Validation of a specific activity questionnaire to estimate exercise tolerance in patients referred for exercise testing

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Background Physical activity and symptom questionnaires have been used as surrogates for exercise testing to estimate a patient's functional capacity and to individualize an exercise testing protocol in accordance with exercise testing guidelines. To validate these approaches, they must be compared with measured oxygen uptake (peak $\dot{V}O_2$).

Methods Before exercise testing was performed, a brief, self-administered questionnaire (Veterans Specific Activity Questionnaire [VSAQ]) was given to 337 patients referred for exercise testing for clinical reasons. The VSAQ was used to estimate exercise tolerance on the basis of symptoms during daily activities to individualize ramp rates on the treadmill so that the test duration would be approximately 10 minutes. Clinical and demographic variables were added to the VSAQ responses in a stepwise regression model to determine their ability to predict both directly measured peak $\dot{V}O_2$ and peak metabolic equivalents (METs) predicted from the treadmill workload.

Results The mean exercise time was 9.6 ± 3 minutes. Responses to the VSAQ and age were the strongest predictors of both measured and predicted exercise capacity. Small but significant contributions to the explanation of variance in both measured and estimated METs were made by resting heart rate, forced expiratory volume in 1 second expressed as a percentage of normal, exercise capacity predicted for age, and body mass index. The multiple *R* values from the regression equations for measured and estimated METs were 0.58 and 0.72, respectively.

Conclusions Estimating a patient's symptoms associated with daily activities along with age are the strongest predictors of a patient's exercise tolerance. The VSAQ, combined with pretest clinical data, predicts the estimated MET value from treadmill speed and grade better than directly measured METs do. When used for estimating a patient's symptom limits to individualize ramp rates on a treadmill, this approach yields an appropriate test duration in accordance with recent exercise testing guidelines. (Am Heart J 2001;142:1041-6.)

Cardiopulmonary exercise testing is commonly performed clinically to obtain an objective assessment of a patient's functional status, to evaluate symptoms, to assess the efficacy of therapeutic interventions, to estimate prognosis, and to determine disability. Several self-administered and interview-based activity questionnaires have been developed to estimate a patient's exercise capacity.[1-6] These approaches are useful in settings where maximal exercise testing is not feasible because of financial, physical, or time limitations or when maximal exercise testing may expose a given patient to higher-than-normal risk. In the last decade another application of the questionnaire approach has evolved: to develop an estimate of a patient's exercise tolerance before an exercise test is begun. Applications of activity questionnaires for this purpose have been used because recent guidelines on exercise testing from major organizations have called for individualizing the test on the basis of the purpose of the test and the patient being tested.[7,8] In addition, studies have suggested that an "optimal" test duration ranges between 8 and 12 minutes.[7-12] A pretest estimate of a patient's exercise tolerance is helpful to individualize the exercise protocol or to set a ramp rate so that the recommended test duration is achieved.

We previously developed the Veteran's Specific Activity Questionnaire (VSAQ), a 13 choice, self-administered questionnaire designed specifically for patients referred for exercise testing for clinical reasons.[2] We observed that among a host of pretest clinical variables, only the patient's age and response to the VSAQ were significant predictors of the subsequent estimated metabolic equivalents (METs) level on the treadmill. However, although that study reported a strong association between the VSAQ and exercise capacity, it was not validated with measured oxygen consumption ($\dot{V}O_2$). The purpose of the current study was 2-fold: (1) to determine the ability

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Table I. Baseline clinical characteristics (n = 337)

Sex (male/female)	324/13
Age (y)	58 ± 12
Height (inches)	69.2 ± 5.0
Weight (pounds)	194.6 ± 45.2
BMI (kg/m^2)	28.6 ± 6.4
Resting heart rate (beats/min)	75 ± 16
Resting systolic blood pressure (mm Hg)	140 ± 24
Resting diastolic blood pressure (mm Hg)	85 ± 14
Diabetes mellitus	29 (9%)
Hypercholesterolemia	117 (35%)
Hypertension	146 (43%)
Tobacco use (any)	212 (63%)
Tobacco use (current)	95 (28%)
History of	
Myocardial infarction	57 (17%)
Coronary artery bypass	36 (11%)
Coronary angioplasty	31 (9%)
Medications at time of test	
β-Blocker	47 (14%)
Calcium antagonist	110 (33%)
Digoxin	8 (2%)
Nitrates	60 (18%)
Other antihypertensive medication	64 (19%)

