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Who Needs an Exercise Stress Test?

Evaluating the New American College of Sports Medicine Risk Stratification Guidelines

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Purpose. The American College of Sports Medicine recently published new guidelines to classify individuals at increased risk for coronary heart disease (CHD) before starting a vigorous (>60% maximum oxygen consumption) exercise program. We compared the prognostic value of the new guidelines to the earlier guidelines.

Methods. Subjects included men and women over 30 years of age,free from known CHD according to the Lipid Research Clinic Follow-up Cohort. Endpoints included an abnormal exercise test result (±1 mm ST, anginal chest pain, or exercise hypotension) and future death of CHD ascertained during an average 12.2 years of follow-up. Data analysis included 2 x 2 contingency tables to compare the test characteristics of the old and new guidelines.

Results. Among 4,074 subjects, 219 (5.4%) had abnormal exercise test results and 65 (1.6%) eventually died of CHD. The new guidelines classified 75.7% of individuals as high risk versus 58.7% using the old guidelines. Comparing the new guidelines with the old, test sensitivity was significantly ($P = 0.007$) higher for patients with an abnormal exercise test result (87% versus 77%) than for patients who died of CHD (100% versus 99%). Test specificity of the new guidelines was significantly ($P < 0.001$) lower than the old guidelines for individuals with abnormal exercise test results (25% versus 42%) and those who died of CHD (25% versus 42%). The new guidelines also showed significantly lower overall diagnostic accuracy and positive likelihood ratios compared with the old guidelines for both patients with abnormal exercise test results and those who died of CHD. The positive predictive value for the new and old guidelines for both patients with abnormal exercise test results and those who died of CHD were similar.

Conclusions. Although the new guidelines are more sensitive in the abnormal exercise test result endpoint, they are less specific and overall less accurate than the old guidelines given the low prevalence of CHD in this asymptomatic population. The current guidelines should be modified to better target high-risk adults.

Key words: exercise stress testing, coronary heart disease, coronary disease risk stratification.

There is convincing evidence that regular physical activity is beneficial in the primary prevention of coronary heart disease (CHD).[1] [2] Given the high prevalence of sedentary lifestyles and the fact that CHD remains the leading cause of death in industrialized countries, there is little doubt that considerable health benefits would arise if sedentary individuals became more active. Despite the many potential benefits of physical activity and although exercise is safe for most individuals, it is prudent to take certain precautions to optimize the benefit-to-risk ratio.

The American College of Sports Medicine (ACSM) recently published new guidelines to stratify individuals based on their CHD risk. These guidelines are used to determine which individuals should receive a medical exam and a diagnostic exercise test before participation in vigorous exercise (above 60% of maximal oxygen consumption).[3] The guidelines recommend that all men over 40 and women over 50 years of age, as well as younger individuals with two or more coronary risk factors be classified at increased risk. There has been no evaluation of these recommendations to determine whether or not they are better than the 1990 guidelines at predicting abnormal stress test results and/or coronary death.[4]

This study uses data from The Lipid Research Clinics Follow-up Cohort to determine if the new guidelines have greater prognostic value than the old guidelines in identifying individuals who will have an abnormal stress test (± 1 mm ST, anginal chest pain, or exercise hypotension) and/or future death of CHD.

Methods

Lipid Research Clinic Cohort

All data for this analysis were derived from public-domain tapes provided by the Lipid Research Clinic (LRC) Program Prevalence and Follow-up Studies. The Prevalence Study was conducted from 1972 to 1976 in 10 North American clinics to determine the prevalence of dyslipoproteinemia and other related factors.[5] [6] [7] A 15% random sample of these participants (representative of the general population), plus all individuals with abnormal lipid values, were invited to return for a second visit. Only individuals in the 15% random sample older than 30 years of age were used for this analysis (4,917 individuals).

We further excluded individuals who (1) had definite CHD or myocardial ischemia at study entry; (2) had a stroke or reported symptoms consistent with peripheral vascular disease; (3) used digitalis or antiarrhythrnics; (4) were missing values for total cholesterol, lipoproteins, or blood pressure; (5) were fasting less than 12 hours before lipid testing; (6) did not perform the exercise stress test; (7) had missing electrocardiographic information on the stress test; (8) were pregnant; or (9) were lost to follow-up.

