Journal of the American College of Cardiology
Vol. 39, No. 4, 2002
ISSN 0735-1097/02/$22.00
PII S0735-1097(01)01801-0
Published by Elsevier Science Inc.

Stress Testing

Prognostic Value of Exercise Echocardiography in 5,798 Patients: Is There a Gender Difference?

Adelaide M. Arruda-Olson, MD, PhD, Eldyn M. Juracan, MD, Douglas W. Mahoney, MS, Robert B. McCully, MD, FACC, Veronique L. Roger, MD, FACC, Patricia A. Pellikka, MD, FACC
Rochester, Minnesota

OBJECTIVES This study was designed to determine the effect of gender on the prognostic value of exercise echocardiography.

BACKGROUND Limited information exists regarding gender differences in prognostic value of exercise echocardiography.

METHODS We obtained follow-up (3.2 ± 1.7 years) in 5,798 consecutive patients who underwent exercise echocardiography for evaluation of known or suspected coronary artery disease.

RESULTS There were 3,322 men (mean age 62 ± 12 years) and 2,476 women (mean age 62 ± 12 years) ($p = 0.7$). New or worsening wall motion abnormalities developed with exercise in 35% of men and 25% of women ($p = 0.001$). Cardiac events, including cardiac death (107 patients) and nonfatal myocardial infarction (148 patients), occurred in 5.3% of men and 3.1% of women ($p = 0.001$). Addition of the percentage of ischemic segments to the clinical and rest echocardiographic model provided incremental information in predicting cardiac events for both men ($X^2 = 137$ to 143, $p = 0.014$) and women ($X^2 = 72$ to 76, $p = 0.046$). By multivariate analysis, exercise electrocardiographic and exercise echocardiographic predictors of cardiac events in both men and women were workload and exercise wall motion score index. There was no significant interaction effect of rest echocardiography ($p = 0.79$), exercise electrocardiography ($p = 0.38$) or exercise echocardiography ($p = 0.67$) with gender.

CONCLUSIONS Although cardiac events occurred more frequently in men, the incremental value of exercise echocardiography was comparable in both genders. Of all exercise electrocardiographic and exercise echocardiographic variables, workload and exercise wall motion score index had the strongest association with outcome. The results of exercise echocardiography have comparable implications in both men and women. (J Am Coll Cardiol 2002;39:625–31) © 2002 by the American College of Cardiology

Ischemic heart disease is the most common cause of death for American men and women (1). In women, the diagnosis of this disease by exercise electrocardiography is limited by lower accuracy when compared with men (2–5). The American College of Cardiology/American Heart Association exercise test guidelines (2) state that "the difficulties posed by clinical evaluation of women for possible coronary artery disease (CAD) have led to speculation that stress imaging approach may be an efficient initial alternative to exercise electrocardiography in women. . . ."

In women, the accuracy of exercise echocardiography is higher than the accuracy of exercise electrocardiography (6,7). However, lower sensitivity and higher specificity of exercise echocardiography in women compared with men has been reported (8). Because only a small percentage of patients undergoing clinically indicated exercise echocardiography are referred for coronary angiography, attempts to determine the true accuracy of the test are confounded by post-test referral bias. The usefulness of exercise echocardiography in women might be best established by studying its prognostic value.

The purposes of the present study were to determine if gender differences exist in the prognostic value of exercise echocardiography and to assess the incremental value of exercise echocardiography in predicting cardiac events in men and women.

METHODS

Patients. The study was approved by the Institutional Review Board. From January 1990 to December 1995, a total of 6,421 patients were referred for clinically indicated exercise echocardiography for evaluation of known or suspected CAD. Of the patients, 254 (4%) had inadequate echocardiographic images and 136 patients (2%) refused to participate in research. Among the remaining 5,798 patients, follow-up was obtained in 5,728 (95%); these make up the study population.

Data regarding patients' cardiac history and risk factors were entered in our computerized database at the time of the exercise echocardiogram. Hypercholesterolemia was defined as total cholesterol >200 mg/dl or use of a cholesterol-lowering agent. Hypertension was defined as blood pressure

From the Division of Cardiovascular Diseases and Internal Medicine, Mayo Clinic and Mayo Foundation, Rochester, Minnesota. Dr. Arruda-Olson was supported by grants from the CAPES Foundation (Fundação Coordenação de Aperfeiçoamento de Pessoal de Nível Superior), Brasília, Brazil, and the Mayo Foundation. The study was supported by a grant from the Mayo Foundation.