Table II. Veterans Specific Activity Questionnaire

Before beginning your treadmill test today, we need to estimate what your usual limits are during daily activities. The following is a list of activities that increase in difficulty as you read down the page. Think carefully, then underline the first activity that, if you performed it for a period of time, would typically cause fatigue, shortness of breath, chest discomfort, or otherwise cause you to want to stop. If you do not normally perform a particular activity, try to imagine what it would be like if you did.

1 MET	Eating, getting dressed, working at a desk
2 METs	Taking a shower, shopping, cooking Walking down 8 steps
3 METs	Walking slowly on a flat surface for 1 or 2 blocks A moderate amount of work around the house, such as vacuuming, sweeping the floors, or carrying groceries
4 METs	Light yard work (ie, raking leaves, weeding, sweeping, or pushing a power mower), painting, or light carpentry
5 METs	Walking briskly Social dancing, washing the car
6 METs	Play 9 holes of golf carrying your own clubs. Heavy carpentry, mow lawn with push mower
7 METs	Carrying 60 pounds, perform heavy outdoor work (ie, digging, spading soil, etc) Walking uphill
8 METs	Carrying groceries upstairs, move heavy furniture Jog slowly on flat surface, climb stairs quickly
9 METs	Bicycling at a moderate pace, sawing wood, jumping rope (slowly)
10 METs	Brisk swimming, bicycle up a hill, jog 6 miles per hour
11 METs	Carry a heavy load (ie, a child or firewood) up 2 flights of stairs Cross-country ski, bicycling briskly, continuously
12 METs	Running briskly, continuously (level ground, 8 min per mile)
13 METs	Any competitive activity, including those that involve intermittent sprinting Running competitively, rowing competitively, bicycle riding

of the VSAQ obtained just before the test to estimate a patient's measured peak $\dot{V}O_2$ and (2) to develop a multivariate model with use of pretest variables to estimate exercise capacity to establish individualized ramp protocols that achieve maximal exercise responses within the 8- to 12-minute range recommended by the American Heart Association/American College of Cardiology and American College of Sports Medicine (ACSM) exercise testing guidelines.[7,8]

Methods

Patients

Three hundred thirty-seven consecutive patients (mean age 58 ± 12 years) referred for exercise testing for clinical reasons were included in the study. Clinical characteristics of the study group are listed in Table I. Patients were excluded if their exercise test was submaximal (eg, post–myocardial infarction with a predetermined submaximal end point) or terminated by the supervising physician for reasons other than symptom or sign limits. Fourteen percent of patients were receiving β-blockers, 33% calcium channel antagonists, and 2% digoxin. Fifty-seven patients (17%) had a history of myocardial infarction and 67 (20%) had a history of either coronary angioplasty or coronary bypass surgery.

Questionnaire

Before exercise testing, the VSAQ was given to each patient (Table II). The VSAQ consists of a list of activities presented in progressive order according to METs. Patients were instructed to determine which activities may typically cause fatigue, shortness of breath, chest discomfort, or claudication during daily activities. The VSAQ was scored as a whole number (1 to 13) directly from the patient's response. The MET values associated with each activity were derived from various sources.[8,13,14] A nomogram to predict exercise capacity, using age and VSAQ responses published previously by our laboratory, was also used[2] (Figure 1).

