Comparison of the Double Two-Step Test and the Maximal Exercise Treadmill Test

Studies in Coronary-Prone Subjects

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SUMMARY
A comparison of the double two-step test and a more strenuous type of exercise test was made to assess the value of the latter procedure in increasing the sensitivity of the electrocardiographic exercise test.

In young, normal women, 17 to 20 years of age, who represent a group with minimal chances for significant silent coronary heart disease, both the double two-step test and graded maximal exercise tests were always normal. This is consistent with the view that ischemic electrocardiographic changes are not usually elicited in subjects with normal coronary circulation, even after strenuous exercise.

In middle-aged men and women, 40 to 65 years of age, in whom the possible existence of clinically silent coronary heart disease was suggested by age and other parameters (atypical chest pain, hypertension, or diabetes, or all three), the maximal exercise test on the treadmill, as compared to the double two-step test, increased the yield of positive electrocardiographic results by 12%. These findings suggest that, in selected "coronary-prone" subjects on whom the double two-step test is negative, increasing the amount of exercise might be of value in the evaluation of the exercise test.

Additional Indexing Words:
ECG exercise test
Radioelectrocardiography
Myocardial ischemia
Coronary atherosclerosis

The value of the electrocardiographic exercise test in the diagnosis of coronary heart disease, silent or clinically overt, has been well established.1-9

In recent years, various attempts have been made to improve the accuracy of the routine electrocardiographic exercise test. The methods employed include: recording the electrocardiogram during exercise as well as in the postexercise period10-13; employment of a more strenuous type of exercise than the usual double two-step test; and a combination of both of these procedures.14-17 Most of the studies in the last group have indicated that more strenuous exercise resulted in an increased yield of positive tests. However, the results of these studies have differed in many respects.

Because of the importance and the relative paucity of such studies, the present investigation was instituted: (1) to determine whether maximal strenuous exercise would produce an ischemic type of electrocardiographic change in young, normal subjects with a presumably normal coronary circulation; and (2) to ascertain whether a more strenuous form of exercise than the two-step test increases significantly the yield of positive results obtained in middle-aged subjects of both sexes in whom the possibility of coronary artery disease is high.

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Table 1

Maximal Heart Rates Reached During Maximal Exercise Test

<table>
<thead>
<tr>
<th>Heart rates/min</th>
<th>Group A</th>
<th>Group B</th>
</tr>
</thead>
<tbody>
<tr>
<td>100-119</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>120-139</td>
<td>0</td>
<td>26</td>
</tr>
<tr>
<td>140-159</td>
<td>16</td>
<td>37</td>
</tr>
<tr>
<td>160-179</td>
<td>24</td>
<td>22</td>
</tr>
<tr>
<td>180-199</td>
<td>20</td>
<td>0</td>
</tr>
<tr>
<td>200+</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>60</td>
<td>93</td>
</tr>
</tbody>
</table>

Methods

Two groups of subjects were studied: (A) 60 young, normal, female student nurses, aged 17 to 20 years, all of whom had normal resting electrocardiograms and no evidence of heart disease; and (B) 150 middle-aged subjects of both sexes, aged 40 to 65 years, who manifested various types of atypical chest pain, hypertension, or diabetes mellitus, or all three, but no electrocardiographic signs of myocardial infarction or ischemia. Subjects with clinical evidence of coronary heart disease (typical angina pectoris or electrocardiographic signs of myocardial infarction or both) were not included in this study.

All studies were performed in the morning in a room with a temperature of 70 to 72 F after the subjects had fasted over night. In both groups of subjects, an initial resting 12-lead electrocardiogram was followed by a double two-step test. This test was performed by the technique of radioelectrocardiography; leads II, V₄, and V₆ were recorded before, during, and after exercise. The method, technique, and electrode placement have been described in previous publications. A maximal exercise test was recorded 30 minutes after the completion of the double two-step test in all subjects of group A but only in those subjects of group B who presented negative double two-step tests.

The multistage maximal exercise test employed was similar to that described by Doan and associates. This consisted of treadmill exercise performed in successive 3-minute periods of gradually increasing severity. The test was

*The instrumentation complies with the specifications of the American Heart Association. The Sanborn specifications (Viso 100 Recorder) state that the response ranges from 0.1 to 80 cycles per sec. The response of the RKG 100 is from 0.15 to about 1,000 cycles per sec. At various degrees of sensitivity, the curve of the Sanborn electrocardiogram alone and the combined Sanborn plus the RKG system were almost identical. Comparison of the ECG’s taken simultaneously by the RKG and the standard Sanborn ECG before, during, and after exercise consistently shows no difference in the contours of the ECG.
Lead V₆: The comparative effect of a double two-step test and a treadmill test. The patient, aged 51 years, complained of vague discomfort in his chest which was not clearly related to exertion or excitement.