Manuscript received May 31, 2001; revised manuscript received November 7, 2001, accepted November 29, 2001.

Abbreviations and Acronyms

CAD	= coronary artery disease
CI	= confidence interval
ECG	= electrocardiogram
METs	= metabolic equivalents
MI	= myocardial infarction
RR	= relative risk
WMSI	= wall motion score index

≥140/90 mm Hg or use of antihypertensive medication. Diabetes mellitus was defined by the presence of a fasting blood glucose concentration ≥140 mg/dl or requirement for insulin or orally administered hypoglycemic agents.

Exercise echocardiography protocol. All patients underwent symptom-limited treadmill exercise testing. Standard blood pressure and 12-channel electrocardiographic monitoring were performed. Exercise was performed according to the Bruce protocol in 3,003 men (90%) and 2,126 women (86%), the Naughton protocol in 190 women (8%) and 150 men (5%), and modified Bruce protocol in 169 men (5%) and 160 women (6%) (overall $p = 0.001$).

Two-dimensional echocardiographic images were obtained from the parasternal and apical windows at rest and immediately after exercise. Studies were recorded on videotape. The standard views were also digitized and stored in quad screen format (9).

Exercise echocardiographic interpretation. Both digitized and videotape-recorded images were used for interpretation (10). Regional wall motion was assessed semiquantitatively by an experienced echocardiographer (11) blind to clinical information. Wall motion at rest and with exercise was scored 1 through 5 according to a 16-segment model (12). Wall motion score index (WMSI) was calculated at rest and with exercise as the sum of the segmental scores divided by the number of visualized segments multiplied by 100%. The development of new or worsening wall motion was considered indicative of myocardial ischemia. A wall motion abnormality present at rest and unchanged with exercise was classified as fixed. Exercise echocardiography results were defined as abnormal if ischemia or fixed wall motion abnormalities were present. The percentage of segments that were abnormal was calculated as abnormal segments divided by the number of visualized segments multiplied by 100%. The percentage of ischemic segments was calculated similarly. Ejection fraction at rest was measured using a previously validated modification of the method of Quinones et al. (13) or by visual estimation (14). The exercise electrocardiogram (ECG) was positive for ischemia if there was horizontal or downsloping ST-segment depression of ≥1 mm at 80 ms after the J point, nondiagnostic if there was baseline ST-segment deviation or negative for ischemia in the absence of these criteria. Workload was measured in metabolic equivalents (METs).

Follow-up. Follow-up was obtained by mailed questionnaires, scripted telephone interviews and review of medical records. Events were verified by contacting the patients' primary physicians and reviewing medical records and death certificates.

The end points considered were cardiac events, including nonfatal myocardial infarction (MI) and cardiac death. Sudden death occurring without another explanation was included as cardiac death. Myocardial infarction was a clinical diagnosis, based on the usual clinical, electrocardiographic and enzymatic criteria. Patients who had coronary revascularization (angioplasty or coronary artery bypass surgery) before other events were censored at the time of revascularization.

Statistical analysis. Continuous variables were reported as mean ± standard deviation and categorical variables as percentages. Comparisons between men and women were based on the Wilcoxon rank-sum test for continuous variables and Pearson's chi-square test for categorical variables.

For outcome analyses, a time to first event approach was used. Survival free of the end point of interest was estimated by the Kaplan-Meier method. Univariable and multivariable association of clinical and exercise echocardiographic variables with the end points were assessed using the Cox proportional hazards model. Variables were selected in a stepwise forward selection manner, with entry and retention in the model set at a significance level of 0.05. All interaction terms were tested jointly by using the global change in the model log likelihood as the test statistic. The results of the univariable and multivariable analyses were summarized as risk ratios with corresponding 95% confidence intervals (CIs). For a continuous multivariate predictor, a dichotomized cut-off value of the multivariate predictor that resulted in the largest change in the likelihood function was used to classify patients into risk groups. This was done separately for each gender.

The incremental value of exercise echocardiography was assessed in two modeling steps. The first step consisted of fitting a multivariable model of clinical, rest echocardiographic and exercise electrocardiographic data. Variables selected from this first step were then used as baseline risk factors, and exercise echocardiographic variables were added in a stepwise forward selection manner. Entry and retention were set at a significant level of 0.05 for each of the three modeling steps.

