limitations (2,3,4,5,6).

Prior investigations have examined the use of both functional classifications and activity questionnaires as a means to assess a patient's exercise functional tolerance when GXT's are not feasible. The New York Heart Association functional classification, the Canadian Cardiovascular Society functional classification, the Goldman Specific Activity Scale and the Duke Activity Status Index are examples (7,8,9,10). One limitation inherent in these studies is the analysis of the classifications versus fixed stage treadmill protocols (i.e., Bruce) which have been found to frequently result in tests which are either abruptly truncated or far too excessive in length, causing inaccurate estimations of functional capacity (2,3,4). The development of ramping style protocols has addressed this issue with results of increased accuracy among both healthy and CAD populations (3,4).

One recent study in this area that involved the design of a questionnaire intended to match the most accurate GXT protocol with the patient is a Veterans Specific Activity Questionnaire (VSAQ) developed by Myers and co - workers which involves the use of a nomogram to predict maximal oxygen uptake (expressed in metabolic equivalents or METs) (11). This is a self administered questionnaire based on the subject's estimation of their highest level of activity a patient he believes he is able of performing in the absence of angina, fatigue or shortness of breath. The study then examined the figure predicted by the VSAQ versus a predicted value based upon the subject's speed and grade at the maximal stage of a GXT. The investigators noted a high degree of association (R = 0.82) between the maximal MET value predicted by the combination of the VSAQ and age and that determined by measurements of speed/grade at peak exercise, expressed as METs (11).

One limitation inherent to the Myer's study was the absence of gas exchange techniques as a standard of comparison for the VSAQ. Several studies have demonstrated that prediction of true maximal oxygen uptake using peak speed/grade values carries significant limitations when compared to gas exchange responses (3,4,5,6). A questionnaire that accurately estimates functional capacity in patients with CAD utilizing a ramping protocol in conjunction with gas exchange measurements might prove to be a useful tool for clinicians desiring a protocol that would bring a patient to his maximum effort level within established parameters. Thus, the purpose of this study was to examine the predictive ability of the VSAQ in patients following a cardiac exercise maintenance program who possess functional capacities of at least 5 METs.

METHODS

Subjects

Characteristics of the 20 male participants are presented in Table I. 3 were receiving beta blockers, 5 were receiving calcium channel blockers, 2 were receiving digoxin, and 3 nitroglycerin at the time of testing. Fifty five percent of the subjects had previous myocardial infarctions while 30 percent had undergone coronary bypass surgery. The mean time spent in a community based exercise program was 6.5 $\pm$ 4.4 years.

Insert Table 1 Here

Experimental Protocol

GXT Orientation Session. The subjects reported to the laboratory on the program day of their normally scheduled date for clinical testing at 6:20 AM. The subjects gave informed consent within the context of usual clinical evaluations as required for their continuing participation in cardiac rehabilitation. Part of this consent process provides permission to use the data when not personally identifiable with them. Each subject had previously undergone $\geq$ six symptom limited treadmill tests while enrolled in Virginia Tech Cardiac Rehabilitation program.

Equipment utilized for this experiment included a Mortara ECG system (Mortara Instruments, Milwaukee, WI) loaded with a ramping style GXT protocol software developed by Myers and co - workers (11) and a Medical Graphics 2000 gas analysis system (Medical Graphics Corporation, St. Paul, MN). Subjects were provided a verbal description of the ramping procedure, explaining that the speed would begin at 1.5 mph and 0% grade and then increase in increments of 0.1 mph every 10 to 15 seconds to a preset walking speed that would be determined in a few moments. Upon reaching this speed, the grade would increase 0.5% every 10 to 15 seconds until their maximal effort endpoint was reached. The goal was to reach that endpoint in 9 minutes. However, if the subjects still felt that they could continue with the test at 9 minutes, the test would continue with subsequent grade increases until one of the predetermined criteria for termination: fatigue, angina, shortness of breath. Skinfold data was gathered in the standard manner with the 3 sites being the chest, abdomen and thigh and the sum of these measures being examined versus a table of percent body fat computations based on the generalized regression equations for men (12).

A detailed description of the Vacumed mouthpiece followed, with time allotted for subject practice and fitting. A system of hand signals was established to ensure thorough communication between the subject and the testing staff regarding subject effort level as based on the Borg 15 point Rating of Perceived Exertion Scale (13) and test termination criteria. The subject was then given a description of the acceptable techniques for handrail usage during the GXT and instructed that excessive reliance upon handrail support (greater than 30 consecutive seconds of walking with both hands gripping either front or side railings) during the latter stages of the test would result in test termination .

The subject was then directed to the treadmill where they were instructed on the proper technique of treadmill walking with speed being gradually increased until a brisk yet comfortable walking pace was established for use as the subjects maximum speed during the GXT. While on the treadmill, the subject was shown the 15 point Borg RPE scale (13) and explained it's usage, followed by explanations of both the four point angina and dyspnea scales.

GXT Session

Upon completion of the orientation session, the subjects were asked to complete the VSAQ developed by Myers and co-workers (11) and instructed by a staff member to draw a line below the highest level of activity they could accomplish with minimal or no signs of chest discomfort, shortness of breath or fatigue. If the subjects had any questions regarding the completion of the VSAQ, the staff member repeated the written instructions listed at the top of the questionnaire until the subjects complied. No additional coaching or explanation was undertaken by the interviewing staff member to assist in this process. Subject preparation for testing was done in the standard manner, using the modified electrode placement . Mason Likar 12 lead supine and standing 12 lead ECG's followed by blood pressure (BP) recordings were taken. A second review of the Borg 15 point Rating of Perceived Exertion scale (RPE) (13), four point angina and dyspnea scales and the ramping procedure followed.

Respiratory gas exchange variables analyzed included oxygen uptake (VO_2 , L/min STPD), minute ventilation (V_E L/min, BTPS), and respiratory exchange ratio (RER, VCO_2 divided by VO_2). Througout each test, an eight breath recursive average procedure (mean of the current breath and the seven breaths preceding it) was employed to represent the dynamic responses for each gas exchange measure. Baseline respiratory gas exchange measurements were recorded for 1 minute, with the subject in a standing position.

Upon completion of baseline gas exchange measurements, the subject was instructed to begin walking and upon indication that they were comfortable with ambulation, the ramping protocol was initiated. The ECG recordings were taken via the Mortara system at the last 10 seconds of every minute throughout the test and BP and RPE measures at the last 30 seconds of the odd minutes (1,3,5,7, etc.). Once the subject reached one of the termination criteria (fatigue, shortness of breath or angina), the treadmill belt was stopped and standing immediate post exercise (IPE) ECG, BP, HR and gas exchange measurements were taken. These were followed by post exercise data collection for these same measurements taken in a supine position at 1 minute, 2 minutes and then for the even minutes thereafter until HR and BP values returned to pre-exercise baseline values.

Statistical Procedures

Simple univariate regression was performed utilizing measured peak oxygen uptake as the dependent variable (i.e. VO_2 peak in exercise = MET $_{VO2}$) and predicted exercise capacity from the VSAQ (i.e., MET_{VSAQ} = predicted exercise capacity), age, percent body fat, body mass index (BMI) and time spent in a cardiac exercise maintenance program as independent variables. The procedure was then repeated using peak METs estimated from standard formuli (2) that estimate VO_2 responses based on treadmill speed and grade as the dependent variable (i.e., estimated exercise capacity) and the similar independent variables. Forward stepwise multiple regression procedures were performed with variable order and inclusion being identical to those employed during the aforementioned simple univariate regression analysis. Statistical Graphics Corporation software (Rockville, Maryland) was utilized for all descriptive and experimental statistics as well as regression procedures.

RESULTS

Exercise test responses are listed in Table 2. The mean maximal rating of perceived exertion (RPE) of 17.1 suggested that a near maximal effort was reported for this group. A greater percentage of the current study's population had had previous myocardial infarctions or coronary bypass surgery (55 % and 30 % respectively) with respect to those subjects in the Myer's investigation (11) and yet fewer were receiving pharmacological treatment with heart rate and blood pressure lowering medications such as beta blocking agents or calcium channel blocking agents (15% and 20% respectively).

Patients were asked immediately after the test to state the central factor which limited their exercise performance. Overall fatigue accounted for a large majority of the responses (15 or 75%) while shortness of breath (3 or 15%), chest pain (1 or 5%) and leg pain (1 or 5%) were less frequently reported.

Insert Table 2 Here

Stepwise multiple regression analysis was utilized to predict exercise capacity versus both measured METs based on respiratory gas exchange measurements and METs estimated from peak treadmill speed and grade. The only variable to contribute significantly to the prediction of FC with regard to measured exercise capacity was the VSAQ (Table 3). The VSAQ explained 22% of the variance in actual performance and this variable only showed a modest association with the criterion measure ($r = 0.47$ SEE 2.25, $p<0.05$) (Figure 1). A similar finding was noted when this criterion of exercise performance was estimated from treadmill and speed equations. In this case, the VSAQ accounted for 34% of the variance in exercise performance, (i.e., $r = 0.58$, SEE 2.16, $p <0.05$) and no other variable contributed significantly to the prediction of FC (Table 4)(Figure 2). The final regression equation by which the VSAQ might be used to predict exercise capacity by the gas exchange criterion was: METs = 4.21 + 0.50(VSAQ) (Table 6). The final regression equation for prediction of MET exercise capacity by speed/grade at peak exercise was METs = 4.60 + 0.65(VSAQ) (Table 6).

The correlation between measured exercise capacity (in METs) and predicted exercise capacity based on peak treadmill speed and grade was r = 0.78, yielding an r squared of 61.56 % (Table 5). Figure 3 shows the relationship between METs predicted from peak treadmill speed and grade versus measured METs via gas exchange measurements.

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Insert Tables 3,4,5 Here

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Insert Table 6 Here

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Insert Figure 1 Here

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Insert Figure 2 Here

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DISCUSSION

The major finding of this study was that the VSAQ did not appear to be an accurate predictor of FC in patients with CAD who were active (average FC by measurement = 8.2 METs, by estimation of peak treadmill workload = 9.7 METs) and had been enrolled in a cardiac maintenance exercise program for a rather long period of time (average length of participation = 6.3 years) since their event or diagnosis. These results are somewhat contradictory to those noted by Myers and co - workers (1994) (11), who noted a strong correlation (R = 0.82) between the VSAQ and a group of fairly active subjects whose average FC was 7.1 METs.

The value of direct oxygen uptake measurement during a treadmill based GXT for the analysis of peak exercise capacity in the CAD population in relation to other types of testing is well documented (2,14,15,16,17). A comparison of a functional classification versus a GXT involving the analysis of gas exchange variables would thus provide a true indication of that classification's predictive ability. Previous investigations have examined the correlations of such functional classifications as the Goldman Specific Activity Scale (SAS) with maximal treadmill GXT's not including gas exchange analysis (9,18) or the Duke Activity Status Index (DASI) with measured maximal oxygen uptake while on a cycle ergometer (10).

Studies detailing the development of the ramping style protocol have indicated that it is more accurate with regards to estimations of FC than it's fixed stage counterparts, with correlations between this type of protocol and both measured and predicted maximal oxygen uptake ranging from r = 0.87 to r = 0.93. (3,4). Although a degree of variability is observed with testing results, investigations which intend to examine the potential ability of a tool to estimate FC in the absence of maximal exercise testing now must seriously consider this more accurate protocol to be the method of choice as a basis of comparison. There has not been a study to date which examines the comparison of a self administered functional classification versus the highly accurate combination of maximal treadmill testing utilizing a ramping style protocol and analysis of oxygen uptake.