Patients considered to have definite CHD or myocardial ischemia were those diagnosed with a myocardial infarction or angina pectoris, who used digitalis or medications for arrhythmias or angina, or who had undergone surgery for a coronary bypass or aortic aneurysm. Peripheral vascular disease was defined as calf pain on walking that was unrelieved unless the individual stopped or slowed down (in which case it was relieved in 10 minutes or less), or a history of surgery for poor circulation for a condition other than varicose veins. Cerebrovascular disease was defined as present if the individual had a history of stroke.

Many individuals did not perform the stress test. Exclusion criteria included possible aortic stenosis, congestive heart failure, systolic blood pressure < 90 or > 200 mm Hg or diastolic blood pressure > 120 mm Hg, suspected congenital heart disease, and many resting electrocardiographic abnormalities (R on T type premature ventricular contraction, two consecutive premature ventricular contraction, frequent premature ventricular contraction, and multifocal premature ventricular contraction, ventricular parasystole, atrial flutter and fibrillation, supraventricular tachycardia except sinus tachycardia, second- and third-degree heart block, left bundle branch block, Wolff-Parkinson-White syndrome, and possible or suspect unhealed myocardial infarction). After these exclusions, 4,074 (83%) of the random-sample participants remained in the data set.

Measures of plasma lipids, lipoproteins, glucose level, blood pressure, height, weight, smoking history, medications, and level of physical activity were obtained from all remaining individuals. A treadmill exercise test by a modified Bruce protocol was also administered to participants.

The exercise stress test consisted of a series of 3 minute stages in which the speed and inclination were increased step wise until the attainment of target heart rate (90% of the predicted maximum heart rate appropriate for age and physical condition). Exercise was performed at the following speeds (mph) and slopes (% grade): stage 0 - 1.7,0%; stage one half - 1.7,5%; stage one - 1.7,10%; stage two -2.5,12%; stage three - 3.4,14%; stage four - 4.2,16%; stage five -5.0, 18%; stage six - 5.5,20%; stage seven - 6.0,22%. The exercise test was begun at stage one, unless the subject's appearance and demeanor suggested that walking capacity was limited. During the exercise test the electrocardiogram was monitored continually for heart rate and voltage changes. The test was terminated before reaching the target heart rate if the participant was unable to continue as a result of advanced fatigue or dyspnea, or if the participant experienced chest pain, leg pain, systolic hypertension (_> 250 mm Hg), a (_> 10 mm Hg) drop in systolic blood pressure, dizziness, or _ >1 mm ST elevation or depression from the original tracing. The latter criterion was applied inconsistently with more than 40% of subjects with ST changes being allowed to begin another stage. A small number of tests were also terminated prematurely because of technical difficulties or noncooperation on the part of the participant.

The exercise stress tests were classified as either positive or non positive for ischemia at the electrocardiographic coding centre in Birmingham, Alabama, which applied uniform criteria for all of the tests performed.[8] Each test was coded by rigorously trained technicians who examined the degree of ST depression (or elevation) at 0.08 seconds after the nadir of the J point. Tests in which the ST changes were at least 1 mm and were observed for at least three consecutive beats in any lead at any time during the exercise or recovery were classified as positive. In addition, most tests were also assessed by a computer coding system that calculated the ST integral. Tests in which the ST integral decreased by at least 10,μV-seconds from its resting value to a value _<10 IlV-second or increased by at least 10 μV-second were classified as positive. If the computer coding differed from the technicians' coding, they were reexamined, and any errors were corrected or suppressed. In most cases (but not all) the technician and computer codes were in agreement. Discordant results were evaluated by a supervisor in consultation with a cardiologist, if necessary, to obtain a final judgment. An abnormal exercise stress test result was indicated by a positive ST change, any test discontinued because of anginal chest pain or hypotension.