The current activity status of each patient was estimated on a 1 to 4 scale as follows: 1 = very sedentary or bed rest, 2 = sedentary, 3 = moderately active, and 4 = very active. This information was obtained independently from the VSAQ. Age-predicted values for exercise capacity (in METs) were derived from normal standards developed from veterans in our laboratory.[15]

Exercise testing

All patients underwent maximal exercise testing with oxygen uptake ($\dot{V}O_2$) analysis with use of an individualized ramp treadmill protocol.[11,16] This test individualizes both warm-up and peak walking speeds (on the basis of a given patient's height, fitness, and familiarity with treadmill walking) and ramp rate (rate of change in speed and grade) to yield a test duration of approximately 10 minutes. A microcomputer automatically increased workload after an individualized walking

Table III. Definitions of terms for exercise capacity

Measured METs–	Peak exercise METs determined directly from measured oxygen uptake (mL/kg/min divided by 3.5)
Estimated METs–	METs determined from peak exercise treadmill speed and grade, estimated from ACSM equations[8]
VSAQ METs–	METs determined from the VSAQ[2]
Nomogram METs–	METs determined from VSAQ and age with a nomogram[2]

Table IV. Responses to exercise testing (mean ± SD)

Peak heart rate (beats/min)	136 ± 24
Maximum predicted heart rate (%)	85 ± 12
Peak double product (beats/mm Hg/min $^{-1}$ × 10^3)	20.9 ± 9.2
Peak rating of perceived exertion	17.7 ± 2
Peak measured Vo_2 (mL/kg/min)	21.1 ± 5.7
Peak measured exercise capacity (METs)	6.0 ± 1.9
Exercise capacity predicted by VSAQ (METs)	6.9 ± 2.6
Peak METs from nomogram	8.0 ± 2.5
Peak METs estimated from treadmill workload	8.5 ± 3.4
Treadmill time (min)	9.6 ± 3.2

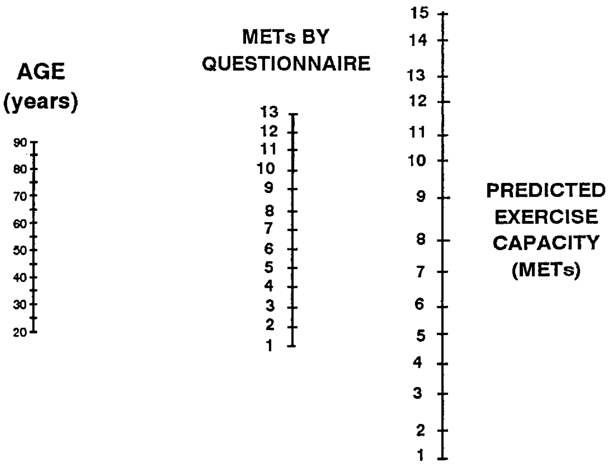
speed and predicted values for maximal exercise capacity were entered. Standardized equations were used to determine the predicted oxygen uptake (in METs) on the basis of treadmill speed and grade (8). With use of a Medical Graphics Breeze metabolic system (St Paul, Minn), expired gases were acquired continuously and minute ventilation, Vo_2, and carbon dioxide output (Vco_2) were acquired and averaged every 30 seconds. Calibration of the system was performed before each test with a 3-L syringe and precision gas mixtures. Vo_2 measurements were obtained with the subject wearing a nose clip and breathing room air through a 1-way directional valve system. Blood pressure was recorded in alternate minutes throughout the test, and a 12-lead electrocardiogram was recorded each minute. The patient's subjective level of exertion was assessed by the Borg 6-20 scale.[17] Standard clinical criteria for terminating the tests were followed,[7,8] but no heart rate or time limit was imposed and a maximal effort was encouraged. Patients were discouraged from holding onto the handrails for support as much as possible.

Because exercise capacity was both measured and estimated by several methods, specific definitions are presented in Table III. "Measured METs" were determined by directly measured Vo_2 (milliliters per kilogram per minute) divided by 3.5. "Estimated METs" were determined from treadmill speed and grade at peak exercise by use of ACSM equations. "VSAQ METs" were those derived from the patient's responses to the VSAQ. "Nomogram METs" were determined from the VSAQ and age by a nomogram as described previously.[2]

Statistical analysis

Standard Pearson correlations were determined between METs obtained from the VSAQ, METs from the nomogram, METs predicted from treadmill workload, and directly measured METs. A stepwise multiple regression analysis was performed with use of peak measured METs as the dependent variable and nomogram METs, current activity status, body mass index (BMI), smoking history (yes/no and pack years), age-predicted exercise capacity, use of β-blockers (yes/no), and resting heart rate and blood pressure as independent variables. This procedure was repeated with use of estimated METs as the dependent variable. Statistical Graphics Corporation software (Rockville, Md) was used for the regression procedures and descriptive statistics.

