Maximal Treadmill Stress Test
Correlated with Postexercise Phonocardiogram
in Normal Subjects

By Wilbert S. Aronow, M.D., Nicholas P. Papageorge's, M.D., Ronald R. Uyeyama, M.D., and John Cassidy, M.D.

SUMMARY
One hundred normal subjects, mean age 51, who had had a simultaneous phonocardiogram and electrocardiogram at rest and after a double Master's test had a maximal treadmill stress test. Thirteen of 100 normal people (13%) had an abnormal maximal treadmill stress test with at least 1.0 mm of ischemic ST-segment depression. Ten of 29 normal subjects (34%) with a fourth heart sound and four of 11 normal people (36%) with a third heart sound after their double Master's test had an abnormal maximal treadmill stress test. Three of 71 normal subjects (4%) without a fourth heart sound and nine of 89 normal people (10%) without a third heart sound after their double Master's test had an abnormal maximal treadmill stress test. Normal subjects with an abnormal maximal treadmill stress test had a significantly higher incidence of fourth heart sounds \((P < 0.001)\) and third heart sounds \((P < 0.02)\) than normals with a normal maximal treadmill stress test.

Additional Indexing Words:
Electrocardiography  Exercise  Treadmill
Third heart sound  Fourth heart sound  Phonocardiography

We previously reported that 29 of 100 normal subjects (29%) had a fourth heart sound and that 11 of these 100 normals (11%) had a third heart sound after a double Master's two-step test.\(^1\) Four of these 100 normal subjects (4%) had at least 1.0 mm of ischemic ST-segment depression after their double Master’s two-step test.\(^1\)

Normal subjects have a higher incidence of ischemic ST-segment depression after a maximal treadmill stress test than after a double Master's two-step test.\(^2, ^3\) Therefore, this study was performed to determine the incidence of abnormal maximal treadmill stress tests in our normal subjects and to correlate this information with the presence or absence of a fourth or third heart sound after exercise.

The predictive value of the maximal treadmill stress test and of the postexercise phonocardiogram remains to be determined. Therefore, we are also following our normal subjects to determine the value of the maximal treadmill stress test and of the postexercise phonocardiogram in predicting the development of clinical heart disease.

Methods
The 100 normal subjects included 98 men and two women between ages 38 and 64, with a mean age of 51 \(\pm 6\) years. They were hospital personnel or their friends. All normal subjects had a normal 12-lead resting electrocardiogram and blood pressure below 140/90 mm Hg at the time of their treadmill stress test; none of them was on any medication. Tests were performed at least 2 hr after a light meal.
MAXIMAL TREADMILL STRESS TEST

Self-adherent electrodes were affixed in the infraclavicular fossae 2 cm below the lower border of the clavicles and medial to the border of the deltoids, 2 cm above the anterior superior iliac spines, and then these electrodes were attached to leads from an ECG cable. The electrodes were secured by foam rubber cushions and taped in place. The cable was connected to a direct-writing electrocardiograph. An aneroid sphygmomanometer was placed on the right arm for blood pressure measurements. A physician and a technician were present throughout the procedure.

Leads I, aVF, and V5 were recorded in the supine and standing positions before exercise. A multistage maximal uninterrupted treadmill test similar to that described by Doan and associates was then performed. All normal subjects exercised until they reached 100% of their predicted maximal heart rate or exhaustion. Leads V5, aVF, and I were recorded in that order each minute during exercise, continuously after 80% of the predicted maximal heart rate was reached, immediately after exercise in the upright and supine positions, and in the supine position every minute after exercise for at least 6 min. Blood pressures were recorded before, during, and after exercise.

The criterion for an abnormal exercise test was 1.0 mm or more of ischemic ST-segment depression below the resting level, with either the ST segment extending horizontally for at least 0.08 sec or with downward sloping of the ST segment.

The electrocardiograms were reviewed by the authors after the study was completed. We did not know which tracings under review were from the normal people who had a third or a fourth heart sound or an abnormal exercise electrocardiogram after their previous double Master’s two-step test. The final interpretation was the consensus of the group.