RESULTS

Study group. Of the 5,798 patients, 1,632 underwent stress echocardiography for evaluation of known CAD, 3,294 for the evaluation of chest pain or dyspnea, 136 for preoperative cardiac risk assessment, 222 because of nondiagnostic or positive exercise ECG and 521 for evaluation of risk factors. There were 3,322 men (57%) and 2,476 women (43%) . The mean age was 62 ± 12 years for men and 62 ± 12 years for women ($p = 0.7$). The baseline characteristics of the patients are summarized in Table 1. Men more often had typical angina; women more often had atypical chest

Table 1. Population Characteristics

Characteristics	Men (n = 3,322)	Women (n = 2,476)	p Value
Symptoms, n (%)			
Asymptomatic	1,570 (47)	786 (32)	0.001
Typical angina	719 (22)	419 (17)	
Atypical chest pain	1,033 (31)	1,271 (51)	
Clinical characteristics, n (%)			
Current smoking	470 (14)	286 (12)	0.004
Diabetes mellitus	335 (10)	227 (9)	0.2
Hypertension	1,487 (45)	1,109 (45)	0.98
Hypercholesterolemia	1,754 (53)	1,409 (57)	0.002
Family history of CAD	1,178 (36)	1,034 (42)	< 0.00001
Prior PTCA	438 (13)	155 (6)	0.001
Prior CABG	591 (18)	127 (5)	0.001
History of MI	818 (25)	278 (11)	0.001
Beta-blocker therapy	835 (25)	556 (22)	0.02
Baseline ECG, n (%)			
Q-wave on ECG	700 (21)	243 (10)	< 0.00001
ST/T abnormalities	1,346 (41)	967 (39)	0.26
Normal	1,337 (40)	1,251 (51)	0.001

CABG = coronary artery bypass graft; CAD = coronary artery disease; ECG = electrocardiogram; MI = myocardial infarction; PTCA = percutaneous transluminal coronary angioplasty.

pain. Risk factors of smoking, hypertension and family history differed significantly in men and women.

Exercise echocardiography. The exercise electrocardiographic and exercise echocardiographic characteristics are summarized in Table 2. The rest and exercise echocardiograms were normal in 1,514 men (46%) and 1,657 women (67%); in 549 men (17%) and 411 women (17%) the echocardiogram was normal at rest but ischemic with exercise; in 641 men (19%) and 193 women (8%) there were wall motion abnormalities at rest without ischemia; in 617 men (19%) and 215 women (9%) there were wall motion abnormalities at rest and ischemia with exercise (overall p = 0.001).

Outcomes. During a median follow-up of 3.2 ± 1.7 years, there were 255 cardiac events. Cardiac death occurred in 74 men and 33 women and nonfatal MI in 105 men and 43 women. Causes of cardiac death included sudden death in 12 men and 7 women, MI in 33 men and 10 women and congestive heart failure in 16 men and 6 women. Of the patients, 178 (31%) underwent revascularization before any cardiac event and were censored. For cardiac death, the estimated one-, three- and five-year survival rates were significantly worse for men (99.5%, 98.0% and 96.7%, respectively) than for women (99.8%, 99.2% and 97.6%, respectively) (p = 0.04). For cardiac events, event-free survival was also worse for men (98.6%, 95.1% and 90.4%,

Table 2. Exercise Echocardiographic Characteristics

Characteristics (Mean ± SD)	Men (n = 3,322)	Women (n = 2,476)	p Value
Functional aerobic capacity (%)	101 ± 30	112 ± 35	< 0.00001
Workload (METs)	9.1 ± 3.0	8.0 ± 2.5	< 0.00001
Baseline heart rate (beats/min)	72 ± 13	78 ± 14	< 0.00001
Exercise heart rate (beats/min)	143 ± 25	148 ± 24	< 0.00001
Baseline systolic blood pressure (mm Hg)	135 ± 20	135 ± 21	0.77
Exercise systolic blood pressure (mm Hg)	180 ± 34	175 ± 28	< 0.00001
Baseline diastolic blood pressure (mm Hg)	83 ± 13	82 ± 12	0.006
Exercise diastolic blood pressure (mm Hg)	87 ± 20	86 ± 15	0.0003
Angina pectoris	371 (11)	195 (8)	< 0.0001
Exercise electrocardiogram			
Positive	746 (22)	388 (16)	< 0.00001
Negative	1758 (53)	1527 (62)	
Nondiagnostic	818 (25)	561 (23)	
Rest ejection fraction	56 ± 10	59 ± 7	< 0.00001
Rest WMSI	1.2 ± 0.4	1.1 ± 0.2	< 0.00001
Exercise WMSI	1.3 ± 0.4	1.1 ± 0.3	< 0.00001
Ischemica by echo	1166 (35)	626 (25)	0.0001

METs = metabolic equivalents; WMSI = wall motion score index.