Figure 1



Nomogram to predict exercise capacity. With use of a straight edge, exercise capacity is predicted on the basis of age and response to specific activity questionnaire (VSAQ). (Reprinted from Myers J, Do D, Herbert W, et al. A nomogram to predict exercise capacity from a specific activity questionnaire and clinical data. Am J Cardiol 1994;73:591-6 with permission from Excerpta Medica Inc.)

Results

Exercise responses

Exercise test results are listed in Table IV. The mean peak heart rate was 136 ± 24 beats/min, which was 85% ± 12% of the maximum predicted heart rate. The mean peak rating of perceived exertion was 18 ± 2, suggesting that a maximal effort was achieved by most patients. The mean exercise test duration was 9.6 ± 3.2 minutes, which falls within the current exercise testing recommendations.[7,8] The exercise tests were terminated for one or more of the following reasons: angina 30 (9.7%), generalized fatigue 174 (56.1%), claudication 10 (3.2%), atypical chest pain 10 (3.2%), shortness of breath 81 (26.1%), leg pain 34 (11%), and leg fatigue 75 (24.2%).

Measured versus predicted exercise capacity

The mean measured peak MET value was 6.0 ± 1.9, whereas that predicted from the VSAQ was 6.9 ± 2.6 and from the nomogram 8.0 ± 2.5. The mean MET value cal-

Table V. Correlation coefficients between measures of exercise capacity

	Peak measured METs	VSAQ METs	Nomogram METs
Peak measured METs	–		
VSAQ METs	0.42	–	
Nomogram METs	0.50	0.93	–
Peak estimated METs	0.72	0.59	0.63

Peak measured METs, METs by ventilatory gas analysis; *peak estimated METs,* METs determined from treadmill speed and grade.

Table VI. Explanation of maximal oxygen uptake by stepwise regression analysis

Variables entered	R	R^2	New variance explained (%)	P value
Nomogram	0.47	0.22	22	<.001
% FEV_1	0.51	0.26	4	<.001
Predicted peak METs	0.55	0.30	4	<.001
BMI	0.56	0.32	2	<.01
Resting heart rate	0.58	0.34	2	<.01

Regression equation: Measured METs = 2.2 + 0.34 (predicted peak METs) – 0.04 (BMI) + 0.21 (nomogram) + 0.02 (% FEV_1) – 0.01 (resting heart rate) (SEE = 1.30). *% FEV_1,* Percent of normal FEV_1; *predicted peak METs,* peak METs predicted for age and sex.

culated from the final speed and grade of the treadmill was 8.5 ± 3.4. Correlation coefficients between questionnaire and exercise responses are presented in Table V. All correlation coefficients between the VSAQ, nomogram, and measured and predicted exercise capacity measurements were significant ($P < .001$). The correlations between peak measured METs and peak estimated METs, nomogram METs, and VSAQ METs were 0.72, 0.50, and 0.42, respectively. The correlation coefficients between peak estimated METs and nomogram and VSAQ METs were somewhat higher, 0.63 and 0.59, respectively. The VSAQ and nomogram MET values were strongly related ($r = 0.93$). With use of a stepwise multiple regression procedure to predict exercise capacity, the nomogram explained the greatest percentage of variance in estimated METs (38%) and measured METs (22%). The final regression equation for measured Vo_2 was as follows: Measured METs = 2.2 + 0.34 (predicted peak METs) – 0.04 (BMI) + 0.21 (nomogram) + 0.02 (% Forced expiratory volume in 1 second [FEV_1]) – 0.01 (resting heart rate). The multiple *R* from the regression equation for measured METs was 0.58 (Table VI). The prediction equation for estimated METs was as follows: Estimated METs = 1.36 – 0.94 (β-blocker) – 0.07 (BMI) + 0.03 (%FEV_1) – 0.05 (resting heart rate) + 0.64 (predicted peak METs) + 0.65 (nomogram). The multiple *R* from the regression equation for estimated METs was 0.72 (Table VII). Activity status and smoking history were not significant predictors of exercise capacity.

