Electrocardiographic Changes in Clinically Normal Older Men Following Near Maximal and Maximal Exercise

By F. Martin Lester, M.D., L. T. Sheffield, M.D., and T. Joseph Reeves, M.D.

SUMMARY
This study was undertaken to compare the incidence of electrocardiographic abnormalities associated with a near maximal and a maximal exercise test, because of previous reports of high incidence of such abnormalities among older men.

One hundred fourteen male volunteers ranging in age from 40 to 75 years were studied by both near maximal and maximal exercise testing. All subjects were considered normal by history and physical examination. Electrocardiographic responses to exercise testing were monitored by telemetered bipolar leads during and immediately after exercise and by standard electrocardiographic leads made during the recovery period between 30 seconds and 5 minutes after the termination of exercise. Both near maximal and maximal exercise testing were accomplished without significant complication. The incidence of segmental ST depression following the near-maximal test was less than 1%. The incidence of segmental ST depression following the maximal exercise test was 5.2% (6-114). Only one of the five abnormalities detected during or after maximal exercise persisted for more than 30 seconds after the conclusion of exercise. Since such changes occur in a high percentage of patients with heart disease, such changes appear to have a high degree of specificity for some form of cardiac abnormality.

Additional Indexing Words:
Maximal heart rate related to age
Exercise test safety precautions
Resting ECG abnormalities in asymptomatic volunteers
Timing of ECG abnormalities during test

ST-segment measurement
Graded exercise test (GXT)

The sensitivity of exercise electrocardiographic testing in the diagnosis of angina pectoris can be increased by utilizing exercise levels of near maximal severity.1-3 There is doubt, however, as to the relative specificity, in a diagnostic sense, of the changes that occur under such conditions. Bellet and Muller4 and Doan and associates5 have reported that a high percentage of "healthy" men 40 years or over will develop segmental ST depression following exercise of "maximal" tolerated severity. This experience is in apparent sharp disagreement with that of Sheffield and associates,1 and of Mason and associates.2 6 These authors have reported that exercise of "near maximal" severity results in flat or sagging ST depression in a very small percentage (less than 1%) of clinically normal men whose ages were similar to those studied by Doan and associates.5 The present study was designed to compare directly the responses of older males to a two-step exercise test of "near-maximal" severity (GXT) with the multistaged "maximal" treadmill test utilized by Doan and his colleagues.5
Method

One hundred fourteen males, 40 to 75 years of age, including local physicians, dentists, businessmen, members of the Birmingham Y. M. C. A., and fire department were as volunteers for this study. Their age distribution per half decade and maximal heart rate attained during the maximal exercise test are presented in table 1. Subjects were placed in one of three activity categories prior to testing on the basis of the exercise habits. The sedentary group included anyone without a regular habit of exercise. The moderately active classification included anyone who regularly took part in an activity such as golf, swimming, or occasional tennis. The trained subjects were in a supervised running program of at least 3 months' duration and ran 1 to 12 miles per day, three or more times a week. One champion weight lifter in active weight training was also included in this group, although the physiological difference in the kinds of exercise was recognized.

Prior to testing, a cardiovascular history was taken and a physical examination was performed. An X-ray of the chest, the vital capacity, and a hematocrit determination were made in all subjects. No anemia or evidence of significant lung disease was found. Subjects admitting to chest pain were seen by at least two experienced physicians prior to electrocardiographic testing and classified as (1) definitely angina pectoris, (2) probably angina pectoris, (3) probably not angina pectoris, and (4) definitely not angina pectoris. A diagnosis of definite angina pectoris was made in only one subject. One patient was classified as definitely not angina pectoris by one examiner, and probably not angina pectoris by another. He was tested and included in the study. A few patients had a diagnosis of chest pain, definitely not angina, by both examiners. They were included as normal subjects. Three persons with diastolic blood pressures of 95 to 100 mm Hg were tested and included in the study as normal subjects.

Five additional volunteers were excluded from this study because of the diagnosis of lobar pneumonia, hypertension with left ventricular hypertrophy, or because they were receiving cardiac medications. No subjects having left ventricular hypertrophy by electrocardiogram or who were receiving digitalis, nitrites, and antihypertensive or antiarrhythmic drugs were studied.