Table 3. Univariable Predictors of Cardiac Events

	Men			Women		
Variable	RR	95% CI	p	RR	95% CI	p
History of angina	1.69	1.23–2.33	0.001	1.92	1.14–3.23	0.01
Hypertension	1.47	1.09–1.97	0.01	1.74	1.10–2.74	0.02
Prior MI	3.37	2.51–4.52	0.0001	6.13	3.88–9.67	0.0001
Diabetes mellitus	2.51	1.73–3.63	0.0001	2.49	1.42–4.40	0.002
Age, per decade	1.48	1.22–1.63	0.0001	1.63	1.22–1.97	0.0001
Prior coronary revascularization*	2.21	1.65–2.97	0.0001	4.65	2.91–7.43	0.0001
Q waves on rest ECG	2.71	2.02–3.66	0.0001	3.68	2.22–6.09	0.0001
Rest ejection fraction†	0.60	0.54–0.66	0.0001	0.54	0.43–0.66	0.0001
Rest WMSI‡	1.96	1.72–2.24	0.0001	2.41	1.88–3.09	0.0001
Workload (METs)§	0.83	0.79–0.87	0.001	0.79	0.71–0.87	0.0001
Ischemia by echo	2.00	1.49–2.69	0.0001	2.18	1.38–3.46	0.0009
Exercise % abnormal segments‖	1.75	1.58–1.93	0.0001	1.68	1.39–2.00	0.0001
% Ischemic segments‖	1.71	1.42–2.04	0.0001	1.71	1.33–2.24	0.0001
Exercise WMSI‡	1.95	1.73–2.20	0.0001	2.14	1.71–2.66	0.0001

*Either percutaneous transluminal coronary angioplasty or coronary artery bypass surgery; †per 10 unit charge; ‡per 0.5 unit change; §per 1 MET change; ‖per 25%, or four of 16 segments.
CI = confidence interval; ECG = electrocardiogram; METs = metabolic equivalents; MI = myocardial infarction; RR = risk ratio; WMSI = wall motion score index.

respectively) than for women (99.5%, 97.6% and 94.9%, respectively) ($p < 0.0001$).

Predictors of cardiac events. Univariable associations with cardiac events are shown in Table 3; all of these variables were considered as potential predictors for multivariable models. Positive exercise ECG and angina during the exercise test were not predictive. Multivariable predictors of cardiac events are reported in Table 4.

The independent predictors for events in both men and women included history of MI, workload and exercise WMSI. In men, an increase of 1 MET in workload was associated with a reduction of 10% in the risk of events. In women, an increase of 1 MET in workload was associated with a reduction of 14%. In men, a 0.5-unit increase in exercise WMSI carried a 52% increase in the risk of events. In women, this change was associated with a 48% increase in the risk of events. The survival free of cardiac events for both genders according to workload and exercise WMSI is shown in Figures 1 and 2, respectively. Workload ≤6 METs and exercise WMSI ≥1.25 were the best discriminators of increased risk for both men and women. The relationship of exercise WMSI and cardiac events per person-year of follow-up is shown in Figure 3.

Table 4. Multivariable Predictors of Cardiac Events (Cox Regression Analysis) in Patients Undergoing Exercise Stress Echocardiography

Variable	RR	95% CI	p Value
Men			
Prior MI	1.90	1.37–2.63	0.0001
Diabetes mellitus	1.76	1.21–2.57	0.003
Workload (METs)	0.90	0.85–0.95	0.0002
Exercise WMSI*	1.53	1.32–1.77	0.0001
Women			
Prior MI	3.75	2.23–6.29	0.0001
Workload (METs)	0.86	0.78–0.95	0.002
Exercise WMSI*	1.49	1.14–1.94	0.003