Both the correlation between the VSAQ and measured exercise capacity in this study (r = 0.47) and that between the VSAQ and estimated exercise capacity (r = 0.58) appear to initially indicate that the classification may not be an accurate method of estimating FC in highly active CAD patients. Several potentially limiting factors must be taken into consideration, the first of which is that previous classifications were often compared versus estimated maximal exercise capacity values. This method carries significant limitations due to the fact that estimations of FC based on peak exercise workloads have been consistently demonstrated to over estimate exercise capacity in those with CAD (2,3,4,5,6,14,15,16,17,19,20). Such comparisons may have led to an over estimation of the predictive ability of classifications such as the DASI, SAS, CCS and NYHA by the original investigators and re - analysis of these systems with respect to maximal oxygen uptake values obtained during treadmill testing may possibly indicate lower correlations of these classifications with exercise capacity than originally anticipated. This overestimation may also be true with respect to the high correlation R = 0.82 (SEE 1.42, p<0.001) noted between the VSAQ and estimated FC based on peak treadmill workload in the Myers study (11).

None of the clinical or demographic variables (age, BMI, percent body fat, time of participation in an exercise program) included in this study added significantly to the prediction of exercise capacity (Tables 3 and 4). Previous studies have demonstrated age alone to correlate with estimated exercise capacity from r = -0.3 to r = -0.6 (11,20,21,22). Other investigators have concluded that if age adds significantly to the prediction of FC, then the correlation between the predictor tool , i.e., a functional classification and FC as measured by a treadmill GXT will likely be higher than the tool alone (21). Such studies noted R values of 0.95 and 0.90 when age was involved in the prediction of FC versus values derived from GXT's involving the use of treadmills (21). The Myers study (1994) noted that a correlation of r = -0.6 existed between age and estimated FC, adding 4 % to the explanation of variance in peak estimated METs and raising the correlation coefficient between the VSAQ and predicted exercise capacity from R =0.79 to R = 0.82 (11). This study noted that age did not add significantly to the prediction of exercise capacity when the VSAQ was examined against either measured or estimated FC even though a similarity exists between the current subject population (64 ± 9 years) and that of the Myers'(1994) investigation (62 ± 8 years). There may be several factors, one being the relatively small subject population, which might have contributed to this variable's lack of influence.

Correlations of body composition expressed as either percent fat, BMI or weight with estimated exercise capacity have varied widely in previous research, with percent body fat typically providing the highest correlations of the three (19,23). Jackson and co - workers noted a correlation of r = 0.37 between FC and body composition expressed as BMI but a correlation of r = -0.68 when expressed as percent body fat (19). BMI in this study was somewhat less (25.9 ± 38 versus 28 ± 5) than in the Myers, et al group (1994), suggesting a longer duration of participation by the subjects in a scheduled exercise maintenance program. Neither the current study nor that undertaken by Myers and co-workers found body composition to contribute significantly to the prediction of FC.

Examination of testing results in Table 2 indicates that 70 % of the tests in this study (14 out of 20) were outside the optimal test duration range of 8 to 12 minutes as determined by prior investigations (2,11,14), with 55% of the tests (11 of the 20) exceeding the ideal 12 minute maximum. This is in stark contrast to the results noted by Myers and co- workers, who determined that 90 % of the tests in their study fell in that range (11) and indicates that some of the patients may have significantly underestimated their FC while completing the VSAQ. One concern in this study was the effect of the tests outside the optimal 8 to 12 minute range upon the prediction of FC. Subjective examination of these tests indicated that they did not add to the error variance.

Analysis of the relationship between measured METs based upon respiratory gas exchange data and estimated METs based upon peak treadmill speed and grade in this study reveals that the correlation amongst the two is $r = 0.78$ (Table 5). This value is somewhat low with respect to correlations of measured and estimated VO_2 ranging from $r = 0.84$ to $r = 0.90$ noted in previous studies (6,11) in which the MET values associated with particular speed and grade combinations are based upon generally accepted ACSM equations (2). These results indicate that the MET values noted at certain speeds and grade may not have been accurate in this population of CAD patients. Prior research has noted that estimations of FC based on peak treadmill workload carries significant limitations in the CAD population due to the fact that the equations were designed using healthy individuals and did not recognize such factors as differences in stride length, mechanical efficiency, excessive reliance upon handrails for support and the fact that CAD patients attain lower FC's at identical workloads when compared versus healthy individuals (6,11). Thus, the VSAQ with a correlation of $R = 0.58$ may be quite close in accuracy with respect to prediction of FC versus estimations of peak workload and therefore have potential use in this population when measurements of gas exchange variables are not feasible.

The average self estimated FC of 7.9 METs by the subjects on the VSAQ in the current study is somewhat lower than the estimated FC based on peak treadmill workload of 9.7 METs. As the Myer's group self estimated 6.3 METs and peak treadmill values indicated 7.1 METs, the current study's population clearly possessed FC's higher than those of the Myer's study (1994) and yet also significantly underestimated their FC on the VSAQ to a greater degree. The combination of an almost 2 MET self underestimation by the subjects on the VSAQ and the high percentage of abnormally lengthy GXT's indicate that there may have been some difficulty with regards to comprehension of the procedure for proper completion of the VSAQ by the subject group.

An interesting point that continues this hypothesis is the lack of influence registered by the duration of a subject's enrollment in an exercise maintenance program upon the prediction of exercise capacity. All of the subjects in this study had been enrolled in a community based exercise program for several years since their event, with the mean amount of time of attendance being 6.5 years. These individuals had undergone semi - annual GXT's as part of their enrollment prior to their participation in this study, with several having had up to 20 prior GXT's. Prior investigators have noted that subjects who undergo serial exercise testing tend to register higher FC's than individuals of identical FC's who are undergoing testing for the first time (24). Reasons for this difference include improvements in mechanical efficiency due to added practice at the task being performed and lowered anxiety with regards to the test outcome. Many of the subjects included in this study not only were very familiar with the type of testing they received but had also been engaging in a regular pattern of exercise at virtually the same MET level for several years. It thus stands to reason that they should have been able to estimate their maximal level of activity with relative accuracy.

The aforementioned reasons help raise the possibility that the VSAQ was not applicable to this population due to it's inclusion of activities with which this subject group did not engage on a regular basis. Previous research has indicated that functional classifications must be specific to the population being studied (9,10,25,26). The somewhat lengthy GXT duration of the subjects in this study (mean GXT duration = 12.5 minutes) in relation to optimal test duration of 10 minutes highlights this concern and underscores the possibility that several of the subjects may have underestimated their FC when completing the VSAQ.

This concern was confirmed upon examination of each subject's VSAQ with the MET values of the activities they were engaging in at that time. Many subjects classified themselves in MET levels on the VSAQ far below that which they currently exercised in the Virginia Tech morning exercise program, despite being instructed to select the highest level which contained activities they felt they could achieve. Upon being questioned after the GXT as to why this occurred, several mentioned that the MET level on the VSAQ which contained those activities that they normally engaged in also listed activities with which they were not familiar.

Specifically, some of the activities mentioned were those which required significant isometric movements (such as carrying 60 pounds) which they had not undertaken since their event. The presence of such movements at that MET level created doubt in the minds of the subjects as to whether they could actually complete the task, despite the fact that they easily accomplished many of the others that were listed. This may have led to the subjects choosing MET levels below that which they may otherwise have typically chosen and thus leading to significant underestimation of FC and excessive GXT duration.

Results from this study provide only minimal support for the hypothesis that the VSAQ is generalizable to patient populations which possess higher FC's and treadmill GXT experience than the type of subjects chosen in the Myers study (1994). Potential reasons include the narrow range of MET levels (6 to 10 METs present in this population, the low number of subjects (N = 20), the lack of accurate AT data and improper usage of the VSAQ due to confusion over the presence of activities not relevant to this population. Future studies in this area should therefore consider (1) utilizing larger, more diverse subject populations with wider ranges of maximal MET levels than those used here and (2) modifying the VSAQ by deleting those activities which are not typically undertaken by patients with CAD who are enrolled in supervised exercise programs designed primarily to enhance aerobic endurance.

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Table 1: Description of Characteristics for study patients

Characteristic	Mean	Standard Deviation
Age (years)	64.5	8.8
Height (cm)	176.0	6.8
Weight (kg)	80.3	12.1
Skinfold percent body fat (%)	22.0	6.5
Body mass index (kg/m^2)	25.8	2.9
Resting heart rate (beats per minute)	67.0	11.0
Resting systolic blood pressure (mm Hg)	131.0	15.0
Resting diastolic blood pressure (mm Hg)	78.0	8.0
Time in community exercise program (years)	6.3	4.5
Prior myocardial infarction	11 (55%)	
Prior coronary bypass surgery	6 (30%)	
Medications at time of GXT:		
Beta Blocker	3 (15%)	
Calcium Channel Blocker	5 (20%)	
Digoxin	2 (10%)	
Nitroglycerin	3 (20%)	
Hypertension by physician diagnosis	6 (30%)	

Table 2: Maximal Exercise Test Responses of Subjects in Ramping protocol

Response	Mean	Standard Deviation
Heart rate (b • min)	142	16
Systolic blood pressure (mm Hg)	173	21
Diastolic blood pressure (mm Hg)	84	3
Rating of perceived exertion (RPE)	17.1	1.5
Exercise Capacity by gas exchange [1] (METs)	8.2	2.4
Exercise Capacity by speed/grade [2] (METs)	9.7	2.5
Exercise Capacity by VSAQ [3] (METs)	7.9	2.3
Test duration (minutes)	12.5	3.6
Abnormal ST response to exercise ECG [4]	6 (30%)	

1. Determined from respiratory gas exchange studies.
2. Exercise tolerance estimated from peak treadmill speed and grade.
3. Exercise tolerance estimated from VSAQ.
4. Frequency of cases with > 1 mm ST depression V4-V5 at peak exercise.

Table 3: Multiple Regression Analysis

Dependent Variable: METs by respiratory gas exchange

Parameter	Estimate	Standard Error	T Statistic	P-Value
Constant	4.21	1.83	2.30	0.034
VSAQVO2	0.50	0.22	2.28	0.035

Final Equation: Measured METs = 4.21 + 0.50(VSAQ)

Analysis of Variance

Source	Sum of Squares	DF	Mean Square	F Ratio	P Value
Model	26.18	1	26.18	5.18	0.035
Residual	90.95	18	5.05		

R-squared = 22.35 percent
Standard Error of Estimate = 2.25

Table 4: Multiple Regression Analysis

Dependent Variable: METs by VO_2 formula from speed/grade

Parameter	Estimate	Standard Error	T Statistic	P-Value
Constant	4.60	1.76	2.61	0.018
VSAQVO2	0.65	0.21	3.04	0.007

Final Equation: Estimated METs = 4.60 +0.65(VSAQ)

Analysis of Variance

Source	Sum of Squares	DF	Mean Square	F Ratio	P Value
Model	43.00	1	43.00	9.23	0.007
Residual	83.83	18	4.66		

R-squared = 33.91 percent
Standard Error of Estimate = 2.16

Table 5: Regression Analysis of Predicted on Measured FC

Dependent Variable: Measured METs

Parameter	Estimate	Standard Error	T Statistic	P-Value
Constant	0.87	1.41	0.62	0.54
Estimated METs	0.75	0.14	5.37	0.0000

Final Equation: Measured METs = 0.87 + 0.75(Estimated METs)

Analysis of Variance

Source	Sum of Squares	DF	Mean Square	F Ratio	P Value
Model	72.11	1	72.11	28.83	0.0000
Residual	45.02	18	2.50		

r-squared = 61.56 percent
Standard Error of Estimate = 1.58

Table 6: Summary of Prediction Equations: Measured[1], Predicted[2] and Predicted on Measured[3] Exercise Capacity.

Y	=	Intercept	+	B_1 (X_1)	R^2	SEE
y	`` =	4.20	+	0.50(VSAQ)	22.35	2.24
y	=	4.59	+	0.64(VSAQ)	33.90	2.15
y	=	0.87	+	0.75(Estim. FC)*	61.56	1.58

* Estimated based on peak treadmill speed and grade.