Because a greater ST response, or one that occurs at a lower work load is likely to be indicative of more severe impairment of the myocardial circulation, abnormal test results were further subdivided according to the degree of ST depression (or elevation) and the time in the test that it was observed.9 10 A test result was classified as very abnormal if the ST response was _> 2 mm or 20 μV-second, occurred during the first 6 minutes of the exercise test, or at a heart rate _< 80% of age-predicted maximum.11

All individuals were followed-up prospectively to provide data on subsequent mortality. Mortality surveillance began annually in July 1977, and individuals were followed-up through June 1987, for an average follow-up of 12.2 years. Annual contact by mail or telephone was maintained with participants, or a reliable source, to determine each participants' mortality status. When a death did occur, the death certificate was obtained and interviews with a witness or next of kin were conducted. Details of laboratory and quality-control procedures have been published elsewhere.12 13

The American College of Sports Medicine Guidelines

The ACSM currently recommends that all high risk individuals receive a diagnostic exercise stress test before embarking on a vigorous exercise program (> 60% maximum oxygen consumption). For our analysis, individuals were classified into high- and low-risk groups based on the ACSM risk stratification guidelines. For both the old and new guidelines, high-risk individuals are men > 40 years, women > 50 years, and younger individuals with at least two of the ACSM positive risk factors listed in Table 1.

Data Analysis

Using 2 x 2 contingency tables, we calculated the following of both the old and new guidelines: the test sensitivity (probability of an abnormal test result in a patient with the target disorder), specificity (probability of a normal test result in a patient without the target disorder), prevalence or pretest probability (proportion of patients with target disorder among all tested patients), positive predictive value and post test probability (proportion of patients with an abnormal test result who have the target disorder), diagnostic accuracy (the ability of a test result to correctly identify individuals with and without a target disorder), and the test discrimination ability as described by the positive likelihood ratio (odds that an abnormal test result will be found in a patient with the target disorder versus one without the disorder). Target disorders include an abnormal exercise stress test result, a very abnormal exercise test result, and coronary death (see Appendix A for further definitions).[14] These analyses were also performed for subgroups based on gender.

The 95% confidence intervals for test sensitivity, specificity, positive predictive value, and diagnostic accuracy were calculated using the exact method for binomial proportions. All proportions compared between the old and new guidelines were also evaluated using chi-square analysis. Confidence intervals for likelihood ratios were determined using a Taylor series expansion for the variance provided by True Epistat.[15]

All individuals were divided into high- and low-risk groups using both the old and new ACSM guidelines. These groups were further divided into abnormal and normal stress tests results to determine the ability of these classifications to predict future death of CHD.

Results

The LRC cohort consisted of 4,074 individuals of which 2,164 (53%) were men and 1,910 (47%) were women. The average ages of the men and women were 45.3 (± 10.6) and 46.5 (± 11.3) years respectively. All individuals completed an exercise stress test with 2,958 (72.6%) of individuals reaching their target heart rates (10% actually attained at least 95% of their age-predicted maximum) and 780 (19.2%) individuals stopping because of fatigue or dyspnea (subjective maximal test). The remaining 336 (8.2%) individuals developed clinical endpoints (electrocardiographic changes, angina pectoris, leg pain, severe hypertension, etc.), technical difficulties, or refused to continue.

There were 219 (5.4%) individuals who were classified as having an abnormal exercise stress test results (103 men and 116 women) and 65 (1.6%) individuals who died of CHD (48 men and 17 women) (Table 2). Of the 219 abnormal exercise stress test results, 91 (42%) individuals had a very abnormal result (39 men and 52 women). The very abnormal test results included 26 (12%) individuals with severe ST segment depression (> 2 mm), 31 (14%) with ST depression occurring at a heart rate less than 80% of the age-predicted maximum, 46 (21%) with ST depression in the first 6 minutes of the exercise test, and 6 (3%) who stopped the test because of hypotension. Some individuals had more than one of these indicators. More than half of the abnormal test results and about a quarter of the very abnormal test results occurred in individuals who attained their target heart rate.