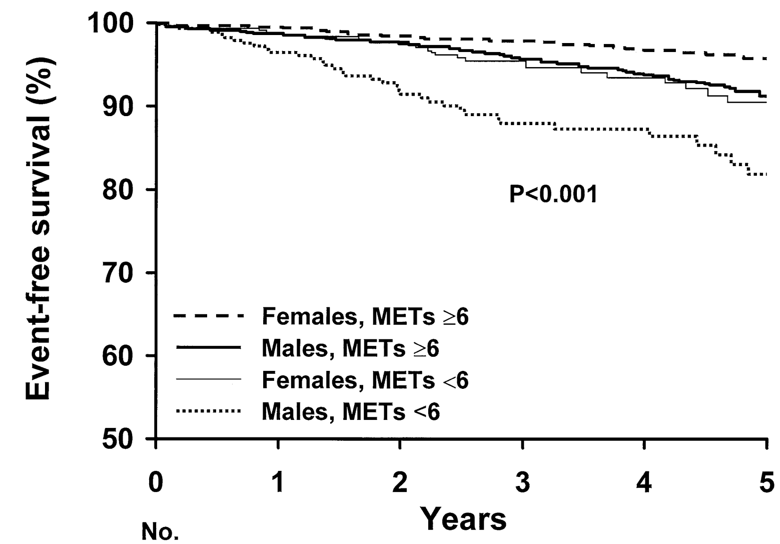
*Per 0.5 unit charge.
Abbreviations as in Table 3.

For men, the independent predictors for cardiac death were: workload (relative risk [RR] = 0.78; 95% CI 0.71 to 0.85; p = 0.0001); rest ejection fraction (RR = 0.53; 95% CI 0.45 to 0.64 per 10 units of change; p = 0.0001); and change in WMSI from rest to exercise (RR = 1.67; 95% CI 1.15 to 2.43 per 0.5 unit change; p = 0.01). Independent predictors in women were: typical angina (RR = 2.60; 95% CI 1.27 to 5.35; p = 0.009); previous MI (RR = 3.42; 95% CI 1.68 to 6.97; p = 0.007); diabetes mellitus (RR = 2.26; 95% CI 1.04 to 4.89; p = 0.04); and workload (RR = 0.82; 95% CI 0.70 to 0.95; p = 0.10).

Incremental value of exercise echocardiography. For both genders, the clinical, rest echocardiogram and exercise electrocardiographic predictors of cardiac events included age, diabetes mellitus, typical angina, prior MI, rest ejection fraction and workload (men: $X^2 = 137$; women: $X^2 = 72$). Addition of the exercise echocardiographic variable, percentage of ischemic segments, improved both models (men: $X^2 = 143$, p = 0.014; women: $X^2 = 76$, p = 0.046). There was no significant interaction effect of rest echocardiography (p = 0.79), exercise electrocardiography (p = 0.38) or exercise echocardiography (p = 0.67) with gender, indicating comparable risk stratification for both genders.

DISCUSSION

In this study of 5,798 patients, the treadmill exercise echocardiogram provided significant incremental value when compared with clinical, rest echocardiographic and exercise electrocardiographic variables for predicting cardiac death and cardiac events in both genders. Although cardiac events were more common in men, there was no interaction effect of gender with predictors for events, suggesting that exercise echocardiography as a method for assessment of prognosis is comparable in both men and women. The best exercise echocardiographic predictor of events was the

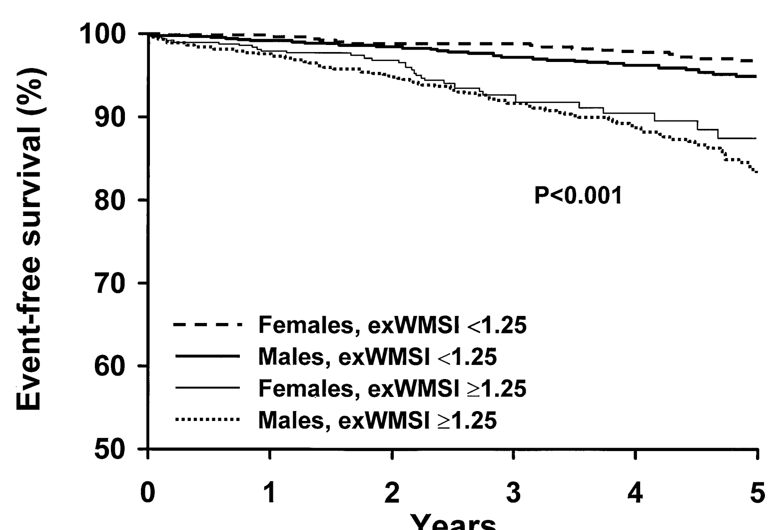


Category	No. at risk					
F ≥6	1999	1845	1340	870	487	274
M ≥6	2981	2621	2016	1321	807	459
F <6	468	420	335	230	151	88
M <6	366	266	206	150	106	61

Figure 1. Survival free of cardiac death and myocardial infarction are shown in men and women, with exercise capacity ≥6 metabolic equivalent (METs) and <6 METs.

exercise WMSI, an indicator of the extent and severity of exercise-induced ischemia.