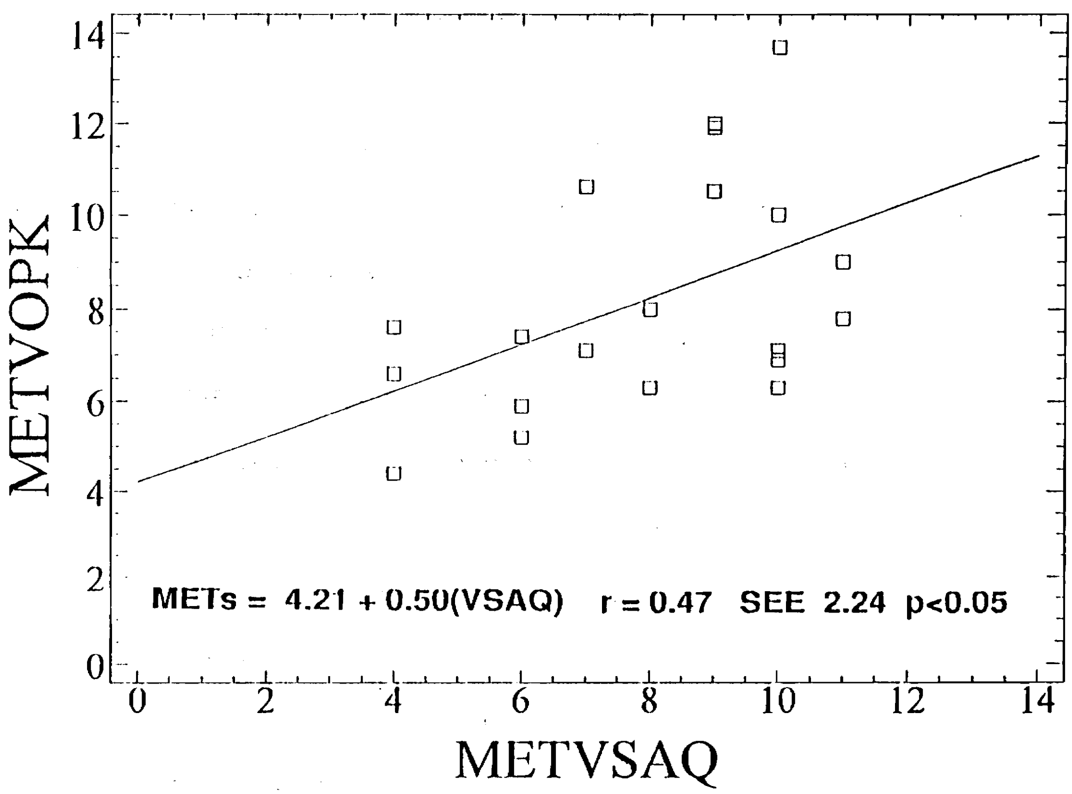

Figure 1. Regression of the relation between metabolic equivalents predicted by multiple regression and those measured by gas exchange

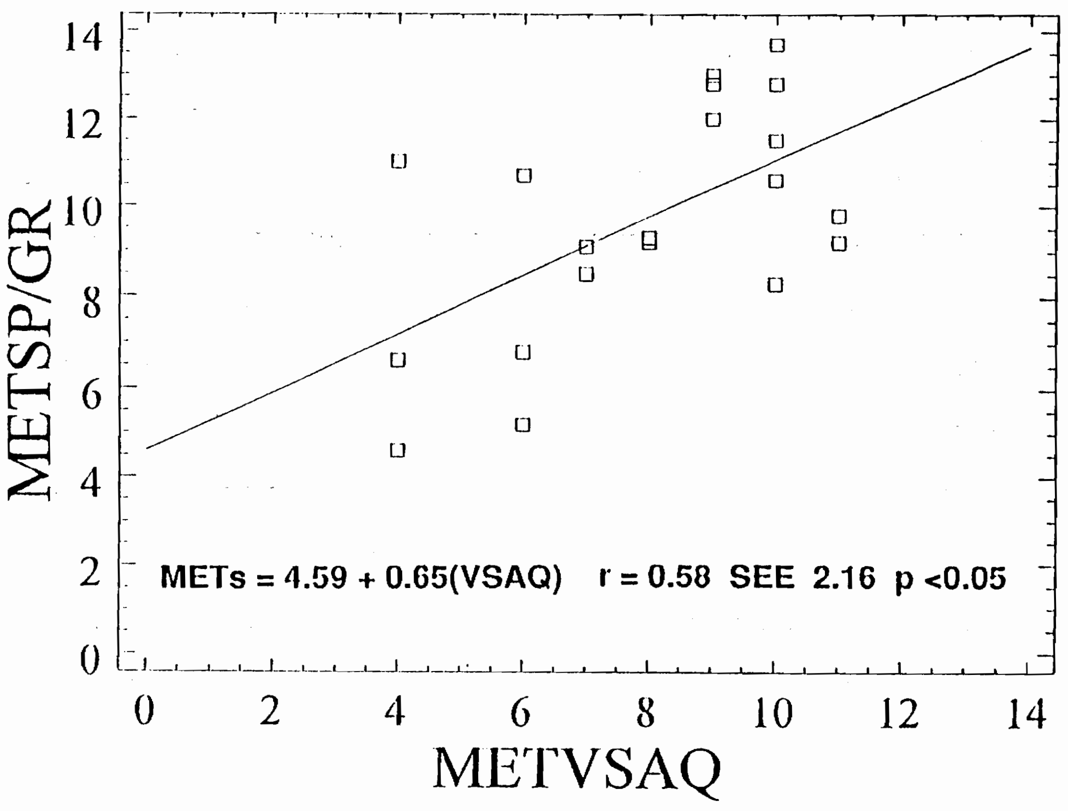

Figure 2. Regression of the relation between metabolic equivalents predicted by multiple regression and those estimated by speed and grade

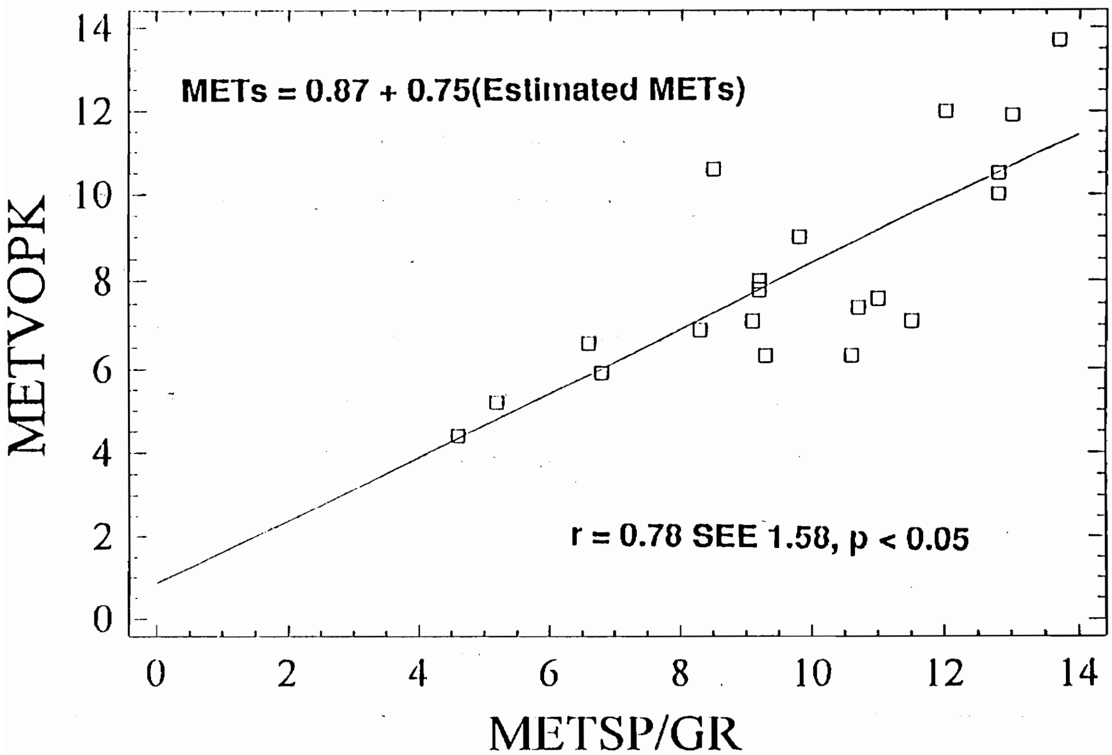

Figure 3. Regression of the relation between metabolic equivalents measured by gas exchange and those estimated by speed and grade

Chapter IV

SUMMARY AND RESEARCH RECOMMENDATIONS

Summary

This study was conducted to determine the predictive ability of the Veterans Specific Activity Questionnaire (VSAQ) to estimate the functional capacities of a group of active coronary artery disease (CAD) patients. Specifically, the purpose of this study was twofold: (1) to examine the predictive ability of the VSAQ in a population of males diagnosed with CAD who were asymptomatic at rest and participated regularly in a cardiovascular maintenance and exercise program; (2) to measure directly the maximal oxygen uptake of the individuals and determine the predictive ability of the VSAQ when this measure was used as the criterion for functional capacity; (3) to compare the results of 2 and 3.

Twenty male subjects currently enrolled in the Virginia Tech Cardiac Therapy and Intervention Center morning exercise program were selected. Each reported to the Virginia Tech Laboratory for Health and Exercise Science on the program day of their normally scheduled date for clinical testing. Informed consent was obtained. Full descriptions of the ramping protocol, the endpoint criteria for termination, the requirements for utilization of gas exchange techniques and the acceptable techniques for handrail usage during the GXT were given. The subject was then instructed to walk on the treadmill in order to determine the proper peak walking speed to be used during the GXT.

Upon completion of the GXT orientation session, the subject was asked to complete the VSAQ developed by Myers and co - workers (1994) and the corresponding maximal MET level along with the peak walking speed were entered into the ramping protocol software program also developed by the authors

(Myers, Herbert, Ribisl, & Froelicher, 1994). The subjects were then prepared for testing in the standard manner, skinfold fat measures were recorded and upon completion of baseline gas exchange and the arrival of the supervising physician, the GXT commenced. ECG, gas exchange and BP measures were recorded throughout the GXT and the test terminated when the subject reached one of the termination criteria. Post exercise measures were recorded until all values resumed their baseline readings.

Simple univariate regression was performed utilizing peak METs via respiratory gas exchange analysis as the dependent variable (i.e., VO_2 peak in exercise = MET_{VO2} and predicted exercise capacity from the VSAQ (i.e., METVSAQ = predicted exercise capacity), age, percent body fat, body mass index (BMI) and time spent in a cardiac exercise maintenance program as the independent variables. The procedure was then repeated using peak METs estimated from standard formuli (American College of Sports Medicine 1994) that estimate VO_2 responses based on treadmill speed and grade as the dependent variable (i.e., estimated exercise capacity) and the similar independent variables.

Forward stepwise multiple regression procedures were then performed with variable order and inclusion being identical to those employed during the aforementioned simple univariate regression analysis. Statistical Graphics Corporation Software (Rockville, Maryland) was utilized for all descriptive and experimental statistics as well as regression procedures.

Stepwise multiple regression analysis was utilized to predict exercise capacity versus both measured METs based on respiratory gas exchange measurements and then METs estimated from peak treadmill speed and grade . The only variable to add significantly to the prediction of FC with regards to measured exercise capacity was the VSAQ (Table 3). The VSAQ explained 22% of the variance in actual performance and this variable only showed a modest association with the criterion measure ($r = 0.47$ SEE 2.25, $p < 0.05$)(Figure 1). A similar finding was noted when this criterion of exercise performance was estimated from treadmill and speed equations. In this case, the VSAQ accounted for 34% of the variance in exercise performance, r = of 0.58 (SEE 2.16, $p<0.05$) and no other variable contributed significantly to the prediction of FC(Table 4) (Figure 2). The final regression equation by which the VSAQ might be used to predict exercise capacity by the gas exchange criterion was: METs = 4.21 + 0.50(VSAQ) (Table 6). The final regression equation for prediction of MET exercise capacity by speed/grade at peak exercise was METs = 4.60 + 0.65(VSAQ).