By defining high-risk individuals as all men older than 40 years and all women older than 50 years, and all younger individuals with _> 22 risk factors, the new guidelines classified significantly (P < 0.0001) more individuals as high risk compared with the old guidelines, 3,084 (76%) versus 2,393 (59%).

Table 1. American College of Sports Medicine Guidelines for Exercise Testing and Participation

Old Guidelines (high risk _> 2 risk factors)16

Blood pressure _> 160/90 mm Hg on at least two separate occasions, or on antihypertensive medication.*

Total serum cholesterol _> 6.20 mmol/L.?

Current cigarette smoker.

Persons > 30 years of age with IDDM or have had IDDM for more than 15 years, and persons with non-IDDM > 35 years of age.?

Family history of premature coronary or other atherosclerotic disease in parents or siblings before age 55.§

New Guidelines (high risk _> 2 risk factors)17

Men > 45 years of age; women > 55 years of age or premature menopause without estrogen replacement therapy. ||

Family history of premature coronary disease (myocardial infarction or sudden death before 55 years of age in father or other male first-degree relative, or before 65 years of age in mother or other female first-degree relative).§

Current cigarette smoker.

Blood pressure _> 140/90 mm Hg on at least two separate occasions, or on antihypertensive medication.*

Total serum cholesterol > 5.2 mmol/L or HDL cholesterol < 0.9 mmol/L.?

Persons > 30 years of age with IDDM or have had IDDM for more than 15 years, and persons with non-IDDM >35 years of age.?

Sedentary lifestyle. Persons comprising the least active 25% of the population, as defined by the combination of sedentary jobs involving sitting for a large part of the day and no regular exercise or active recreational pursuits.¶

If HDL is greater than 1.6 mmol/L, subtract one risk factor from the sum of positive risk factors, since high HDL decreases coronary risk.

IDDM: Insulin-dependent diabetes mellitis; HDL: high-density lipoprotein. For both the old and the new guidelines, the ACSM recommends that all men older than 40 years of age, women older than 50 years of age, and all younger individuals at high risk receive a medical exam and diagnostic exercise test before starting vigorous exercise (intensity > 60% VO_2 max).

*Hypotensives or diuretics.

?Serum cholesterol was estimated by multiplying plasma cholesterol by 1.03.

?Must be taking medication for diabetes (Orinase, Diabenese, Phenformin, Insulin, or other medicine used in the treatment of diabetes) or have a blood glucose level greater than 120 mg/dL.

§Family history could not be determined precisely according to the guidelines, because of a lack of specific information in the Lipid Research Clinic data set. For our analyses, family history was considered positive if either the mother or father died of a heart attack before the age of 55 (mother before the age of 65 for the new guidelines) or either the mother, father, or siblings had congenital heart disease (heart attack or angina) before the age of 60.

||Premature menopause was considered all women who had a hysterectomy (uterus and both ovaries removed) before reaching menopause.Estrogen replacement therapy was considered to be taking oral contraceptives, pills for hot flashes, or pills to regulate periods.

¶The Lipid Research Clinic defines sedenatry lifestyle as not engaging in regular physical exercise or an occupation which requires physical exertion at least three times a week.

The new guidelines had a significantly higher test sensitivity ($P = 0.007$) compared with the old guidelines for an abnormal stress test result, 190 (87%) of 219 versus 168 (77%) of 219. There were no significant differences in test sensitivity between the new guidelines and old guidelines for either the very abnormal stress test result 85 (93%) of 91 versus 82 (90%) of 91, or death of CHD 65 (100%) of 65 versus 64 (99%) of 65.

Because of the far greater number of individuals targeted for testing, the new guidelines showed a significantly ($P < 0.0001$) lower test specificity than the old guidelines for the two stress test endpoints (25% versus 42%) and death of CHD (25% versus 42%). The new guidelines showed a significantly ($P < 0.0001$) lower diagnostic accuracy than the old guidelines for all three outcome measures. The new and old guidelines were similar for positive predictive value for each of the outcome variables.

The likelihood ratio was significantly lower for the new guidelines compared with the old guidelines for the abnormal stress test result, very abnormal stress test result, and death of CHD, with differences of 0.17 (95% confidence interval; 0.05 to 0.29), 0.31 (0.17 to 0.45), and 0.38 (0.33 to 0.43) respectively (Table 2).