Detection of CAD in women. Noninvasive detection of CAD is challenging in women, in part because of the lower prevalence of disease (15). Because of the lower pretest probability of disease in women, tests are more often false positive. The exercise electrocardiogram has been shown to be less accurate in women than in men (2–5). Differences in the prevalence of multivessel CAD and prior MI (16–18), differences in exercise capacity (16) and microvascular function and in the prevalence of syndrome X and mitral valve prolapse (2) may account for these distinctions. These difficulties have led to the suggestion that stress imaging may be the preferred strategy in women (7). However,



Category	No. at risk					
F <1.25	1929	1808	1348	890	518	299
M <1.25	1945	1783	1376	920	568	321
F ≥1.25	538	457	327	210	120	63
M ≥1.25	1372	1104	846	551	345	199

Figure 2. Survival free of cardiac death and myocardial infarction are shown in men and women, with exercise wall motion score index (WMSI) <1.25 and ≥1.25.

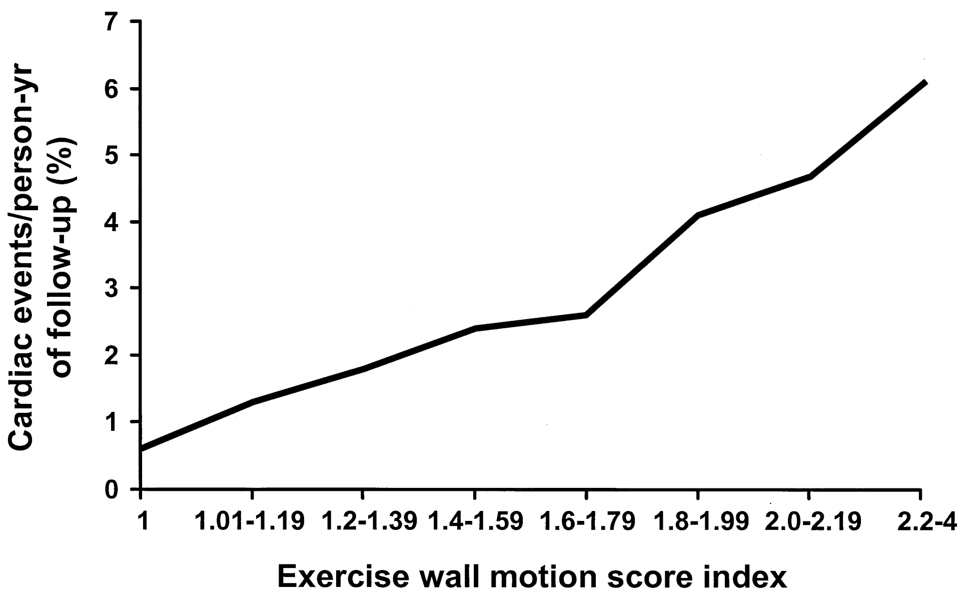


Figure 3. The relationship of cardiac events per person-year of follow-up is plotted against exercise wall motion score index.

intrinsic gender differences have been noted with exercise radionuclide angiography (19). Breast artifact is a recognized difficulty of nuclear perfusion imaging (20).

Stress echocardiography has been recommended as a cost-effective approach to the diagnosis of CAD in women (7). However, in several large studies, the accuracy for detection of angiographic disease (7,8,21,22) has varied. When test referral bias is considered, the positive predictive value and adjusted sensitivity are lower in women than in men (8). Because test results influence the decision whether to perform coronary angiography, with only 9% of the population undergoing stress echocardiography subsequently referred to angiography, the utility of the test is difficult to discern (8). Therefore, this study was undertaken to examine the outcomes of all patients undergoing exercise echocardiography.