The correlation between measured exercise capacity (in METs) and predicted exercise capacity based on peak treadmill speed and grade was r = 0.78, yielding an r squared of 61.56 % (Table 5). Figure 3 shows the relationship between METs predicted from peak treadmill speed and grade versus measured METs via gas exchange measurements.

Research Implications

The results of this study suggest that the VSAQ did not appear to be an accurate predictor of FC in patients with CAD who were active and had been enrolled in a cardiac maintenance exercise program for a rather long period of time (average length of participation = 6.5 years) since their event or diagnosis. These results are somewhat contradictory to those noted by Myers and co - workers (Myers, et al., 1994), who noted a strong correlation ($R = 0.82$) between the VSAQ and a group of subjects whose average FC was only slightly lower than those utilized in this study.

The value of direct oxygen uptake measurement during a treadmill based GXT for the analysis of peak exercise capacity in the CAD population in relation to other types of testing is well documented (American College of Sports

Medicine, 1994; Buchfuhrer, Hansen, Robinson, Sue, Wasserman, & Whipp, 1983; Franklin, 1986; Foster, Jackson, Pollock, Taylor, Hare, Sennet, Rod, Sarwar, & Schmidt 1983; Glassford, Baycroft, Sedgewick, MacNab,1965). A comparison of a functional classification versus a GXT involving the analysis of gas exchange variables would thus provide a true indication of that classification's predictive ability. Previous investigations have examined the correlations of such functional classifications as the Goldman Specific Activity Scale (SAS) with maximal treadmill GXT's not including gas exchange analysis (Goldman, Hashimoto, Cook, & Loscalzo, 1981) or The Duke Activity Status Index (DASI) with measured maximal oxygen uptake while on a cycle ergometer (Hlatkey, Boineau, Higginbotham, Lee, Mark, Califf, Cobb, & Pryor 1989). Studies detailing the development of the ramping style protocol have indicated that it is more accurate with regards to estimations of FC than it's fixed stage counterparts, with correlations between this type of protocol and both measured and predicted maximal oxygen uptake ranging from $r = 0.87$ to $r = 0.93$. (Myers, Buchanan, Smith, Neutel, Bowes, Walsh, & Froelicher, 1991; Myers, Buchanan, Walsh, Kraemer, McAuley, Hamilton-Wesser, Froelicher, 1991). Although a degree of variability is observed with testing results, investigations which intend to examine the potential ability of a tool to estimate FC in the absence of maximal exercise testing now must seriously consider this more accurate protocol to be the method of choice as a basis of comparison. There has not been a study to date which examines the comparison of a self administered functional classification versus the highly accurate combination of maximal treadmill testing utilizing a ramping style protocol and analysis of oxygen uptake.

Both the low individual correlation between the VSAQ and measured exercise capacity ($R = 0.47$) and the lack of correlation with regards to stepwise forward multiple regression in this study appear to initially indicate that the classification may not be an accurate method of estimating FC in highly active CAD patients. Several potentially limiting factors must be taken into consideration, the first of which is that previous classifications were often compared versus estimated maximal exercise capacity values. This method carries significant limitations due to the fact that estimations of FC based on peak exercise workloads have been consistently demonstrated to over estimate exercise capacity in those with CAD (American College of Sports Medicine, 1994; Myers, et al.,1991; Myers, Buchanan, Walsh, et al., 1991; Sullivan, & McKirnan, 1984; Haskell, Savin, Oldridge, & DeBusk, 1982; Buchfuhrer, et al., 1983; Franklin, 1986; Foster, et al., 1983; Glassford, et al., 1965; Jackson, Blair, Mahar, Wier, Ross, & Stuteville, 1990; Milesis, 1987). Such comparisons may have led to an over estimation of the predictive ability of classifications such as the DASI, SAS, CCS and NYHA by the original investigators and re - analysis of these systems with respect to maximal oxygen uptake values obtained during treadmill testing may possibly indicate lower correlations of these classifications with exercise capacity than originally anticipated. This overestimation may also be true with respect to the high correlation $R = 0.82$ (SEE 1.42, $p<0.001$) noted between the VSAQ and estimated FC based on peak treadmill workload in the Myers study (Myers, Do, et al., 1994). Several possible explanations may exist as to why such low correlations were noted between the VSAQ both measured and estimated exercise capacity.

None of the clinical or demographic variables (age, BMI, percent body fat, time of participation in an exercise program) included in this study added significantly to the prediction of exercise capacity (Tables 5 and 6). Previous studies have demonstrated age alone to correlate with estimated exercise capacity from $r = -0.3$ to $r = -0.6$ (Myers, Do, et al., 1994; Milesis, 1987; Hermiston & Faulkner, 1971; Bruce, Kusumi & Hosmer, 1973). Other investigators have concluded that if age adds significantly to the prediction of FC, then the correlation between the predictor tool , i.e., a functional classification and FC as measured by a treadmill GXT will likely be higher than the tool alone (Hermiston & Faulkner, 1971). Such studies noted R values of 0.95 and 0.90 when age was involved in the prediction of FC versus values derived from GXT's involving the use of treadmills (Hermiston & Faulkner, 1971). The Myers study (1994) noted that a correlation of r = -0.6 existed between age and estimated FC, adding 4 % to the explanation of variance in peak estimated METs and raising the correlation coefficient between the VSAQ and predicted exercise capacity from R = 0.79 to R = 0.82 (Myers, Do, et al., 1994). This study noted that age did not add significantly to the prediction of exercise capacity when the VSAQ was examined against either measured or estimated FC even though a similarity exists between the current subject population (64 ± 9 years) and that of the Myer's(1994) investigation (62 ± 8 years). There may be several factors, one being the relatively small subject population, which might have contributed to this variable's lack of influence.

Correlations of body composition expressed as either percent fat, BMI or weight with estimated exercise capacity have varied widely in previous research, with percent body fat typically providing the highest correlations of the three (Jackson, et al., 1990; Kline, Porcari, Hintermeister, Freedson, Ward, McCarron, Ross & Rippe, 1987). Jackson and co - workers noted a correlation of r = 0.37 between FC and body composition expressed as BMI but a correlation of r = -0.68 when expressed as percent body fat (Jackson, et al., 1990). The lack of this variable to add significantly to the prediction of exercise capacity may have helped to create the low correlations between the VSAQ and both measured and predicted exercise capacity in this study.

Examination of testing results in Table 2 indicates that 70 % of the tests in this study (14 out of 20) were outside the optimal test duration range of 8 to 12 minutes as determined by prior investigations (Myers, , et al., 1994; Buchfuhrer, et al., 1983), with 55% of the test (11 out of 20) exceeding the ideal 12 minute maximum. This is in stark contrast to the results noted by Myers and co-workers, (Myers, Do, et al., 1994) who determined that 90 % of the tests in that study fell in that range.

Analysis of the relationship between measured METs based upon respiratory gas exchange data and estimated METs based upon peak treadmill speed and grade in this study reveals that the correlation amongst the two is $r = 0.78$ (Table 5). This value is somewhat low with respect to correlations of measured and estimated VO2 ranging from $r = 0.84$ to $r = 0.90$ noted in previous studies (Foster,Jackson, Pollock, Taylor, Hare, Sennet, Rod, Sarwar, & Schmidt,1984; Foster, Hare, Taylor, Goldstein, Anaholm, Pollock, 1984) in which the MET values associated with particular speed and grade values are based upon generally accepted ACSM equations (American College of Sports Medicine). These results indicate that the MET values noted at certain speed and grade combinations may not have been accurate in this population of CAD patients. Prior research has noted that estimations of FC based on peak treadmill workload carries significant limitations in the CAD population due to the fact that the equations were designed using healthy individuals and did not recognize such factors as differences in stride length, mechanical efficiency, excessive reliance upon handrails for support and the fact that CAD patients attain lower FC's at identical workloads when compared versus healthy individuals (Foster, Jackson, et al., 1984). Thus, the VSAQ with a correlation of $R = 0.58$ may be quite close in accuracy with respect to prediction of FC versus estimations of peak workload and therefore have potential use in this population when measurements of gas exchange are not feasible.

The average self estimated FC of 7.9 METs by the subjects on the VSAQ in the current study contrasts with the estimated FC based on peak treadmill workload of 9.7 METs .As the Myer's group self estimated 6.3 METs and peak treadmill values indicated 7.1 METs, the current study's population clearly possessed FC's higher than those of the Myer's study (1994) and yet also significantly underestimated their FC on the VSAQ to a greater degree. The combination of an almost 2 MET self underestimation by the subjects in this study on the VSAQ and the high percentage of abnormally lengthy GXT's indicate that there may have been some difficulty with regards to comprehension of the procedure for proper completion of the VSAQ by the subject group.

An interesting point that continues this hypothesis is the lack of influence registered by the duration of a subject's enrollment in an exercise maintenance program upon the prediction of exercise capacity. All of the subjects in this study had been enrolled in a community based exercise program for several years since their event, with the mean amount of time of attendance being 6.3 years. These individuals had undergone semi - annual GXT's as part of their enrollment prior to their participation in this study, with several having had up to 20 prior GXT's. Prior investigators have noted that subjects who undergo serial exercise testing tend to register higher FC's than individuals of identical FC's who are undergoing testing for the first time (Froelicher, Brammel, Davis, Noguera, Stewart, & Lancaster, 1974). Reasons for this difference include improvements in mechanical efficiency due to added practice at the task being performed and lowered anxiety with regards to the test outcome. Many of the subjects included in this study not only were very familiar with the type of testing they received but had also been engaging in a regular pattern of exercise at virtually the same MET level for several years. It thus stands to reason that they should have been able to estimate their maximal level of activity with relative accuracy.

The aforementioned reasons help raise the possibility that the VSAQ was not applicable to this population due to it's inclusion of activities with which this subject group did not engage on a regular basis. Previous research has indicated that functional classifications must be specific to the population being studied (Goldman, et al., 1981; Hlatkey, et al., 1989; Lamb & Brodie, 1990; Cox & Naylor, 1992). The somewhat lengthy GXT duration of the subjects in this study (mean GXT duration = 12.5 minutes) in relation to optimal test duration of 10 minutes highlights this concern and underscores the possibility that several of the subjects may have underestimated their FC when completing the VSAQ.

This concern was confirmed upon examination of each subject's VSAQ with the MET values of the activities they were engaging in at that time. Many subjects classified themselves in MET levels on the VSAQ far below that which they currently exercised in the Virginia Tech morning exercise program, despite being instructed to select the highest level which contained activities they felt they could achieve. Upon being questioned after the GXT as to why this occurred, several mentioned that the MET level on the VSAQ which contained those activities that they normally engaged in also listed activities with which they were not familiar. Specifically, some of the activities mentioned were those which required significant isometric movements (such as carrying 60 pounds) which they had not undertaken since their event. The presence of such movements at that MET level created doubt in the minds of the subjects as to whether they could actually complete the task, despite the fact that they easily accomplished many of the others that were listed. This may have led to the subjects choosing MET levels below that which they may otherwise have typically chosen and thus leading to significant underestimation of FC and excessive GXT duration.

Recommendations for Future Research

Results of this study warrant a need for further research investigating the predictive ability of the VSAQ with regards to measured and estimated exercise capacity in a population of active individuals diagnosed with CAD. Recommendations for future research include a variety of areas which may aid in an accurate assessment of the VSAQ's capabilities.

Future investigations examining the predictive ability of the VSAQ should utilize gas exchange measures as the primary basis of comparison for the classification. The value of direct oxygen uptake measurement during a treadmill based GXT for the analysis of peak exercise capacity in the CAD population in relation to other types of testing is well documented (American College of Sports Medicine, 1994; Buchfuhrer, Hansen, Robinson, Sue, Wasserman, & Whipp, 1983; Franklin, 1986; Foster, Jackson, Pollock, Taylor, Hare, Sennet, Rod, Sarwar, & Schmidt 1983; Glassford, Baycroft, Sedgewick, MacNab,1965). Previous investigations have examined the correlations of such functional classifications as the Goldman Specific Activity Scale (SAS) with maximal treadmill GXT's not including gas exchange analysis (Goldman, Hashimoto, Cook, & Loscalzo, A. 1981) or The Duke Activity Status Index (DASI) with measured maximal oxygen uptake while on a cycle ergometer (Hlatkey, Boineau, Higginbotham, Lee, Mark, Califf, Cobb, & Pryor 1989). Comparisons of the VSAQ versus the analysis of gas exchange variables would thus provide true indications of the classification's predictive ability.