(A. Double two-step test) Note that the lying and standing positions show relatively little change in the T waves or ST segments. During exercise, note the flattening of the T waves and junctional ST depression from 30 to 180 sec. The junctional ST depression is also present in the postexercise period; these changes are slight and are not significant.

(B. Treadmill test) The control (in standing position) is within normal range. Note the progressive ST-segment depression with the treadmill exercise test. Marked ST depressions are observed with the second stage. The stat tracing taken immediately after exercise shows moderate ST-segment depression; this becomes more marked at 1 min; and at 3 and 5 min a significant ischemic type of ST depression is observed.

Criteria for a positive test were restricted to halting when the subject experienced chest pain or was too tired to continue. Ischemic-type ST depression $\geq 1$ mm or the appearance of multiple premature ventricular contractions during or within the first 5 minutes.
Figure 4

Lead V1. Patient, 45 years old, had hypertension (blood pressure, 170/110 mm Hg). There was no history of precordial or substernal pain.

(A. Double two-step test) Note the normal control while patient was lying and standing. Slight ST-segment depressions are observed during exercise and in the postexercise period. However, these changes cannot be said to be significant.

(B. Treadmill test) Note progressive ST-segment depressions. The postexercise tracings taken at 3 and 5 min show significant ischemic ST-segment depressions; these were not observed with the double two-step tests.
after exercise. Tracings which did not show these changes were considered to constitute a negative test.

**Results**

In group A (60 young student nurses), none of the subjects developed ischemic changes or multiple premature ventricular contractions during either the double two-step test or the maximal exercise test. The performance of group A, evaluated by the highest stage which the subjects completed during the treadmill test, is presented in figure 1. Almost all subjects (58 of the 60 subjects) were able to continue the graded exercise to the fourth or fifth stage; the test was usually stopped after this stage because of exhaustion. In only two subjects was the test discontinued after the third stage because of marked exhaustion.

The maximal heart rates reached during treadmill exercise are shown in table 1. Those in group A ranged from 140 to 200/min. This illustrates the amount of physical effort entailed during the performance of this test.

In group B (150 middle-aged subjects of both sexes), 57 subjects (38%) presented positive double two-step tests; in these, the maximal exercise test was not performed because it would not have provided additional diagnostic information.

The remaining 93 subjects in group B presented negative double two-step tests. Their performance in the treadmill test is shown in figure 2. The stage reached during the maximal exercise test and the sex distribution in each stage are indicated. Most subjects completed the third or fourth stage. Generally, men were able to continue the test longer than women. The five subjects who reached the fifth stage were all men; 14 of the 19 who were able to complete only two stages were women. As can be seen in table 1, the maximal heart rate in group B varied from 100 to 200/min; however, most of the rates fell within the range of 120 to 180/min.

In seven of these 93 subjects with negative double two-step tests, the maximal exercise test resulted in the appearance of ischemic changes in the electrocardiogram (figs. 3 and 4). This represents a 12% additional yield to the 57 subjects with positive double two-step tests. Exercise-induced multiple premature ventricular contractions were not observed in this group. Five of the seven subjects with positive treadmill tests were men; four of the seven completed three stages of graded exercise, and the other three completed the fourth stage.

**Discussion**

**Significance of Electrocardiographic Exercise Tests**

The value of the electrocardiographic exercise test as an objective method for the diagnosis of overt or clinically silent coronary heart disease has been studied extensively in the past 25 years. In the majority of subjects with clinically clear-cut coronary heart disease the electrocardiographic exercise test was found positive, although the results obtained by various authors differed to some extent. Of particular interest are the long-term prospective studies which have shown correlation between positive exercise tests and incidence of subsequent coronary heart disease. Robb and Marks followed 1,659 applicants for life insurance, most of whom had some type of chest pain, and found that among those who showed ischemic ST depression after exercise, the subsequent mortality due to coronary heart disease was six times that among those with negative exercise tests. In a comparable study, Mattingly obtained similar results, and a correlation between positive electrocardiographic exercise tests and severe, diffuse coronary atherosclerosis was found at postmortem examination. Prospective studies of normal subjects have also shown subsequent coronary heart disease to be significantly more frequent among subjects with positive exercise tests than among those with negative tests.