In our previous study these 100 normal subjects had simultaneous electrocardiograms using lead II and phonocardiograms recorded in the supine position at the maximum apical impulse at rest and immediately, 2, 4, and 6 min after performing a double Master’s two-step test. An eight-channel recorder was used. Phonocardiograms were obtained with a dynamic microphone using a frequency response between 25 and 400 Hz. All tracings were recorded at 75 mm/sec with 0.04-sec time lines. In addition, a separate electrocardiogram was simultaneously recorded with an electrocardiograph. This 12-lead electrocardiogram was obtained at rest, and leads II, V5, V4, V3, V6 were obtained immediately, 2, 4, and 6 min after the double Master’s two-step test.

Results

All of our 100 normal subjects completed their maximal treadmill stress test without any chest pain developing or any complications occurring.

Figure 1 illustrates an abnormal exercise electrocardiogram recorded in lead V5 3 min after exercise in one of our normal men, aged 45.

Table 1 indicates the incidence of an abnormal maximal treadmill stress test and of an abnormal double Master’s test in our normal subjects. Four of our 100 normal people (4%) had at least 1.0 mm of ischemic ST-segment depression after their double Master’s test, and 13 of our 100 normal subjects (13%) had at least 1.0 mm of ischemic

*Sanborn-Hewlett-Packard, Waltham, Massachusetts. The 350 series recorder was used in these studies.

Figure 1

Recording of an abnormal postexercise electrocardiogram in lead V5 3 min after exercise in a normal man, aged 45.
Table 1
Abnormal Double Master's Test and Abnormal Maximal Treadmill Stress Test in 100 Normal Subjects

<table>
<thead>
<tr>
<th></th>
<th>Ischemic ST-segment depression (\geq 1.0) mm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No.</td>
</tr>
<tr>
<td>Double Master's test in 100 normal subjects</td>
<td>4</td>
</tr>
<tr>
<td>Maximal treadmill stress test in 100 normal subjects</td>
<td>13</td>
</tr>
</tbody>
</table>

Table 2
Abnormal and Normal Maximal Treadmill Stress Test in Normal Subjects with a Fourth or a Third Heart Sound After a Double Master's Test

<table>
<thead>
<tr>
<th></th>
<th>Abnormal maximal treadmill stress test</th>
<th>Normal maximal treadmill stress test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No.</td>
<td>%</td>
</tr>
<tr>
<td>Normal subjects with a fourth heart sound after a double Master's test (29)</td>
<td>10</td>
<td>34</td>
</tr>
<tr>
<td>Normal subjects with a third heart sound after a double Master's test (11)</td>
<td>4</td>
<td>36</td>
</tr>
</tbody>
</table>

Table 3
Abnormal and Normal Maximal Treadmill Stress Test in Normal Subjects Without a Fourth or a Third Heart Sound After a Double Master's Test

<table>
<thead>
<tr>
<th></th>
<th>Abnormal maximal treadmill stress test</th>
<th>Normal maximal treadmill stress test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No.</td>
<td>%</td>
</tr>
<tr>
<td>Normal subjects without a fourth heart sound after a double Master's test (71)</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Normal subjects without a third heart sound after a double Master's test (89)</td>
<td>9</td>
<td>10</td>
</tr>
</tbody>
</table>

ST-segment depression after their maximal treadmill stress test. All six of our 100 normal subjects (6%) who had at least 0.5 mm of ischemic ST-segment depression after their double Master’s test had an abnormal maximal treadmill stress test with 1.0 mm or more of ischemic ST-segment depression.

Table 2 reveals the incidence of an abnormal and of a normal maximal treadmill stress test in our normal people who had a fourth or a third heart sound after their double Master’s test. Ten of the 29 normal subjects (34%) who had a fourth heart sound after their double Master’s test had an abnormal maximal treadmill stress test. Nineteen of the 29 normal people (66%) who had a fourth heart sound after their double Master’s test had a normal maximal treadmill stress test. Four of the 11 normal subjects (36%) who had a third heart sound after their double Master’s test had an abnormal maximal treadmill stress test.

Table 3 indicates the incidence of an abnormal and of a normal maximal treadmill stress test in our normal subjects who did not have a fourth or a third heart sound after their double Master’s test. Three of 71 normal subjects (4%) who did not have a fourth heart sound after their double Master’s test had an abnormal maximal treadmill stress test. Sixty-eight of 71 normal people (96%) who did not have a fourth heart sound after their double Master’s test had a normal maximal treadmill stress test. Nine of 89 normal subjects (10%) who did not have a third heart sound after their double Master’s test had an abnormal maximal treadmill stress test. Eighty of 89
normal people (90%) who did not have a third heart sound after their double Master’s test had a normal maximal treadmill stress test.