Studies detailing the development of the ramping style protocol have indicated that it is more accurate with regards to estimations of FC than it's fixed stage counterparts, with correlations between this type of protocol and both measured and predicted maximal oxygen uptake ranging from r = 0.87 to r = 0.93. (Myers, Buchanan, Smith, Neutel, Bowes, Walsh, & Froelicher, 1991; Myers, Buchanan, Walsh, Kraemer, McAuley, Hamilton-Wesser, Froelicher, 1991). Although a degree of variability is observed with testing results, future investigations which intend to examine the potential ability of a tool to estimate FC in the absence of maximal exercise testing now must seriously consider this more accurate protocol to be the method of choice as a basis of comparison. Future investigations should thus strongly consider a GXT consisting of the combination of gas exchange measurements and the ramping protocol as the best current method of examining the VSAQ's capabilities.

Previous research has indicated that functional classifications must be specific to the population being studied (Goldman, et al., 1981; Hlatkey, et al., 1989; Lamb & Brodie, 1990; Cox & Naylor, 1992). If subjects are not familiar with the activities listed in a self administered classification, errors of self estimation may occur. Some of the activities which may require close scrutiny are those which require significant isometric movements (such as carrying 60 pounds). The presence of such movements at a particular MET level may create doubt in the minds of the subjects as to whether they can engage in the other activities at that level, despite the fact that they may easily accomplish some of them on a daily basis. As seen in the current study, this situation may lead to the subjects choosing MET levels below that which they may otherwise have chosen, resulting in significant underestimations of FC and excessive GXT duration. Future investigations will need to adapt the VSAQ to the targeted population by either adding applicable activities or removing non applicable ones as the subject population warrants.

Another possible structural modification to the VSAQ which may prove to be useful would be to consider inverting the questionnaire and have the subjects complete it from the top down, i.e., start at 13 METs and work their way down until they find one activity that they can complete without the emergence of the limiting symptoms. This technique may lead to the subjects' self selection of a MET level that is closer to their true maximal exercise capacity.

The limited range of subjects with regards to both number and FC in this study (N = 20) and truncated MET range (6 to 10 METs) was a definite limitation and one that needs to be avoided by subsequent investigators. Future studies should expand the subject base to include several hundred individuals of varying functional capabilities. The absence of female subjects represents another area of this study which should be addressed. Previous investigations throughout the development of the SAQ line of research have suffered from a similar shortcoming (Goldman, et al., 1981; Lee, et al., 1988, Hlatkey, et al., 1989; Myers & Do, et al., 1994). The VSAQ should be modified to include activities specific to the female population, some of which may not be present in the current version.

The final recommendation for future research would be devise a comprehensive study in which all of the SAQ's constructed to date - NYHA, CCS, SAS., DASI, and VSAQ would be administered to subjects and analyzed versus maximal treadmill testing utilizing ramp style protocols and gas exchange analysis. Such a study might determine the most accurate classification currently available for use in the CAD population.

Implications for Clinical Practice

The recent concern over the rising costs of health care in the United States has produced dramatic changes in the methods by which institutions examine the clinical outcomes of the treatments and services offered. While cost effectiveness and efficiency of service are important issues, the assessment of the actual outcome of the treatments has risen to the forefront. Outpatient cardiac rehabilitation is often examined with regard to any changes in physical exercise tolerance made by the patients during their stay in either phase II or phase III maintenance programs. Serial exercise testing is the current method of choice in this regard but financial, time and staffing requirements can limit the application of this method to once every 12 months. The VSAQ could possibly be a rapid, safe and effective adjunct to serial GXT's as it can be easily administered on a more frequent basis without the burdensome requirements of exercise testing.

Another possible use of the VSAQ in this regard might be as a tool for examining the changes in FC of those patients who cannot attend supervised phase II or II exercise programs due to location or other reasons and must thus rely upon home activities. A system could be established whereby staff of either the cardiologist or cardiovascular surgeon administers the classification upon the patient's dismissal from the hospital, at the 4 to 6 week follow-up visit and every 3 to 6 months thereafter. Such a system would allow the physician to track the individual's progress while avoiding the inconvenience of repeated, lengthy visits to the clinic for the purpose of exercise testing.

The VSAQ would also be useful as a screening device for patients with low FC's entering cardiac rehabilitation programs, especially those who did not participate in a GXT at the conclusion of phase I rehabilitation. The classification could possibly replace the New York Heart Association functional classification (Criteria Committee of the New York Heart Association, 1964) in this regard. Programs would be able to screen both incoming and current patients rapidly, accurately, efficiently and at a relatively low cost.

The current trend towards enhanced accuracy in exercise testing may result in the increased utilization of the ramping type protocol. Institutions which use this protocol will very likely need a reliable method for rapidly determining the maximal target MET to be entered into the computer running the testing equipment. The VSAQ would be very effective in this role.

The results of this study indicate that the VSAQ may not be generalizable to patient populations which possess relatively high FC's and treadmill GXT experience due to extended participation in supervised exercise programs. Future studies in this area should therefore consider (1) utilizing larger, more diverse subject populations with wider ranges of MET levels than those used here and (2) modifying the VSAQ by deleting those activities which are not typically undertaken by patients with CAD who are enrolled in supervised exercise programs designed primarily to enhance aerobic endurance.

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APPENDIX A

METHODOLOGY

METHODOLOGY

Subjects

The subjects in this study were twenty participants currently enrolled in the Virginia Tech Cardiac Therapy and Intervention Center morning exercise program . Each had been previously diagnosed with coronary artery disease, suffered a myocardial infarction or undergone coronary bypass surgery prior to entrance into the program.

Experimental Protocol

GXT Orientation Session. The subjects reported to the Virginia Tech Laboratory for Health and Exercise Science on the program day of their normally scheduled date for clinical testing at 6:20 AM. Physician supervised exercise evaluations are given periodically as part of the continual evaluation protocol of the patients in the Virginia Tech Cardiac Therapy and Intervention Center clinical exercise program. The subjects were asked to read and sign an informed consent as approved by the Virginia Tech Education Department Investigators Review Board describing the test and the risks and benefits applicable to such a procedure. After being given the opportunity to ask questions and their questions answered, their informed consent was obtained.

The first few minutes after their arrival were utilized to describe the differences between the present protocol and the previous GXT they underwent. A full description of the ramping procedure followed, explaining that the speed would begin at 1.5 mph and 0% grade and then increase in increments of 0.1 mph every 10 to 15 seconds to a preset walking speed that would be determined in a few moments. Upon reaching this speed, the grade would increase 0.5% every 10 to 15 seconds until the endpoint was reached. The goal was to reach that endpoint in nine minutes. However, if the subjects still felt that they could continue with the test at nine minutes, the test would continue with subsequent grade increases until one of the predetermined criteria for termination was reached. The subjects were then advised of these endpoint criteria for GXT termination: fatigue, angina or shortness of breath.

A detailed description of the Vacumed mouthpiece followed. The subject was told why the mouthpiece was going to be used - the fact that gas analysis is the highest standard of measurement of oxygen uptake and provides a true indicator of functional capacity. Next, the staff member displayed the mouthpiece to the subject and described the proper method for mouthpiece usage: to bite down on the rear inner projections and to make a tight seal around the edges with their lips, trying to avoid excess tension. The staff member demonstrated this technique to the subject and watched as they tried it. The individual was then told that they might experience some throat dryness from usage of the mouthpiece and that they would be given water before the GXT to alleviate the dryness.

The subject was then given a description of the acceptable techniques for handrail usage during the GXT. They were given the option of selecting one of two methods, the first of which was a right handed, open palm grip on the front rail. The second was the usage of two fingers on each side rail for balance. Once the subject was observed by a staff member to begin to demonstrate significant muscular tension development in their arms due to excessive reliance upon the handrail, they would be asked once to lighten their grip. If the subject reverted back to the heavy handrail holding again during the GXT, an endpoint would be considered to have been reached and the test terminated.

The subject was then told that the mouthpiece would preclude any verbal communication during the GXT and that a system of hand signals was going to be established. A thumbs up signal from the subject meant that they felt no chest pain, shortness of breath or significant fatigue and that they could continue the GXT. This signal would be used in response to the question "How do you feel?" asked by a staff member during the GXT just after the Borg 15 point Rating of Perceived Exertion Scale was presented. A thumbs down signal meant that they did not feel well and would elicit a series of questions from a staff member as to what was wrong. The first of the questions was: "Are you experiencing any chest, shoulder or jaw discomfort?" If the answer was yes to this question, a four point angina scale would be produced and the subject asked to rate the pain. The other questions were: " Are you having any leg or calf pain?", "Are you experiencing shortness of breath?" and "Do you want to stop the test right away?" Answers of yes (a thumbs up sign) would result in test termination. Towards the endpoint at nine minutes, the subject would be asked: "Can you continue another 30 seconds?" A horizontal abduction - adduction movement of the wrist would mean that they chose to stop the test within 30 seconds.

The subject was then directed to the treadmill where they were instructed on the proper technique of treadmill walking and asked to walk at a speed of 1.5 miles per hour for a minute as a warm up. Speed was gradually increased until a brisk walking pace was established, taking into account the individual's locomotive ability and stride length. While on the treadmill, the subject was shown the 15 point Borg RPE scale and explained it's usage, followed by both the four point angina and dyspnea scales. Upon determination of the subject's walking speed, they were brought back down to 1.5 miles per hour and the belt was stopped.

<u>GXT Session</u>

Upon completion of the orientation session, the subjects were asked to complete the VSAQ developed by Myers and co-workers (1994) and instructed by a staff member to draw a line below the highest level of activity they could accomplish with minimal or no signs of chest discomfort, shortness of breath or fatigue. The corresponding maximal MET level was entered into a ramp protocol software program in a Mortara computer also developed by the authors which automatically increases treadmill speed and grade after a predicted value for maximal exercise capacity and individualized walking speed are entered.

Skinfold measurement sites for percent body fat analysis were in order :chest, abdomen and thigh. Three measures were recorded at each site. The total value in millimeters was compared versus a table of percent fat computations based on the generalized regression equations for men developed by Jackson, et al (1978). The subject was then prepared for testing in the standard manner with electrode placement being the Mason - Likar 12 lead system. Both supine and standing 12 lead ECG and blood pressure (BP) recordings were taken. The subject was then seated on a chair placed on the treadmill and offered water to alleviate some possible throat dryness that might occur with mouthpiece usage. A review of the Borg 15 point Rating of Perceived Exertion scale (RPE) and four point angina and dyspnea scales followed. The subject was reminded of the ramping procedure, i.e., the fact that the speed would increase to their previously established walking speed and that the grade changes would occur almost continuously after that point until the subject reached their maximal physical effort.

Upon arrival of the Board Certified Cardiologist or Internist, the subject was fitted with a Hans Rudolph 2700 non rebreathing valve equipped with a Vacumed mouthpiece and headgear apparatus connected to a calibrated Medical Graphics 2001 metabolic measurement cart. Respiratory gas exchange variables analyzed included oxygen uptake (VO2 , L/min STPD), minute ventilation (V_E L/min, BTPS), and respiratory exchange ratio (RER, VCO2 divided by VO2). An eight breath moving average sample (mean of the current breath and the seven breaths preceding it) corresponding to the treadmill speed and grade at peak exercise was used. Baseline respiratory gas exchange measurements were recorded for one minute with the subject in a standing position.