These analyses were also performed after grouping by gender. The prevalence of abnormal stress test results was less for the men compared to the women (4.8% versus 6.1%), whereas the prevalence of death of CHD was greater (2.2% versus 0.9%). The men had a significantly ($P < 0.05$) greater test sensitivity for the abnormal stress test result compared with the women for both the old (86% versus 68%) and the new (97% versus 78%) guidelines. These increases in sensitivity were associated with a significantly lower ($P < 0.0001$) test specificity and diagnostic accuracy for both guidelines. The sensitivity for predicting death of CHD was similar for both men and women and always near 100%, whereas the specificity and diagnostic accuracy were both significantly lower ($P < 0.0001$) for the men compared to the women for both sets of guidelines. Although there were significant differences between genders for various test characteristics, the differences between the old and new guidelines followed the same pattern as when both genders are combined.

Figures 1 and 2 show the ability of the old and new guidelines, with the addition of exercise stress test results, to predict future death of CHD. There were no deaths of CHD in the 990 individuals classified at low risk using the new guidelines and only 1 (0.06%) death in the individuals classified at low risk using the old guidelines. Using the old guidelines, for higher risk individuals there were 54 deaths of CHD (2.4%) in individuals with a normal exercise stress test result, and 10 deaths of CHD (6.0%) in individuals with abnormal stress test results. Using the new guidelines, for higher risk individuals there were 55 deaths of CHD(1.9%)% in individuals with normal exercise stress test results and 10 deaths of CHD(5.2%)% in individuals with abnormal stress test results. For both sets of guidelines the majority of deaths of CHD occurred in individuals with normal stress test results (85% for new guidelines; 83% for old guidelines).

Table 2. Test Characteristics of the Old and New American College of Sports Medicine Guidelines for Abnormal Exercise Stress Tests, Very Abnormal Stress Tests, and CHD Death

Outcomes (95% CI)

		Abnormal Exercise Stress Test (n = 219)	Very Abnormal Stress Test (n=91)	CHD Death (n=65)
Sensitivity	OG	77% (71-82%)	90% (82-95%)	99% (92-100%)
	NG	87% (82-	93% (88-	100% (95-

		91%)*	99%)	100%)
Specificity	OG	42% (41-44%)	42% (41-44%)	42% (41-44%)
	NG	25% (24-26%)?	25% (23-26%)?	25% (23-26%)?
Diagnostic Accuracy	OG	44% (43-46%)	43% (42-45%)	43% (41-44%)
	NG	28% (27-30%)?	26% (25-28%)?	26% (25-27%)?
Positive Predictive Value	OG	7.0% (6.0-8.1%)	3.4% (2.7-4.2%)	2.7% (2.1-3.4%)
	NG	6.2% (5.3-7.1%)	2.8% (2.2-3.4%)	2.1% (1.6-2.7%)
Likelihood Ratio	OG	1.33 (1.23-1.43)	1.55 (1.44-1.67)	1.71 (1.67-1.75)
	NG	1.16 (1.10-1.22)	1.24 (1.17-1.32)	1.33 (1.31-1.36)
	Difference	0.17 (0.05-0.29)	0.31 (0.17-0.45)	0.38 (0.33-043)

CHD: coronary heart disease; Cl: cardiac index; NG: new guidelines; OG: old guidelines.

*OG different from NG, P = 0.007.

?OG different from NG, P < 0.0001.

We also examined the accuracy of the guidelines to identify those at risk of death of CHD within a short term. If length of follow-up is decreased to 5 years, then there are 22 deaths of CHD in individuals classified at high risk and no deaths in low-risk individuals using either the old or new guidelines. Eighteen (82%) of these deaths occurred in individuals who had normal exercise stress test results. If the length of follow up is further decreased to only 2 years then there are only 7 deaths of CHD of which 6 (86%) occur in individuals with normal exercise stress test results.