Current study. In our study, women presented less often with typical angina, were less likely to have had prior MI or prior coronary revascularization and less often had electrocardiographic evidence of ischemia. Wall motion score index, at rest and with stress, was lower in women. Cardiac events occurred less frequently in women. These differences are compatible with the lower prevalence and lesser severity of CAD in women (15,16). Despite these differences, the clinical, exercise electrocardiographic and echocardiographic predictors of cardiac events and cardiac death were very similar in men and women. The clinical variable prior MI was an independent predictor for events in both genders. This variable has been described as a predictor of the presence of multivessel CAD (18). In the current study, an increase in workload was associated with decreased risk of cardiac events and cardiac death in both men and women. Similarly, other investigators using exercise electrocardiography (23–25) as well as exercise imaging tests (26,27) have reported that a higher workload was associated with a reduction in the risk of events in both genders.

The presence of myocardial ischemia detected by exercise echocardiography was previously reported as a predictor of cardiac events in women (28). In the present study, the exercise WMSI and the percentage of ischemic segments detected by exercise were independent predictors of events for both genders. These echocardiographic variables reflect the extent and severity of CAD and were superior to the dichotomous variable, ischemia. We have previously reported satisfactory agreement between experienced observers for scoring of the 16 segments at rest and with stress (29). Thus, efforts should be made to quantify the extent of ischemia by scoring the individual segments.

Study limitations. In our population, exercise echocardiographic results were used in managing patients; this may have reduced the prognostic value of the test. Therefore, an analysis was performed using only MI and cardiac death as end points, because the decision for revascularization might be most influenced by test results. Follow-up was available for only 95% of patients. Lastly, baseline characteristics differed in men and women. However, the intent of this study was to describe a large consecutive series of men and women referred for clinically indicated exercise echocardiography.

CONCLUSIONS

Exercise echocardiography provides independent prognostic information for both men and women that is incremental to clinical, rest echocardiographic and exercise electrocardiographic data. Of all exercise electrocardiographic and exercise echocardiographic variables, workload and exercise WMSI had the strongest association with outcome. Although cardiac events occurred more frequently in men, the incremental prognostic value of exercise echocardiography was comparable in both genders.

Reprint requests and correspondence: Dr. Patricia A. Pellikka, Mayo Clinic, Division of Cardiovascular Diseases and Internal Medicine, 200 First Street SW, Rochester, Minnesota 55905. E-mail: pellikka.patricia@mayo.edu.