Upon completion of baseline gas exchange measurements, the subject was instructed to straddle the treadmill belt and the belt turned on to a speed of 1.5 miles per hour. A staff member then asked the subject to swing one foot over the belt to get a feel for the speed and then to begin walking. Once the subject appeared to feel comfortable with ambulation, the ramping protocol was initiated. ECG recordings were taken via the Mortara system at the last ten seconds of every minute throughout the test and BP and RPE measures at the last 30 seconds of the odd minutes. The F_ECO2, F_EO2, and V_EATPS values were automatically recorded every 30 seconds by the Medical Graphics system upon processing through the instrument's pneumotach, O_2 and CO_2 analyzers. Once the subject reached on of the termination criteria (fatigue, shortness of breath or angina), the treadmill belt was stopped and standing immediate post exercise measurements (IPE) ECG, BP, HR and gas exchange were taken. These were followed by identical post exercise measurements at one minute, two minutes and then for the even minutes thereafter until HR and BP values returned to pre-exercise baseline values.

Statistical Procedures

Simple univariate regression was performed utilizing peak METs via respiratory gas exchange analysis as the dependent variable (i.e., measured exercise capacity) and METs estimated by the VSAQ (i.e., predicted exercise capacity), percent body fat by skinfold, BMI, age and time spent in a cardiac exercise maintenance program as the independent variables. The procedure was then repeated with peak METs estimated from treadmill speed and grade as the dependent variable (i.e., estimated exercise capacity) and the independent variables remaining the same.

A forward stepwise multiple regression procedure was then performed with measured exercise capacity as the dependent variable and METs by VSAQ, age, percent body fat, body mass index, time since event and time spent in the supervised exercise program as independent variables. The procedure was repeated with estimated exercise capacity as the dependent variable with the independent variables remaining the same. Statistical Graphics Corporation software (Rockville, Maryland) was utilized for all descriptive and experimental statistics as well as regression procedures.

APPENDIX B

INFORMED CONSENT

Cardiac Therapy & Intervention Center at Virginia Tech

INFORMED CONSENT FOR EXERCISE EVALUATION OF PARTICIPANTS FOR CARDIAC THERAPY & CARDIAC FITNESS PROGAMS

Name ____

1. Purpose and Explanation of Procedure

I hereby consent to voluntarily engage in an exercise test to determine my exercise capacity and state of cardiovascular health. I also consent to the taking of samples of my exhaled air during exercise to properly measure my oxygen consumption. I also consent, if necessary, to have a small blood sample drawn by needle from my arm for blood chemistry analysis and to the performance of lung function and body fat (skinfold pinch) and standard psychological tests. It is my understanding that the information obtained will help me evaluate future physical activities in which I may safely engage and will aid my doctor in his determination of an appropriate medical treatment for me.

Before I undergo the test, I certify that my health condition has not changed recently and that I have had a physical examination conducted by a licensed medical physician within the last _____ months, and that my physician has recommended the exercise test and referred me to this particular center for performance of the test. Further, I have completed the pre-test history interview presented to me by the program staff and have provided correct responses to the questions as indicated on the history form or as supplied to the interviewer. It is my understanding that I will be interviewed by a physician and another person prior to my undergoing the test. In the course of these interviews, it will be determined if there are any reasons which would make it undesireable or unsafe for me to take the test. Consequently, I understand that it is important that I provide complete and accurate responses to the interviewer and recognize that my failure to do so could lead to possible unnecessary injury to myself during the test.

The test which I will undergo will be performed on a motor driven treadmill or bicycle ergometer with the amount of effort gradually increasing. As I understand it, this increase in effort will continue until I verbally report to the operator any symptoms such as fatigue, shortness of breath or chest discomfort which may appear. It is my understanding and I have been clearly advised that it is my right to request that the test be stopped at any point if I feel unusual discomfort or fatigue. I have been advised that I should immediately upon experiencing any such symptoms or if I so choose, inform the operator that I wish to stop the test at that or any other point. My stated wishes in this regard shall be absolutely carried out.

It is further my understanding that prior to beginning the test, I will be connected by electrodes and cables to an electrocardiographic recorder which will enable the program personnel to monitor my cardiac (heart) activity. During the test itself, it is my understanding that a physician or his trained observer will monitor my responses continuously and take frequent readings of blood pressure, the electrocardiogram, and my expressed feelings of discomfort or effort.

Once the test has been completed, but before I am released from the test area, I will be given special instructions about showering and recognition of certain symptoms which may appear within the first 24 hours after the test. I agree to follow these instructions and promptly contact the program personnel or medical providers if such symptoms develop.

2. Risks

It is my understanding and I have been informed that there exists the possibility during exercise of adverse changes during the actual test. I have been informed that these changes could include abnormal blood pressure, fainting, disorders of heart rhythm, and very rare instances of heart attack. Every effort, I have been told, will be made to minimize these occurrences by preliminary examination and by precautions and observations taken during the test. I have also been informed that emergency equipment and personnel are readily available to deal with unusual situations should these occur. I understand that there is a risk of injury or heart attack as a result of my performance of this test but knowing those risks, it is my desire to proceed to take the test as herein indicated.

3. Benefits to be Expected and Alternatives Available to the Exercise Testing Procedure

I understand that the possible beneficial results of this test depend upon my doctor's medical reasons for requesting it. It may be helpful in determining my chances of having heart disease that should be treated medically. If my doctor suspects or knows already that I have heart disease, this test may help to evaluate how this disease affects my ability to safely do certain types of physical work or exercises and how to best treat the disease. Other tests for determining the presence or severity of heart disease may be available as alternatives to this exercise test, as are alternative ways to assess my physical fitness. I have had an opportunity to ask about these and have been given answers regarding advantages/disadvantages as noted below:

____

____

4. **Confidentiality and Use of Information**

I have been informed that the information which is obtained in this exercise program will be treated as privileged and confidential and will consequently not be released or revealed to any person without my express written consent. I do however agree to the use of any information which is not personally identifiable with me for research statistical purposes so long as same does not identify my person or provide facts which could lead to my identification. Any other information obtained however, will be used only by the program staff in the course of prescribing exercise for me, and evaluating my progress in the program.

5. **Inquiries and Freedom of Consent**

I have been given an opportunity to ask certain questions as to the procedures of this program. Generally these requests which have been noted by the interviewing staff member and his/her responses are as follows:

____

____

____

____

6. **Program Personnel Notes and Observations as to Conduct of the Informed Consent Procedure**

____

____

____

7. **Release:** In consideration of my participation in this program, I hereby release, hold harmless and indemnify Virginia Polytechnic Institute and State University, and its agents, officers and employees from any and all liability or responsibility for any injury, illness or other similar occurrence, including heart attack or its resultant complications which might arise out of my participation in this program.

Date	Patient Signature	Staff Name (Print)	Staff Signature
Date	Patient Signature	Staff Name (Print)	Staff Signature
Date	Patient Signature	Staff Name (Print)	Staff Signature
Date	Patient Signature	Staff Name (Print)	Staff Signature

APPENDIX C
SUBJECT DATA SHEET

VSAQ STUDY DATA SHEET

Name__________________ Age_____ Ht:______cm Wt:______kg Date:___/___/___

Medical History ____

____

Medications: ____

Previous GXTprotocol: ________ VSAQ predicted max METs: ________

Previous GXT max METs: ________ Mortara max METs: ________

Previous GXT max workload: ________ Med Graphics max METs: ________

Ramp max speed: ________ (Max speed not > 4mph)

Pre- Exercise Data

	Supine	Standing		Supine	Standing
HR	______	________	BP	______	______

Exercise Data

	Mortara						MedGr			
Min	Workload	METs	HR	BP	RPE	VE/VCO2	VE/VO2	VCO2	VO2	METs
1:00				/						
2:00				/						
3:00				/						
4:00				/						
5:00				/						
6:00				/						
7:00				/						
8:00				/						
9:00				/						
10:00				/						
11:00				/						
12:00				/						

Reason for termination1)____________________ 2)________________ Total Time:_____

Skinfold Data:

Site	Trial 1	Trial 2	Trial 3	Total		
					BMI =	
Chest:						
Abdomen:					%Fat=	______
Thigh:						

APPENDIX D

SPECIFIC ACTIVITY QUESTIONNAIRES

New York Heart Association Functional Classification

Class I. Patients with cardiac disease but without resulting limitations of physical activity. Ordinary physical activity does not cause undue fatigue, palpitation, dyspnea or anginal pain.

Class II. Patients with cardiac disease resulting in slight limitation of physical activity.They are comfortable at rest. Ordinary physical activity results in fatigue, palpitation, dyspnea or anginal pain.

Class III. Patients with cardiac disease resulting in marked limitation of physical activity.They are comfortable at rest. Less than ordinary activity causes fatigue, palpitation, dyspnea or anginal pain.

Class IV. Patients with cardiac disease resulting in an inability to carry on any physical activity without discomfort.Symptoms of cardiac insufficiency or of the anginal syndrome may be present even at rest. If an physical activity is undertaken, discomfort is increased.

The Canadian Cardiovascular Society Functional Classification

Class I	Ordinary physical activity does not cause angina, such as walking and climbing stairs. Angina with strenuous or rapid or prolonged exertion at work or recreation.
Class II	Slight limitation of ordinary activity. Walking or climbing stairs rapidly,walking uphill, walking or stair climbing after meals,or in cold,or in wind,or under emotional stress, or only during the few hours after awakening. Walking more than 2 blocks on the level and climbing more than one flight of ordinary stairs at a normal pace and in normal conditions.
Class III.	Marked limitation of ordinary physical activity. Walking 1 to 2 blocks on the level and climbing one flight of stairs in normal conditions and at normal pace.
Class IV.	Inability to carry on any physical activity without discomfort anginal syndrome may be present at rest.

Criteria for Determination of the Specific Activity Scale Functional Class

	Question	Any yes	No
1.	Can you walk down a flight of steps without stopping? (4.5-5.2 mets)	Go to #2	Go to #4
2.	Can you carry anything up a flight of 8 steps without stopping (5 - 5.5 mets) or can you: (a) have sexual intercourse without stopping (5 - 5.5 mets). (b) garden, rake, weed (5.6 mets) (c) roller skate, dance foxtrot	Go to #3	Class III
3.	Can you carry at least 24 pounds up 8 steps (10 Mets) or can you: (a) carry objects that are at least 80 pounds (8 mets) (b) do outdoor work - shovel snow, spade soil (7 mets) (c) do recreational activities such as skiing, basketball, touch football, squash, handball (7-10 mets) (d) jog/walk 5 miles per hour (9 mets)	Class I	Class II
4.	Can you shower without stopping (3.6- 4.2 mets) or can you: (a) strip and make bed (3.9 - 5 mets) (b) mop floors (4.2 mets) (c) hang washed clothes (4.4 mets) (d) clean windows (3.7 mets) (e) walk 2.5 miles per hour (3-3.5 mets) (f) bowl (3-4.4 mets) (g) play golf (walk and carry clubs) (4.5 mets) (h) push power lawn mower (4 mets)	Class III	Go to #5
5.	Can you dress without stopping because of symptoms? (2-2.3 mets)	Class III	Class IV

Summary of Criteria for Specific Activity Scale Classifications

Class I.	Patient can perform to completion any activity requiring ≥ 7 metabolic equivalents.
Class II.	Patient can perform to completion any activity requiring ≥ 5 metabolic equivalents by cannot or does not perform to completion activities requiring ≥ 7 metabolic equivalents.
Class III.	Patient can perform to completion any activity requiring ≥ 2 metabolic equivalents but cannot or does not perform to completion any activities requiring ≥ 5 metabolic equivalents.
Class IV.	Patient cannot or does not perform to completion activities requiring ≥ 2 metabolic equivalents.