Discussion

The new ACSM guidelines for classifying individuals at increased risk for CHD were developed to include a number of important risk factors that were not considered in the old guidelines. The new guidelines added age and sedentary lifestyle as new risk factors whereas an elevated high-density lipoprotein level was considered a negative risk factor. The new guidelines also reduced the cutoff values of total cholesterol (from 6.2 to 5.2 mmol/L) and systolic blood pressure (from 160 to 140 mm Hg) that classified these measures as risk factors. Although a number of new risk factors were added, the total number of risk factors needed to be considered at high risk remained unchanged. Accordingly, 691 (30%) more individuals were classified as being high risk using the new guidelines.

Figure 1. Prevalence of abnormal exercise stress test results and deaths of coronary heart disease in high- and low-risk individuals classified using The American College of Sports Medicine's old guidelines.

Asymptomatic Adults
4074

High Risk
2398 (58.9%)

Low Risk
1676 1676

Abnormal Exercise Stress Test	Normal Exercise Stress Test	Abnormal Exercise Stress Test	Normal Exercise Stress Test
168 (7.0%)	2230 (93.0%)	51 (3.0%)	1625 (97%)
CHD Death 10 (6.0%)	CHD Death 54 (2.4%)	CHD Death 0	CHD Death 1 (0.06%)

Figure. 2. Prevalence of abnormal exercise stress test results and deaths of coronary heart disease in high and low-risk individuals using The American College of Sports Medicine's new guidelines.

Asymptomatic Adults
4074 (100%)

High Risk
3084 (75.7%)

Low Risk
990 (24.3%)

Abnormal Exercise Stress Test 1190 (6.2%)	Normal Exercise Stress Test 2894 (93.8)	Abnormal Exercise Stress Test 29 (2.9%)	Normal Exercise Stress Test 961 (97.1%)
CHD Death 10 (5.2%)	CHD Death 55 (1.9%)	CHD Death 0	CHD Death 0

These modifications improved the sensitivity of the new guidelines for predicting abnormal stress test results compared with the old guidelines. However, the new guidelines performed worse than the old guidelines for test specificity, diagnostic accuracy, and the positive likelihood ratio for all three outcome measures. There were no differences between the two sets of guidelines for positive predictive value or test sensitivity for a very abnormal stress test result and death of CHD.

One of the new variables that greatly increased the number of people being classified at high risk was sedentary behavior. There may have been some problems in classifying this variable accurately because of a lack of available information in the LRC data set. Individuals were classified as being sedentary in the LRC data set if they did not regularly engage in strenuous exercise or hard physical labor (further defined as not taking part in some physical exercise or not having an occupation that requires physical exertion).18 Using this criterion 76% of the LRC sample was considered sedentary. In Table 1, the new ACSM guidelines defines sedentary behavior as the least active 25% of the population (further defined as the combination of sedentary jobs involving sitting for a large part of the day and no regular exercise or active recreational pursuits).19 Both the LRC and ACSM definitions are broad and vague and it is difficult to classify individuals accurately. Health professionals may have similar problems accurately classifying sedentary individuals.

The LRC data set had two other weaknesses. The follow-up endpoints consisted only of death of CHD and not all CHD events. We are unable to determine if the exercise stress test result possibly predicted myocardial infarctions that were then treated and death of CHD was avoided. The second weakness was the use of a submaximal rather than a maximal test. It is likely that a maximal test would have provided more specific clinical diagnoses. However, the purpose of this study was to compare the old guidelines and new guidelines and any suboptimal diagnoses should have affected both sets of guidelines similarly.

Given the low prevalence of CHD mortality among asymptomatic adults, a low-risk classification using either guideline was associated with a risk of death of CHD of less than 0.05% (1 of 1676). Accordingly, either guideline can be used to reassure adults that exercising is safe. However, only 24.3% of adults would be so reassured using the new guidelines versus 41.1% using the old guidelines.

Nearly all deaths of CHD, both short term and long term occurred among those classified as high risk using either guidelines. Using the old guidelines, individuals with abnormal test results were 2.5 times more likely to die than those with a normal exercise test results (6% versus 2.4%). Using the new guidelines, this ratio increases slightly to 2.7 (5.2% versus 1.9%). This slight improvement is not driven by correctly predicting deaths of CHD by an abnormal test result because only 10 deaths of CHD would be correctly predicted by either classification system.