Of the 114 volunteers included in this study, the resting electrocardiograms were entirely within normal limits in 101. In 13 subjects abnormal or borderline electrocardiogram findings were as follows: right bundle-branch block, one; suggestive of healed inferior myocardial infarction, one; left axis deviation (counterclockwise of $-30^\circ$), six; frontal axis between $0^\circ$ and $-15^\circ$, three. (None had an axis between $-15^\circ$ and $-30^\circ$.) Two subjects had premature ventricular contractions at rest. Neither the 13 subjects listed above nor the three subjects with mild blood pressure abnormalities mentioned above developed segmental ST depression during or after exercise.

The same physician and technician were in attendance for all tests, which were conducted in an air-conditioned room with an ambient temperature of 72 F plus or minus 2.0 degrees. Emergency drugs, resuscitation equipment, and a DC defibrillator were always present in the laboratory. Careful monitoring of rate and rhythm during exercise was accomplished by a telemeter system* having a time constant of 0.46 second overall† employing a bipolar lead from the tip of the right scapula to the $V_5$ position. The resulting lead, similar to the standard $V_5$ lead, was monitored visually during exercise on an oscilloscope. The same lead was recorded at 30-second intervals during exercise on a Sanborn 100 direct-writing recorder. The time constant of this instrument is 4 seconds. All tracings were recorded at a chart speed of 50 mm per second with a sensitivity of 1 cm/mv.

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* Manufactured by Avionics Research Products Corporation, 6901 W. Imperial Highway, Los Angeles, California.
† See Addendum.

Table 1

<table>
<thead>
<tr>
<th>Groups by age</th>
<th>Sedentary</th>
<th>Moderately active</th>
<th>Trained for age</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No.</td>
<td>MHR mean</td>
<td>MHR-range</td>
</tr>
<tr>
<td>40-44</td>
<td>10</td>
<td>190.6</td>
<td>180-200</td>
</tr>
<tr>
<td>45-49</td>
<td>12</td>
<td>189</td>
<td>178-204</td>
</tr>
<tr>
<td>50-54</td>
<td>11</td>
<td>178.5</td>
<td>162-194</td>
</tr>
<tr>
<td>55-59</td>
<td>12</td>
<td>183</td>
<td>174-185</td>
</tr>
<tr>
<td>60 or &gt;</td>
<td>9</td>
<td>178.7</td>
<td>164-192</td>
</tr>
<tr>
<td>Total</td>
<td>54</td>
<td>184.2</td>
<td></td>
</tr>
</tbody>
</table>

*MHR, maximal heart rate.
ELECTROCARDIOGRAPHIC CHANGES

Table 2
Multistage Exercise Capacity Test*

<table>
<thead>
<tr>
<th>Stage</th>
<th>Speed (mph)</th>
<th>Grade (%)</th>
<th>Grade (degree)</th>
</tr>
</thead>
<tbody>
<tr>
<td>First</td>
<td>1.7</td>
<td>10</td>
<td>5.7</td>
</tr>
<tr>
<td>Second</td>
<td>2.5</td>
<td>12</td>
<td>6.8</td>
</tr>
<tr>
<td>Third</td>
<td>3.4</td>
<td>14</td>
<td>8.0</td>
</tr>
<tr>
<td>Fourth</td>
<td>4.2</td>
<td>16</td>
<td>9.0</td>
</tr>
<tr>
<td>Fifth</td>
<td>5.0</td>
<td>18</td>
<td>10.0</td>
</tr>
<tr>
<td>Sixth</td>
<td>5.5</td>
<td>20</td>
<td>11.0</td>
</tr>
<tr>
<td>Seventh</td>
<td>6.0</td>
<td>22</td>
<td>12.4</td>
</tr>
</tbody>
</table>

*Speed and elevation of the treadmill with regard to each 3 minute stage of the maximal exercise test (MET). The values are identical to those used by Doan and associates.⁵

The skin was prepared at all electrode sites by vigorous abrasion with gauze pads saturated with alcohol, followed by a similar application of acetone. Fluid contact disc electrodes* were used for the telemeter leads and standard plate electrodes for the postexercise recordings. The same electrolyte cream† was used throughout the study.