The data in tables 2 and 3 were analyzed using a chi-square test. Normal subjects with an abnormal maximal treadmill stress test had a significantly higher incidence of fourth heart sounds after exercise than normals with a normal maximal treadmill stress test ($P < 0.001$). Normal subjects with an abnormal maximal treadmill stress test had a significantly higher incidence of third heart sounds after exercise than normals with a normal maximal treadmill stress test ($P < 0.02$).

The normal subjects with a normal double Master’s two-step test but with an abnormal maximal treadmill stress test and a fourth heart sound after exercise had a mean systolic blood pressure of 126.4 ± 10.4 mm Hg at rest and 180.8 ± 27.4 mm Hg after the completion of their maximal treadmill stress test; this group had a mean diastolic blood pressure of 78.1 ± 4.5 mm Hg at rest and 84.9 ± 12.5 mm Hg after the completion of their maximal treadmill stress test. The normal subjects with a normal treadmill stress test had a mean systolic blood pressure of 121.1 ± 12.0 mm Hg at rest and 186.1 ± 23.5 mm Hg after the completion of their maximal treadmill stress test; this group had a mean diastolic blood pressure of 77.9 ± 7.4 mm Hg at rest and 82.9 ± 12.3 mm Hg after the completion of their maximal treadmill stress test. There was no significant difference between the mean systolic or diastolic blood pressure at rest or after the maximal treadmill stress test in these two groups of normal subjects.

**Discussion**

Thirteen of our 100 normal subjects (13%) between ages 38 and 64, with a mean age of $51 \pm 6$, had an abnormal maximal treadmill stress test with at least 1.0 mm of ischemic ST-segment depression. Nine of our 100 normal subjects (9%) had an abnormal maximal treadmill stress test and less than 1.0 mm of ischemic ST-segment depression after a double Master’s two-step test. However, the predictive value of the maximal treadmill stress test needs to be determined by long-term follow-up studies.

The presence of a fourth heart sound is usually dependent on effective atrial contraction, unimpeded ventricular filling, and decreased ventricular compliance. Benchimol and Dimond postulate that an ischemic left ventricle has an increased resistance to distensibility, causing the left ventricular end-diastolic pressure to rise and the left atrium to contract more vigorously. This increased force of atrial contraction suddenly distending the left ventricle probably produces the vibrations recognized as the fourth heart sound.

However, 29% of our normal subjects had a fourth heart sound after exercise. All of our normal subjects who had a third heart sound after exercise also had a fourth heart sound after exercise. Ten of these 29 normal subjects (34%) who had a fourth heart sound after exercise had an abnormal maximal treadmill stress test. Three of our 71 normal subjects (4%) who did not have a fourth heart sound after exercise had an abnormal maximal treadmill stress test. There was a significantly higher incidence of fourth heart sounds after exercise associated with an abnormal maximal treadmill stress test than with a normal maximal treadmill stress test ($P < 0.001$).

Tavel states that "the third heart sound probably results from sudden tension upon the chordae tendineae and mitral valve leaflets as the ventricle quickly expands and elongates in response to rapid inflow in early diastole."

Eleven of our 100 normal subjects (11%) had a third heart sound after exercise. Four of our 11 normal subjects (36%) who had a third heart sound after exercise had an abnormal maximal treadmill stress test. Nine of our 89 normal subjects (10%) who did not have a third heart sound after exercise had an abnormal maximal treadmill stress test. There was a significantly greater incidence of third heart sounds after exercise associated with an abnormal maximal treadmill stress test than with a normal maximal treadmill stress test ($P < 0.02$).

Enos and associates reported that 77.3% of soldiers with a mean age of 22.1 years who
were killed in action or killed accidentally had gross evidence of coronary arteriosclerosis. Does the presence of an abnormal maximal treadmill stress test or of a fourth or third heart sound recorded after exercise represent subclinical latent myocardial ischemia in our normal subjects?

The predictive value of the maximal treadmill stress test and of the postexercise phonocardiogram needs to be determined by long-term follow-up studies. We are following our normal subjects to determine whether there will be an increased incidence of clinical heart disease in those people who had a fourth or a third heart sound at rest or after their double Master’s test or an abnormal maximal treadmill stress test.

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References


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WILBERT S. ARONOW, NICHOLAS P. PAPAGEORGE'S, RONALD R. UYEYAMA and JOHN CASSIDY

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