Our recent personal experience further supports these findings. During a 3-year follow-up of 795 normal males, aged 30 to 150 years, 116 men (14.7%) had had a heart attack at the time of the test, and 27 of these 116 men showed positive electrocardiographic exercise tests.
65, the incidence of coronary episodes was almost 10 times greater in the group with initially positive exercise tests than in the group with negative tests.

These observations have led many workers in this field, including ourselves, to feel that in the absence of other causes of impaired coronary blood flow or of disturbed ionic membrane exchanges in the myocardial cell (for example, congenital or rheumatic heart disease, myocardiopathies, severe anemia, electrolyte imbalance, or digitalis therapy), a positive electrocardiographic exercise test is in most instances due to coronary heart disease, overt or clinically silent. Exceptions are possible but are relatively uncommon.

**Value of Strenuous Types of Exercise Tests**

In most of the above-mentioned studies, the electrocardiogram was recorded during or after a double two-step test. In recent years, in an attempt to improve the accuracy of the exercise test, more strenuous types of exercise have been used. Several studies employing a maximal type of exercise have been performed on a treadmill or with other techniques and compared with the two-step test.

A number of studies were performed on groups of physically active subjects. Doan and associates reported that among 201 normal men in top form of physical training, 34 to 60+ years of age, maximal exercise increased the number having positive exercise tests from two (1%) detected by the double two-step test to 18 (9%) during maximal exercise. Therefore, these authors claimed that maximal exercise increases the sensitivity of the electrocardiographic exercise test ninefold in comparison to the double two-step test. However, Sheffield and co-workers did not find a single positive test among 112 healthy subjects, aged 14 to 94, although strenuous exercise (treadmill exercise, climbing stairs, walking, or bicycling) was continued until the subject reached 85% of his age-predicted maximal heart rate. Berkson and co-workers employing strenuous treadmill exercise in a group of physically active, healthy, middle-aged men, found positive tests (ischemic ST-segment depression) in 44% of cases. In this study, no comparison with the two-step test was performed.

Studies have also been performed on subjects with various types of myocardial abnormality. In a study of 24 subjects with various types of heart disease, Doan and associates reported that the two-step tests were positive in eight and the maximal exercise test was positive in an additional five. Sheffield and co-workers employing both tests on the same group of patients with coronary heart disease obtained approximately 20 to 25% more positive results from the maximal exercise test than from the double two-step test.

These results show considerable diversity.

Our primary aim in the present study was to determine whether ischemic electrocardiographic changes could be induced by exercise in subjects with normal coronary circulation. Previous work has shown the absence of positive electrocardiographic findings in young, normal male subjects even after strenuous exercise. We elected to study young women because the possibility of silent coronary heart disease is minimal in this group. In our series of young normal women, the exercise test was normal with both the two-step and the maximal exercise technique. Our findings therefore confirm the fact that ischemic electrocardiographic changes are not elicited, even by strenuous exercise, in subjects with normal hearts and presumably normal coronary circulation.

In group B, comprised of 150 middle-aged subjects of both sexes with hypertension, diabetes, or atypical chest pain, the double two-step test was positive in 57 cases. As was previously mentioned, the maximal exercise test was not performed in these subjects as no additional information would have been provided. The high incidence of positive exercise tests was to be expected in such a group of subjects who are known to be coronary prone and in whom clinically silent coronary heart disease is frequent. We
have reported our findings in such groups previously.\textsuperscript{21, 22} In 100 hypertensive subjects free of symptomatic coronary heart disease and of rheumatic or congenital heart disease, the incidence of positive double two-step tests was 37\%.\textsuperscript{21} Moreover, in a similar group of diabetic patients without overt symptoms of heart disease, the electrocardiographic exercise test was positive in 22\% of cases.\textsuperscript{22}

The maximal exercise test was subsequently performed and found to be positive in seven of the 93 subjects of group B in whom the double two-step test was negative. Thus, in comparison with the double two-step test, the additional yield of positive results due to more strenuous exercise was 12\%.

Our present study therefore appears to indicate that, in selected "coronary-prone" subjects with negative double two-step tests, the performance of more strenuous exercise may be helpful in evaluation of the electrocardiographic exercise test.

\textbf{Acknowledgment}

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\textbf{References}

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