REFERENCES

1. U.S. Bureau of the Census. Statistical abstract of the United States: 1997. 117th ed. Washington, DC: U.S. Government Printing Office, 1997:97.
2. Gibbons RJ, Balady GI, Beasley JW, et al. ACC/AHA guidelines for exercise testing: a report of the American College of Cardiology/American Heart Association task force on practice guidelines (Committee on Exercise Testing). J Am Coll Cardiol 1997;30:260–315.
3. Sketch MH, Mohiuddin SM, Lynch JD, Zenka AE, Runco V. Significant sex differences in the correlation of electrocardiographic exercise testing and coronary arteriograms. Am J Cardiol 1975;36: 169–73.
4. Detry JR, Kapita BM, Cosyns J, Sottiaux B, Brasseur LA, Rosseau MF. Diagnostic value of history and maximal exercise electrocardiography in men and women suspected of coronary artery disease. Circulation 1977;56:756–61.
5. Barolsky SM, Gilbert CA, Faruqui A, Nutter DO, Shlant RC. Differences in electrocardiographic response to exercise of women and men: a non-Bayesian factor. Circulation 1979;60:1021–7.
6. Sawada SG, Ryan T, Fineberg NS, et al. Exercise echocardiographic detection of coronary disease in women. J Am Coll Cardiol 1989;14: 1440–7.
7. Marwick TH, Anderson T, Williams MJ, et al. Exercise echocardiography is an accurate and cost-efficient technique for detection of coronary artery disease in women. J Am Coll Cardiol 1995;26:335–41.
8. Roger VL, Pellikka PA, Bell MR, Chow CW, Bailey KR, Seward JB. Sex and test verification bias: Impact of exercise echocardiography. Circulation 1997;95:405–10.
9. Roger VL, Pellikka PA, Oh JK, Miller FA, Seward JB, Tajik AJ. Stress echocardiography. Part I. Exercise echocardiography: techniques, implementation, clinical applications, and correlations. Mayo Clin Proc 1995;70:5–15.
10. Attenhofer CH, Pellikka PA, Oh JK, et al. Is review of videotape necessary after review of digitized cine-loop images in stress echocardiography: a prospective study in 306 patients. J Am Soc Echocardiogr 1997;10:179–84.
11. Armstrong WF, Pellikka PA, Ryan T, Crouse L, Zoghbi WA. Stress echocardiography: recommendations for performance and interpretation of stress echocardiography. Stress Echocardiography Task Force of the Nomenclature and Standards Committee of the American Society of Echocardiography. J Am Soc Echo 1998;11:97–104.
12. Schiller NB, Shah PM, Crawford M, et al. Recommendations for quantification of the left ventricle by two-dimensional echocardiography: American Society of Echocardiography Committee on Standards, Subcommittee on Quantification of Two-dimensional Echocardiograms. J Am Soc Echocardiogr 1989;2:358–67.
13. Dujardin KS, Enriquez-Sarano M, Rossi A, Bailey KR, Seward JB. Echocardiographic assessment of left ventricular remodeling: are left ventricular diameters suitable tools? J Am Coll Cardiol 1997;30:1534–41.
14. Stamm RB, Carabello BA, Mayers DL, Martin RP. Two-dimensional echocardiographic measurement of left ventricular ejection fraction: prospective analysis of what constitutes an adequate determination. Am Heart J 1982;1047:136–44.
15. Weiner DA, Ryan TJ, McCabe CH, et al. Exercise stress testing: correlations among history of angina, ST-segment response and prevalence of coronary artery disease in the Coronary Artery Surgery Study (CASS). N Engl J Med 1979;301:230–5.
16. Okin PM, Kligfield P. Gender-specific criteria and performance of the exercise electrocardiogram. Circulation 1995;92:1209–16.
17. Pratt CM, Francis MJ, Divine GW, Young JB. Exercise testing in women with chest pain: are there additional exercise characteristics that predict true positive test results? Chest 1989;95:139–44.
18. Pryor DB, Shaw L, Harrell FE, et al. Estimating the likelihood of severe coronary artery disease. Am J Med 1991;90:553–62.
19. Hanley PC, Zinsmeister AR, Clements IP, Bove AA, Brown ML, Gibbons RJ. Gender-related differences in cardiac response to supine exercise assessed by radionuclide angiography. J Am Coll Cardiol 1989;13:624–9.
20. Taillefer R, DePuey EG, Udelson JE, Beller GA, Latour Y, Reeves F. Comparative diagnostic accuracy of T1-201 and Tc-99m sestamibi SPECT imaging (perfusion and ECG-gated SPECT) in detecting coronary artery disease in women. J Am Coll Cardiol 1997;29:69–77.
21. Sawada SG, Ryan T, Fineberg NS, et al. Exercise echocardiographic detection of coronary artery disease in women. J Am Coll Cardiol 1989;14:1440–7.
22. Masini M, Picano E, Lattanzi F, et al. High dose dipyridamole-echocardiography test in women: correlation with exercise-echocardiography test and coronary arteriography. J Am Coll Cardiol 1988;12:682–5.
23. Roger VL, Jacobsen SJ, Pellikka PA, Miller TD, Bailey KR, Gersh BJ. Prognostic value of treadmill exercise testing: a population-based study in Olmsted County, Minnesota. Circulation 1998;98:2836–41.
24. Alexander KP, Shaw LJ, Delong ER, Mark D, Peterson ED. Value of exercise treadmill testing in women. J Am Coll Cardiol 1998;32:1657–64.
25. Weiner DA, Ryan TJ, McCabe CH, et al. Prognostic importance of a clinical profile and exercise test in medically treated patients with coronary artery disease. J Am Coll Cardiol 1984;3:772–9.
26. Snader CE, Marwick TH, Pashkow FJ, Harvey SA, Thomas J, Lauer MS. Importance of estimated functional capacity as a predictor of all-cause mortality among patients referred for exercise thallium single-photon emission computed tomography: report of 3,400 patients from a single center. J Am Coll Cardiol 1997;30:641–8.
27. McCully RB, Roger VL, Mahoney DW, et al. Outcome after normal exercise echocardiogram and predictors of subsequent cardiac events: follow up of 1,325 patients. J Am Coll Cardiol 1998;31:144–9.
28. Heupler S, Mehta R, Lobo A, Leung D, Marwick TH. Prognostic implications of exercise echocardiography in women with known or suspected coronary artery disease. J Am Coll Cardiol 1997;30:414–20.
29. Chuah SC, Pellikka PA, Roger VL, McCully RB, Seward JB. Role of dobutamine stress echocardiography in predicting outcome in 860 patients with known or suspected coronary artery disease. Circulation 1998;97:1474–80.