Following the evaluation of the resting electrocardiogram, the near maximal test (hereafter referred to as GXT) was performed first by all subjects over 50 and most of the subjects over 45. This group included 83 men. The GXT was omitted in the remaining 31 younger volunteers. The subjects climbed back and forth over a standard Master two-step box rapidly enough to attain within 2% minutes a heart rate 90 ± 5% of the predicted maximal heart rate, continuing to climb slightly less rapidly to sustain this heart rate for an additional 2½ minutes. The total duration of the exercise was approximately 5 minutes.

Following a recovery period of at least 20 minutes, a "maximal" multistaged, uninterrupted treadmill test was performed (hereafter referred to as the MET). All 114 subjects included in this study were subjected to this maximal test. The outline of this procedure is presented in table 2. The duration of each stage was 3 minutes. The end-point of the test occurred when the subject was unable or unwilling to continue, usually because of severe shortness of breath, fatigue, or both. This test was identical with that of Doan and associates⁶ except for the body posture during recovery and the location of the remote electrode of the telemetered electrocardiogram.

After each of the exercise tests the subject was placed supine and reconnected to an electrocardiographic cable. A standard V₃ recording was obtained at 30 seconds, 2, 4, and 6 minutes after exercise. A 12-lead standard electrocardiogram was recorded during the second minute after exercise. In all postexercise V₃ leads, cardiac cycle length, the magnitude of J (S-ST junction) depression, and the slope of the ST segment were measured. All records, including the telemetered tracings during exercise and the first 15 seconds after exercise, plus the standard lead electrocardiograms made during the second minute after exercise, were carefully examined for abnormalities by two or more experienced electrocardiographers. If any questionable change was seen in any lead, the magnitude of the "J" depression and the slope of the ST segment in that lead were measured as described below and classified accordingly. Because of the short time constant of the telemeter system, J-amplitude and ST-slope measurements were not reported on tracings thus recorded. Interpretation of these tracings was by visual analysis only.

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* Manufactured by Avionics Research Products Corporation, 6901 W. Imperial Highway, Los Angeles, California.
† EKG Sol, Manufactured by Burton, Parsons and Company, Inc., Washington, D. C.

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**Figure 1**

Method of calculation of the ST-segment slope: Three consecutive PQ points (A) are connected to form a baseline. A tangent is drawn to the first 0.08 second of the ST segment, and the slope in mV per second is derived.

\[
\frac{dV}{dt} = \frac{D}{BC}
\]

where \( D \) = cm from baseline to intersection of ST tangent (1 cm deflection = 1 mV)

\( BC = \) cm chart travel from intersection with line \( D \), divided by chart speed, cm/sec.
Figure 1 illustrates the methods utilized for determining the ST-segment slope. The J depression of 1 mm is easily seen. Three consecutive PQ points (A) are connected to form a baseline. A tangent then is drawn to the first 0.08 second of the ST segment, and the slope in millivolts per second is derived. The complexes measured were typical of those over a period of several seconds. On no occasion was a single unusual beat measured.

Results

The individuals tested were cooperative and in many cases quite competitive. All subjects performed the exercise to the satisfaction of the examiner and no one had to be stopped because of chest pain or electrocardiographic changes during exercise. Only one subject was able to complete all seven phases (21 minutes) of the MET. Most subjects stopped during the fourth or fifth phase after 9 to 15 minutes of exercise. In general, no objection to either test (MET or GXT) was raised in these well-motivated subjects. There has been, however, an occasional subsequent refusal of retesting at maximal level.

Performance by heart rate attained during exercise is seen in figure 2 for the GXT and figure 3 for the MET. The predicted maximal heart rate is indicated by the unbroken line in both figures. The GXT level (90% of the predicted maximal heart rate according to the data of Robinson7) is illustrated by the double broken line; 70%, 80%, and 110% of predicted maximal heart rate are illustrated by broken lines and labeled accordingly on each graph. It is shown that the GXT heart rate range was almost always attained. This rate was easily maintained for 2½ minutes by reducing steps per minute on the box after the desired rate was reached. On rare occasions, men who lacked agility for the step climbing had difficulty attaining or sustaining target rate. The maximal heart rate as predicted from the older studies of Robinson was exceeded by 88% of the subjects of this study during the maximal exercise test. These values for maximal heart rate were slightly higher, in each age group, than those recently reported by Doan and associates.5

The individual subjects were usually quite hyperpneic during the GXT and were noted to sweat profusely. Recovery following the CXT was rapid and no one declined to proceed to the MET. In contrast, the skin of almost every subject tested was noted to be cold and pale just prior to spontaneous termination of the MET. A feeling of profound weakness was described by several of the subjects. This sensation occasionally persisted as long as 3
to 5 hours after the maximal exercise test, and was not always endured graciously.