The Duke Activity Status Index

Activity	Weight
Can you...	
1. take care of yourself, that is eating, dressing, bathing or using the toilet?	2.75
2. walk indoors, such as around your house?	1.75
3. walk a block or 2 on level ground?	2.75
4. climb a flight of stairs or walk up a hill?	5.50
5. run a short distance?	8.00
6. do light work around the house like dusting or washing dishes?	2.70
7. do moderate work around the house like vacuming, sweeping floors or carring in groceries?	3.50
8. do heavy work around the house like scrubbing floors, or lifting or moving heavy furniture?	8.00
9. do yard work like raking leaves, weeding or pushing a power mower?	4.50
10. have sexual relations?	5.25
11. participate in moderate activities like golf, bowling,danc-ing, doubles tennis, or throwing a baseball or football?	6.00
12. participate in strenuous sports like swimming, singles tennis, football, basketball or skiing?	7.50

The Veterans Specific Activity Questionnaire

METs		Draw One Line Below the Activities You are able to Do Routinely with Minimal or No Symptoms, Such as Shortness of Breath, Chest Discomfort, Fatigue
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 vacumming, sweeping the floor 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, carry 60 pounds.
8	-	Move heavy furniture.
	-	Jog slowly, climb stairs quickly, carry 20 pounds upstairs.
9	-	Bicycling at a moderate pace, sawing wood, jumping rope (slowly).
10	-	Brisk swimming, bicycle up a hill, walking briskly uphill, jog six miles per hour.
11	-	Cross Country Ski.
	-	Play basketball (full court).
12	-	Running briskly, continuously (level gound, eight minutes per mile).
13	-	Any competitive activity, including those which involve intermittent sprinting.
	-	Running competitively, rowing, backpacking.

APPENDIX E

DATA TABLES

Table 1: Description of Characteristics for study patients

Characteristic	Mean	Standard Deviation
Age (years)	64.5	8.8
Height (cm)	176.0	6.8
Weight (kg)	80.3	12.1
Skinfold percent body fat (%)	22.0	6.5
Body mass index (kg/m^2)	25.8	2.9
Resting heart rate (beats per minute)	67.0	11.0
Resting systolic blood pressure (mm Hg)	131.0	15.0
Resting diastolic blood pressure (mm Hg)	78.0	8.0
Time in community exercise program (years)	6.3	4.5
Prior myocardial infarction	11 (55%)	
Prior coronary bypass surgery	6 (30%)	
Medications at time of GXT:		
Beta Blocker	3 (15%)	
Calcium Channel Blocker	5 (20%)	
Digoxin	2 (10%)	
Nitroglycerin	3 (20%)	
Hypertension by physician diagnosis	6 (30%)	

Table 2: Maximal Exercise Test Responses of Subjects in Ramping protocol

Response	Mean	Standard Deviation
Heart rate (b • min)	142	16
Systolic blood pressure (mm Hg)	173	21
Diastolic blood pressure (mm Hg)	84	3
Rating of perceived exertion (RPE)	17.1	1.5
Exercise Capacity by gas exchange [1] (METs)	8.2	2.4
Exercise Capacity by speed/grade [2] (METs)	9.7	2.5
Exercise Capacity by VSAQ [3] (METs)	7.9	2.3
Test duration (minutes)	12.5	3.6
Abnormal ST response to exercise ECG [4]	6 (30%)	

1. Determined from respiratory gas exchange studies.
2. Exercise tolerance estimated from peak treadmill speed and grade.
3. Exercise tolerance estimated from VSAQ.
4. Frequency of cases with > 1 mm ST depression V4-V5 at peak exercise.

Table 3: Multiple Regression Analysis

Dependent Variable: METs by respiratory gas exchange

Parameter	Estimate	Standard Error	T Statistic	P-Value
Constant	4.21	1.83	2.30	0.034
VSAQVO2	0.50	0.22	2.28	0.035

Final Equation: Measured METs = 4.21 + 0.50(VSAQ)

Analysis of Variance

Source	Sum of Squares	DF	Mean Square	F Ratio	P Value
Model	26.18	1	26.18	5.18	0.035
Residual	90.95	18	5.05		

R-squared = 22.35 percent
Standard Error of Estimate = 2.25

Table 4: Multiple Regression Analysis

Dependent Variable: METs by VO_2 formula from speed/grade

Parameter	Estimate	Standard Error	T Statistic	P-Value
Constant	4.60	1.76	2.61	0.018
VSAQVO2	0.65	0.21	3.04	0.007

Final Equation: Estimated METs = 4.60 +0.65(VSAQ)

Analysis of Variance

Source	Sum of Squares	DF	Mean Square	F Ratio	P Value
Model	43.00	1	43.00	9.23	0.007
Residual	83.83	18	4.66		

R-squared = 33.91 percent
Standard Error of Estimate = 2.16

Table 5: Regression Analysis of Predicted on Measured FC

Dependent Variable: Measured METs

Parameter	Estimate	Standard Error	T Statistic	P-Value
Constant	0.87	1.41	0.62	0.54
Estimated METs	0.75	0.14	5.37	0.0000

Final Equation: Measured METs = 0.87 + 0.75(Estimated METs)

Analysis of Variance

Source	Sum of Squares	DF	Mean Square	F Ratio	P Value
Model	72.11	1	72.11	28.83	0.0000
Residual	45.02	18	2.50		

r-squared = 61.56 percent
Standard Error of Estimate = 1.58

Table 6: Summary of Prediction Equations: Measured[1], Predicted[2] and Predicted on Measured[3] Exercise Capacity.

Y	=	Intercept	+	B_1 (X_1)	R^2	SEE
y	`` =	4.20	+	0.50(VSAQ)	22.35	2.24
y	=	4.59	+	0.64(VSAQ)	33.90	2.15
y	=	0.87	+	0.75(Estim. FC)*	61.56	1.58

* Estimated based on peak treadmill speed and grade.

Table 7: Multiple Regression Analysis via NCSS*

Dependent Variable: METs by VO_2 formula from speed/grade

Parameter	Regression	Standard Error	T Statistic	P-Value
Constant	11.81	6.09	1.94	0.071
Age	-7.77	7.51	1.03	0.317
Percent fat skinfold	-0.14	8.11	1.67	0.113
METs by VSAQ	0.43	0.24	1.81	0.090
Time in program	0.01	1.13	1.06	0.302

Final Equation:

$$METs = 11.81 - 7.77(age) - 0.14(\%\ fat) + 0.43(VSAQ) + 0.01(Time)$$

Analysis of Variance

Source	Sum of Squares	DF	Mean Square	F Ratio	P Value
Intercept	1349.72	1	1349.72		
Model	46.47	4	11.62	**2.47**	0.089
Error	70.65	15	4.71		

R-squared = 39.68 percent
Standard Error of Estimate = 2.17

* NCSS = Number Cruncher Statistical Analysis Program

Table 8: Multiple Regression Analysis via NCSS *

Dependent Variable: METs by VO_2 formula from speed/grade

Parameter	Estimate	Standard Error	T Statistic	P-Value
Constant	11.83	5.96	1.98	0.070
Age	-7.90	7.37	-1.07	0.300
Percent fat skinfold	-0.11	7.96	-1.41	0.180
METs by VSAQ	0.57	0.23	2.41	0.030
Time in program	1.20	1.10	0.30	0.175

Final Equation:

METs = 11.83 - 7.90(age) - 0.11(fat) + 0.57(VSAQ)+ 1.20(time)

Analysis of Variance

Source	Sum of Squares	DF	Mean Square	F Ratio	P Value
Intercept	1895.41	1	1895.41		
Model	58.84	4	14.71	3.25	0.042
Error	68.00	15	4.53		

R-squared = 46.39 percent
Standard Error of Estimate = 2.12

* Number Cruncher Statistical Analysis Program.

Table 9: Pearson Correlation via NCSS *

	Age	Fat	VSAQ	Time	SP/GR	VO2
Age	1.00	-0.31	-0.37	0.52	-0.24	-0.18
Fat	-0.31	1.00	0.11	-0.23	-0.19	-0.28
VSAQ	-0.36	0.11	1.00	0.02	0.58	0.47
Time	0.52	-0.23	0.02	1.00	0.19	0.21
SP/GR	-0.23	-0.19	0.58	0.19	1.00	0.78
VO2	-0.17	-0.28	0.47	0.21	0.78	1.00

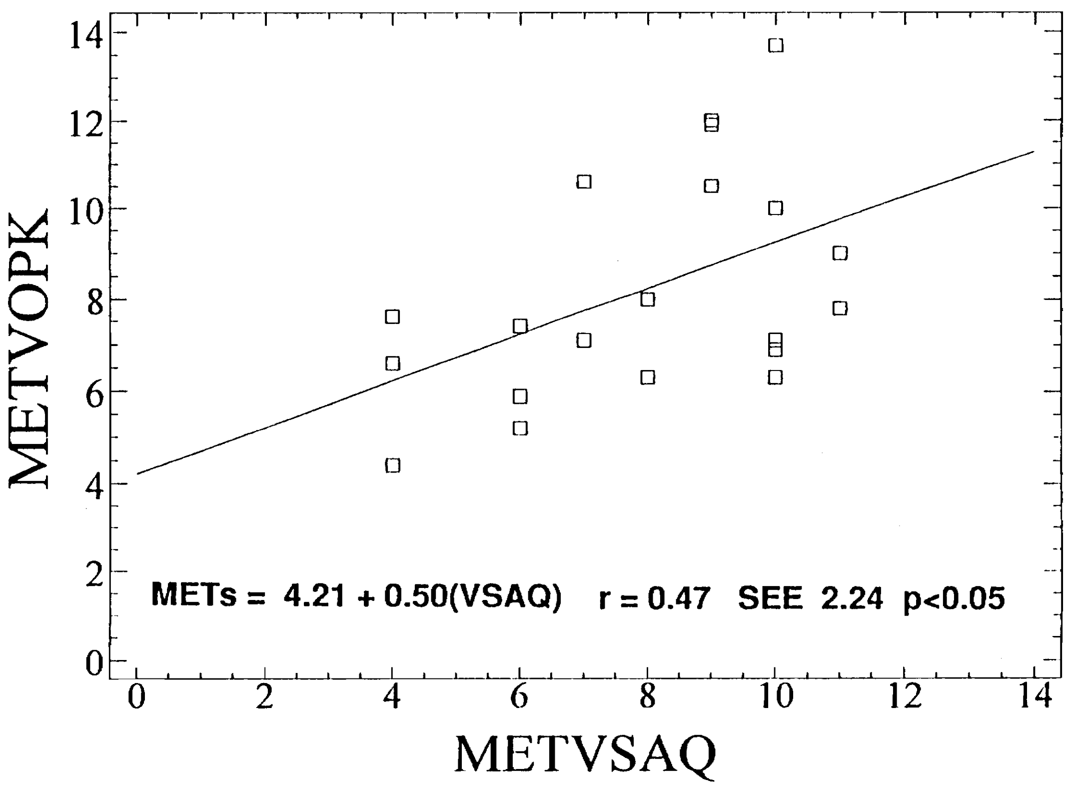

Figure 1. Regression of the relation between metabolic equivalents predicted by multiple regression and those measured by gas exchange