Although the risk of death of CHD will increase at least 2.5 times after an abnormal test result, an individual's risk of death of CHD is still only 6%. A risk of 6% is probably not sufficiently high to initiate any treatment. It should also be noted that a normal stress test result in high-risk individuals is not an assurance that exercise is safe, because there were 54 deaths of CHD (83% of all deaths of CHD) in this group using the old guidelines and 55 (85%) deaths of CHD in this group using the new guidelines.

The rationale for diagnostic exercise stress testing in high-risk individuals before embarking on an exercise program is to look for early evidence of ischemia or arrhythmia to prevent sudden cardiac deaths that occur during moderate or strenuous physical activity.[20] However, exercise stress tests are good predictors of CHD events such as angina, but not of myocardial infarction or sudden death as the initial coronary event.[21] [22] Although there may be a small subgroup of extremely high-risk asymptomatic individuals with a high enough prior probability for exercise stress testing to be useful, for the majority of asymptomatic individuals, a medical evaluation should be sufficient and the negative effects of a false-positive test can be avoided.

There are many other benefits to exercise stress testing, such as to quantify fitness and to help in exercise prescription. However, these additional benefits are just as important for low-risk individuals as their high-risk counterparts. If these other benefits are considered rationale for exercise testing, then it should be recommended for everyone.

These data show that the new guidelines test sensitivity is superior to the old guidelines. However, these improvements come at a cost. A total of 691

(30%) more individuals would be classified at high risk and would therefore have to complete a stress test. Of these extra 691 individuals tested, there would be 22 additional abnormal test results (3%) and 1(0.1%) additional death of CHD, with the death occurring in an individual with a normal exercise test result.

In addition to the financial cost of performing additional tests (increased health-care resources), there is also an emotional cost to the patients who have a false-positive test. It could be argued that there would be little emotional cost because these individuals would likely be reassured that the test is probably a false-positive and would only be placed on minimal follow-up. If this is the case then why bother with the exercise test in the first place.

The American College of Sports Medicine new guidelines do not significantly improve the prediction of deaths of CHD compared with the old guidelines. The ratio of deaths of CHD among high-risk in dividuals with an abnormal versus a normal exercise test results increases only slightly and no new deaths of CHD are identified. These results, in addition to the fact that 691 additional exercise stress tests need to be performed when using the new guidelines, suggests that more appropriate risk classification guidelines for exercise stress testing need to be developed for asymptomatic individuals. This is not an easy proposition because there is a low prevalence of disease in this asymptomatic population and identifying guidelines that are specific enough yet practical is a definite challenge.

Appendix

Definitions of Diagnostic Test Properties

Sensitivity is the number of patients with the given outcome measure (abnormal stress test result or death of CHD) classified at high risk/total number of patients with the given outcome measure **[[A/(A + C)]**.

Specificity is the number of patients without the given outcome measure (normal stress test result or no death of CHD) classified at low risk/total number of patients without the given outcome measure **[[D/(B + D)]**

Table 3. Diagnostic Test Properties

ECG Test or CHD Death

		Abnormal	**Normal**
Guidelines	High risk	A	B
	Low risk		

Diagnostic accuracy is the number of patients with a given outcome measure (abnormal stress test result or death of CHD) classified at high risk plus the number of patients without the given outcome measure classified at low risk/total number of patients in the given population **[(A + D)/(A + B + C + D)**].

Prevalence (pretest probability) is the number of patients with the given outcome measure (abnormal stress test result or death of CHD)/total number of patients in the given population **[(A + C)/(A + B + C + D)]**.

Positive predictive value (posttest probability) is the number of patients with the given outcome measure (abnormal stress test result or death of CHD) classified at high risk/total number of patients classified at high risk **[A/(A + B)]**.

Positive likelihood ratio is the sensitivity/1 specificity **[A/(A + C) + B/(B + D)]**.23

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