No individuals were found to develop significant complications during or after the GXT. Specifically, there were no instances of atrial or ventricular arrhythmias other than occasional ventricular premature beats. Table 3 illustrates all complications that occurred in response to the MET. Two subjects developed brief (3 to 4 beats) runs of ventricular tachycardia immediately before spontaneous termination of exercise. These recurred briefly during the first minute of recovery. No significant delayed complications have occurred, and all subjects were able to return home immediately after the study.

A flat or sagging ST segment with a J depression of 1.0 mm or more was the only criterion used to establish a definitely positive response. This change is designated as criterion I positive. Subjects with ST segment that appeared “ischemic” to inspection but with a slightly upward ST slope by measurement were classified criterion II (doubtful). A flat or sagging ST segment from an elevated junction would have been considered as fulfilling criterion II, although no subject in this study exhibited such change.

Table 4 illustrates the number of positives obtained from each test. Only one individual was found to be positive by criterion I or criterion II during or after the GXT. This individual was positive by criterion II, only on the fourth minute postexercise recording. He later had a completely normal response to maximal exercise test. Four subjects had positive (criterion I) responses to maximal exercise. Each had segmental ST depression only during exercise or for the first 5 to 10 seconds postexercise (by telemeter only). In every instance the postexercise standard tracings were negative in all respects. One other volunteer had a doubtful response (criterion II) during the second minute following the maximal exercise test, without such changes during or immediately after the exercise.

Table 3

Complications That Occurred in Response to the Maximal Exercise Test (MET)

<table>
<thead>
<tr>
<th>Complication</th>
<th>No.</th>
<th>Age</th>
<th>MHR</th>
<th>MET</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ventricular tachycardia (multiple short runs of 3-4 PVC's in a row) during exercise</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>a) 64</td>
<td>186</td>
<td>Neg.</td>
<td></td>
<td>Terminated upon cessation of exercise</td>
</tr>
<tr>
<td></td>
<td>b) 57</td>
<td>188</td>
<td>Neg.</td>
<td></td>
<td>Terminated upon cessation of exercise</td>
</tr>
<tr>
<td>Supraventricular tachycardia after exercise</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>a) 56</td>
<td>168</td>
<td>Neg.</td>
<td></td>
<td>Onset 2 minutes after exercise—terminated spontaneously after 15 seconds</td>
</tr>
<tr>
<td></td>
<td>b) 51</td>
<td>195</td>
<td>Neg.</td>
<td></td>
<td>Onset 6 minutes after exercise without symptoms, was associated with a mild hypotension, and was terminated with a vasopressor after 30 minutes—no recurrences</td>
</tr>
<tr>
<td>Postural hypotension*</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>a) 40</td>
<td>180</td>
<td>Neg.</td>
<td></td>
<td>Occurred 8 minutes after exercise upon standing; relieved by lying down for an additional 10 minutes</td>
</tr>
<tr>
<td></td>
<td>b) 43</td>
<td>180</td>
<td>Neg.</td>
<td></td>
<td>Occurred 30 minutes after exercise; relieved by sitting in chair for a short period</td>
</tr>
<tr>
<td>Syncope during or following exercise</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Delayed complications</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pain with exercise</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Postural hypotension in the two subjects was sufficiently marked to produce faintness.
Table 4

Number of Positive Results Obtained from Each Test and the Criterion by Which Each Is Positive*

<table>
<thead>
<tr>
<th>Age groups</th>
<th>No. of volunteers</th>
<th>Criteria positive</th>
<th>GXT</th>
<th>MET</th>
</tr>
</thead>
<tbody>
<tr>
<td>40-49</td>
<td>29</td>
<td>I II I II I II I II</td>
<td>60 or &gt;</td>
<td>60 or &gt;</td>
</tr>
<tr>
<td>50-59</td>
<td>37</td>
<td>I II I II I II I II</td>
<td>56</td>
<td>56</td>
</tr>
<tr>
<td>60 or &gt;</td>
<td>17</td>
<td>I II I II I II I II</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

*Criterion I (positive) means that the slope of the ST segment, calculated as shown in figure 1, was 0 mV/sec or less (negative slope). Criterion II (doubtful) means the slope appeared to be flat, but my measurement was found to be between 0 and +1.0 mV/sec with a J depression of 0.5 mm or more.