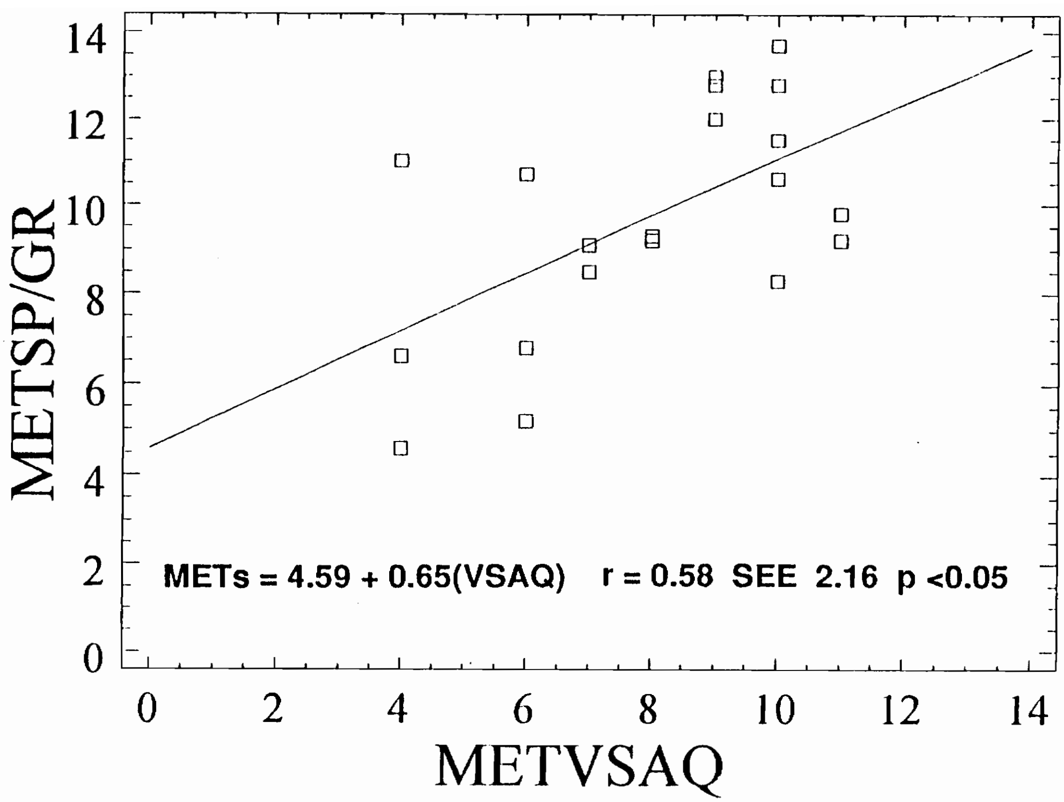

Figure 2. Regression of the relation between metabolic equivalents predicted by multiple regression and those estimated by speed and grade

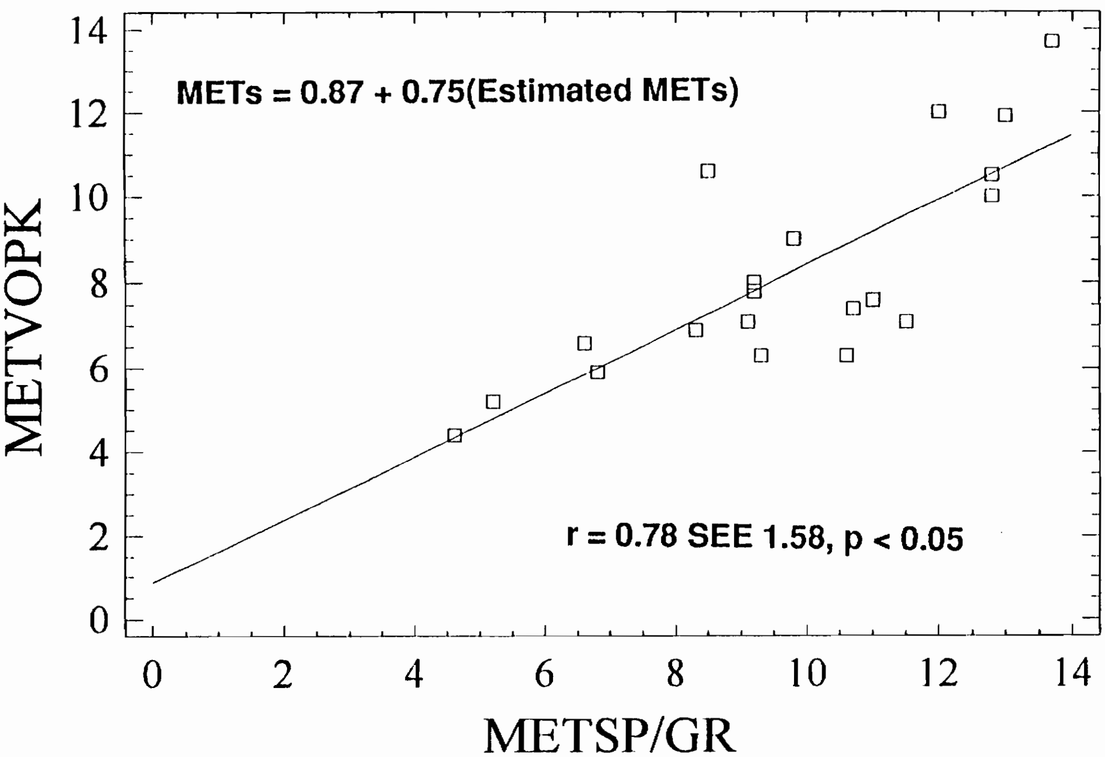

Figure 3. **Regression of the relation between metabolic equivalents measured by gas exchange and those estimated by speed and grade**

APPENDIX F

RAW DATA

DESCRIPTIVE DATA

Subject #	AGE years	HT cm	WT kg	BMI units	FAT %	RHR b•min	RSBP mmHg	RDBP mmHg	HxMI *	HxCABG*	In Program (months)
1.	62	182.0	112.5	33.9	34.4	73.0	148	78	2	2	47
2.	58	180.0	83.2	25.6	19.1	74.0	140	80	2	1	35
3.	71	162.0	72.0	27.4	24.7	88.0	116	78	2	2	55
4.	51	171.0	72.7	25.2	34.7	73.0	102	82	1	2	41
5.	71	181.1	90.5	27.6	25.5	54.0	170	96	2	2	181
6.	58	177.0	74.0	23.6	16.1	70.0	128	74	1	1	108
7.	67	185.0	97.8	28.5	23.0	70.0	154	90	1	2	41
8.	70	181.0	78.6	24.0	17.0	72.0	138	88	2	2	36
9.	49	175.0	94.0	30.7	18.5	73.0	130	88	1	1	29
10.	64	177.0	72.0	22.3	19.7	68.0	126	74	2	1	181
11.	72	169.0	67.3	23.6	17.0	50.0	126	70	1	2	108

* HxMI = History of Myocardial Infarction
* HxCABG = History of Coronary Bypass Surgery
* 1 = Yes 2 = No

DESCRIPTIVE DATA

Subject #	AGE years	HT cm	WT kg	BMI units	FAT %	RHR b•min	RSBP mmHg	RDBP mmHg	HxMI *	HxCABG*	In Program (months)
12.	80	174.0	78.6	26.0	22.0	61.0	142	68	1	2	108
13.	71	168.0	74.5	26.4	18.8	85.0	128	94	1	2	111
14.	64	181.0	80.5	25.0	23.9	65.0	132	80	2	2	46
15.	68	166.0	67.0	24.3	9.6	58.0	108	66	1	1	122
16.	63	172.0	69.8	23.6	29.4	50.0	130	74	1	2	57
17.	58	181.0	81.4	24.8	25.6	69.0	124	70	2	1	37
18.	74	184.0	95.5	28.2	20.5	84.0	138	72	1	2	175
19.	72	169.0	67.3	23.6	11.4	50.0	126	70	1	2	41
20.	47	186.0	77.0	22.3	23.8	56.0	118	80	1	2	13

* HxMI = History of Myocardial Infarction
* HxCABG = History of Coronary Bypass Surgery
* 1 = Yes 2 = No

DESCRIPTIVE DATA

Subject	BB	CALC	DIG	NTG
1.	1.0	2.0	2.0	2.0
2.	2.0	2.0	2.0	2.0
3.	2.0	1.0	2.0	1.0
4.	2.0	1.0	2.0	2.0
5.	1.0	2.0	2.0	2.0
6.	2.0	2.0	2.0	2.0
7.	2.0	1.0	1.0	1.0
8.	2.0	2.0	2.0	2.0
9.	2.0	2.0	2.0	2.0
10.	2.0	2.0	2.0	2.0

Notes:

1. "BB" indicates the subject was receiving beta blocker treatment during this study.
2. "CALC" signifies that the subject was receiving calcium channel blocker treatment during this study.
3. "DIG" signifies that the subject was receiving digitalis treament during this study.
4. "NTG" signifies that the subject was prescribed nitroglycerin during this study.
5. * 1=Yes 2=No

DESCRIPTIVE DATA (continued)

Subject #	BB	CALC	DIG	NTG
11.	2.0	2.0	2.0	2.0
12.	2.0	2.0	2.0	2.0
13.	2.0	2.0	1.0	2.0
14.	2.0	1.0	2.0	1.0
15.	2.0	2.0	2.0	2.0
16.	1.0	2.0	2.0	2.0
17.	2.0	2.0	2.0	2.0
18.	2.0	2.0	2.0	2.0
19.	2.0	1.0	2.0	2.0
20.	2.0	2.0	2.0	2.0

Notes:
1. "BB" indicates the subject was receiving beta blocker treatment during this study.
2. "CALC" signifies that the subject was receiving calcium channel blocker treatment during this study.
3. "DIG" signifies that the subject was receiving digitalis treament during this study.
4. "NTG" signifies that the subject was prescribed nitroglycerin during this study.
5. * 1=Yes 2=No

EXPERIMENTAL DATA

Subject	MET_{VOPK} METs	MET_{VSAQ} METs	MET_{SPGR} METs	Timemax seconds	MaxHR b•min	MaxRPE	MaxSBP mmHg	MaxDBP mmHg
1.	9.0	11.0	9.8	476	151	17	186	88
2.	10.0	10.0	12.8	698	166	17	204	90
3.	4.4	4.0	4.6	780	146	19	142	68
4.	6.3	10.0	10.6	780	132	18	164	78
5.	6.9	10.0	8.3	431	128	20	188	110
6.	7.1	10.0	11.5	727	151	18	168	78
7.	7.8	11.0	9.2	576	150	15	188	96
8.	5.9	6.0	6.8	644	150	17	164	92
9.	10.6	7.0	8.5	988	139	19	174	88
10.	12.0	9.0	12.0	1124	167	17	176	82

Notes:

1. MET_{VOPK} = Measured exercise capacity via gas exchange.
2. MET_{VSAQ} = Exercise Tolerance estimated from the VSAQ
3. MET_{SPGR} =Exercise Tolerance estimated from treadmill speed and grade.

EXPERIMENTAL DATA

Subject	MET_{VOPK} METs	MET_{VSAQ} METs	MET_{SPGR} METs	Timemax seconds	MaxHR b•min	MaxRPE	MaxSBP mmHg	MaxDBP mmHg
11.	13.7	10.0	13.7	669	135	17	130	60
12.	6.6	4.0	6.6	457	127	16	176	84
13.	7.6	4.0	11.0	1035	147	17	130	60
14.	5.2	6	5.2	438	122	15	160	82
15.	11.9	9	13.0	886	160	17	168	66
16.	7.4	6	10.7	1155	122	19	166	92
17.	10.5	9	12.8	900	173	17	230	92
18.	7.1	7	9.1	570	142	17	186	86
19.	6.3	8	9.3	840	129	13	182	82
20.	8.0	8	9.2	840	112	17	162	80

Notes:

1. MET_{VOPK} = Measured exercise capacity via gas exchange.
2. MET_{VSAQ} = Exercise Tolerance estimated from the VSAQ
3. MET_{SPGR} =Exercise Tolerance estimated from treadmill speed and grade.

VITA

Peter J. Nielsen was born in 1968 in Brooklyn New York. He grew up in that city and graduated from Poly Prep Country Day School in 1986. He continued his education at Wake Forest Unversity in Winston - Salem, North Carolina, receving his B.S. in Health and Sports Science in 1990. While attending college, he was a student athletic trainer for 3.5 years and also volunteered in the Cardiac Rehabilitation Department for 2 semesters.

After graduation, he moved to Durham, North Carolina where he worked for a year as a fitness instructor at MetroSport Athletic Club and volunteered at Duke University's Cardiac Rehabilitation Program (Now the Center For Living). He was then promoted to Fitness Director at MetroSport and assumed full time duties there for one year until his entry into Virginia Tech.

Upon finishing his coursework in May of 1994, he began work in the Phase I Cardiac Rehabilitation Department of St. John's Regional Medical Center, allied with Hammons Heart Institute in Springfield, Missouri. He completed his M.S. degree from Virginia Tech in Exercise Physiology in May of 1995. His future goals are to build a family with his wife Susan and to become involved in the management of cardiac rehabilitation or other hospital based programs.