Table VII. Explanation of exercise capacity (estimated METs) by stepwise regression analysis

Variables entered	R	R^2	New variance explained (%)	P value
Nomogram	0.61	0.38	38	<.001
Predicted peak METs	0.66	0.44	6	<.001
Resting heart rate	0.68	0.47	3	<.001
% FEV_1	0.71	0.50	3	<.001
BMI	0.71	0.51	1	<.01
β-Blocker	0.72	0.52	1	<.05

Regression equation: Estimated METs = 1.36 – 0.94 (β-blocker) – 0.07 (BMI) + 0.03 (% FEV_1) – 0.05 (resting heart rate) + 0.64 (predicted peak METs) + 0.65 (nomogram) (SEE = 2.40). *% FEV_1,* Percent of normal FEV_1; *predicted peak METs,* peak METs predicted for age and sex.

Because FEV_1 is not routinely performed in many laboratories, we performed the regression analysis a second time without this variable. The results of this analysis were similar, with the nomogram accounting for 25% and 34% of the variance in measured and estimated METs, respectively. The R^2 for the model predicting measured METs was similar when FEV_1 was included and excluded (34% and 33%, respectively), but the R^2 for the model explaining estimated METs was lower with FEV_1 removed (52% vs 44%).

Discussion

As a surrogate for exercise testing, a number of questionnaire approaches have been developed over the years to estimate a patient's exercise capacity. The advantages of these approaches include their ease of use and the avoidance of the time, expense, and risk associated with maximal exercise. Their disadvantages include the fact that they are subjective, and early approaches, such as the New York Heart Association (NYHA),[18] Canadian Cardiovascular Society (CCS),[19] and Specific Activity Scales (SAS),[4] were limited by classification into only 4 functional groups, by having relatively poor interobserver reliability, and by the fact that they generally provided only modest associations with exercise tolerance measured by exercise testing.[1,4,6,20-23] A more recent application of an activity or symptom questionnaire is to help individualize an exercise protocol before performing an exercise test.[2,3,8,24] This application has arisen in the context of recent exercise testing guidelines, which have recommended that the test be individualized depending on the patient being tested and the purpose of the test.

We previously developed the VSAQ for this purpose and used it to set an individual patient's ramp rate on the treadmill. With use of this approach and by targeting the test duration for 10 minutes, we observed that roughly 90% of tests fell within the recommended test duration range of 8 to 12 minutes.[2] In an evaluation of 212 patients, a multivariate analysis demonstrated that among a host of clinical and other pretest variables, only age and response to the VSAQ were significant predictors of exercise capacity. This led to the development of a nomogram using age and VSAQ responses to predict a patient's exercise capacity (determined from treadmill workload) achieved subsequently. Because the previous study was a retrospective analysis and only estimated MET values based on treadmill workload were obtained, one of the goals of the current study was to evaluate the performance of the nomogram prospectively and to determine which pretest variables predict directly measured peak $\dot{V}O_2$ among patients referred for exercise testing.

The major findings from the current study include a reasonably close agreement between the mean values for achieved METs estimated from the treadmill workload and METs estimated from the nomogram (8.5 and 8.0 for achieved and nomogram METs, respectively, Table IV). In addition, the nomogram yielded a mean test duration of 9.6 ± 3 minutes, which approximates the 10-minute target and falls within the range of 8 to 12 minutes recommended by the above exercise testing guidelines.[7,8,13] However, the mean peak $\dot{V}O_2$ achieved by the patients in our study was only 6.0 ± 1.9 METs, which was significantly lower than the MET values observed from the treadmill workload and the nomogram. This can be explained in part by the fact that the treadmill workload is well known to overpredict measured $\dot{V}O_2$ in patients with heart disease, but it also points out that a symptom questionnaire may be better suited to predict the patient's estimated, rather than measured, MET level on the treadmill.

Although the questionnaire method and the estimated (from treadmill speed and grade) exercise capacity values were similar, there was a fair amount of variation. The VSAQ and nomogram MET values were modestly but significantly related to measured and estimated METs ($r = 0.42$ to 0.72, $P < .001$, Table V). This variation accounts for the relatively modest ability of the multivariate models to predict exercise capacity (Tables VI and VII). As in our previous study, the VSAQ was the strongest predictor of exercise capacity, followed by age (reflected in combination as the nomogram in Figure 1). The predictor variables were similar for measured and estimated METs, with the exception that taking a β-blocker added a significant but minimal 1% to the explained variance in estimated METs. Although the use of the nomogram is an effective method of targeting the exercise duration for routine purposes (mean 9.6 ± 3 minutes), the 48% and 66% unexplained variance in estimated and measured exercise capacity, respectively, underscores the fact that many patients do not precisely estimate their symptom limits. The VSAQ tended to underpredict estimated exercise capacity uniformly across the range of exercise tolerance values in the study population. This differs from our previous study,[2] and the recent study of Bader et al[3] in which the VSAQ tended to overpredict exercise capacity among patients achieving low work rates and tended to underpredict exercise capacity among patients achieving high work rates.

Previous studies

Previous studies using activity questionnaires have varied widely in their ability to predict exercise tolerance. Their performance has depended on such factors as the specificity of the questionnaire, whether the questionnaire was self-administered or interview-based, whether exercise capacity was directly measured or estimated, and whether multivariate models were used. For example, a relatively high correlation would be expected between a questionnaire and a 4-category functional classification, such as the CCS[19] and NYHA[18] scales, but predicting a more specific peak $\dot{V}O_2$ value will undoubtedly be much less precise. Indeed, although a physician's assessment of patient symptoms can accurately classify patients into appropriate CCS and NYHA categories, these scales have generally been poorly correlated with measured $\dot{V}O_2$.[1,22]

In terms of interview compared with self-administered questionnaires, Hlatky et al[1] developed the Duke Activity Status Index, a 12-item activity scale, and reported a higher correlation with measured peak $\dot{V}O_2$ than with other scales (0.80) when the patient was interviewed, but the correlation was only 0.58 when self-administered. Our correlation between the VSAQ and measured METs may similarly have been higher had we used an interview rather than a self-administered approach. The best predictions of exercise capacity have come from multivariate approaches. Among samples of patients referred for exercise testing for clinical reasons, we previously observed a multiple R of 0.82 between the VSAQ and estimated METs, which is similar to that for measured $\dot{V}O_2$ reported by Roy et al[5] ($R = 0.84$) with use of sex, age, weight, and medication status. Rankin et al[6] reported a multiple R of 0.71 with an activity questionnaire combined with height, age, and body weight among clinically referred patients with coronary artery disease. The latter investigators reported a higher correlation coefficient between peak $\dot{V}O_2$ and the VSAQ than we observed in the current study (0.66 vs 0.42). Several multivariate studies have been performed among healthy individuals. Jackson et al[25] reported a multiple R of 0.81 with peak $\dot{V}O_2$ with use of percent body fat, sex, age, and self-reported activity status. Similarly, Milesis[26] observed multiple *R* values of 0.85 and 0.87 for men and women respectively, with age, BMI, physical activity status, and smoking history.

Summary

Exercise tolerance among patients referred for exercise testing can be reasonably estimated before the test by use of an activity questionnaire. Adding age to the VSAQ responses (using a nomogram) significantly improves the estimation of both estimated and measured peak VO_2, but other pretest variables add only minimally to the explanation of variance in exercise capacity. The questionnaire more accurately predicts exercise capacity estimated from the treadmill workload achieved than measured peak VO_2. The nomogram routinely used in our laboratory, using age and the VSAQ, provides an estimate of a patient's symptom limits to individualize ramp rates on the treadmill and appropriately targets the exercise test duration in accordance with exercise testing guidelines.

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