Table 5

Clinical Data for Each Positive Responding Volunteer

<table>
<thead>
<tr>
<th>Age</th>
<th>Clinical diagnosis</th>
<th>Exercise habits</th>
<th>Termination of exercise</th>
<th>MHR attained</th>
<th>Positive</th>
<th>GXT</th>
<th>MET</th>
</tr>
</thead>
<tbody>
<tr>
<td>G.W.* 47</td>
<td>Angina pectoris</td>
<td>Sedentary</td>
<td>10' 45&quot;</td>
<td>190</td>
<td>Neg.</td>
<td>Criteria I pos. post exercise</td>
<td></td>
</tr>
<tr>
<td>J.F. 66</td>
<td>Normal</td>
<td>Trained</td>
<td>12' 0&quot;</td>
<td>175</td>
<td>Neg.</td>
<td>Criteria I pos. post exercise</td>
<td></td>
</tr>
<tr>
<td>F.J. 68</td>
<td>Normal</td>
<td>Sedentary</td>
<td>9' 40&quot;</td>
<td>180</td>
<td>Neg.</td>
<td>Criteria II pos. post exercise</td>
<td></td>
</tr>
<tr>
<td>J.P.† 51</td>
<td>Normal</td>
<td>Sedentary</td>
<td>10' 0&quot;</td>
<td>184</td>
<td>Neg.</td>
<td>Criteria I pos. during exercise only</td>
<td></td>
</tr>
<tr>
<td>E.J.† 47</td>
<td>Normal</td>
<td>Mod. active</td>
<td>15' 40&quot;</td>
<td>195</td>
<td>Neg.</td>
<td>Criteria I pos. during exercise only</td>
<td></td>
</tr>
<tr>
<td>D.D.† 48</td>
<td>Normal</td>
<td>Sedentary</td>
<td>13' 30&quot;</td>
<td>204</td>
<td>Neg.</td>
<td>Criteria I pos. during &amp; 1st 10 sec. post exercise only</td>
<td></td>
</tr>
<tr>
<td>J.K.† 68</td>
<td>Normal</td>
<td>Mod. active</td>
<td>12' 15&quot;</td>
<td>170</td>
<td>Neg.</td>
<td>Criteria I pos. during &amp; 1st 10 sec. post exercise only</td>
<td></td>
</tr>
<tr>
<td>J.C. 54</td>
<td>Normal</td>
<td>Sedentary</td>
<td>11' 50&quot;</td>
<td>168</td>
<td>Crit. II pos. 4 min. post exercise</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Subject tested but not included in the study.
†By telemeter during exercise.

Table 5 illustrates the age of the individual subjects, their exercise habits, duration of treadmill exercise, maximal heart rate attained during exercise, and ST segment response to exercise for all subjects classified “positive” by either criterion. These subjects could not be distinguished from the “normal responders” by exercise habits, maximal heart rate attained, or level of exercise reached at termination of exercise.
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Figures 4 and 5 depict the relation of J depression and the ST-segment slope measured from the 30-second postexercise tracings for the GXT and MET. J depression of 0.5 mm or more was observed in all but 17 subjects. None of the subjects had such depression exceeding 2.0 mm. The ST slope ranged up to 6 mv/sec. Although poor correlation was found between the magnitude of these values, such a display has a potential clinical usefulness. Area B is an arbitrarily constructed area on the graph, free from normal responses where questionable ST segments might fall if the ST slope is slightly upward in the presence of “J” depression. The two subjects positive by criterion II fall in this area. Experience to date indicates that patients with angina pectoris may have data-points falling in this area after mild exercise, whereas more severe exercise produces frankly “positive” segmental depression. Similarly, the complexes immediately before or after a series of frankly “positive” beats may have J-ST-slope relationships falling in this zone.

Display of the magnitudes of J-junction depression and ST-segment slope at 2, 4, and 6 minutes after exercise showed a similar but less marked J depression and a lesser degree of ST slope. No other subject developed significant changes following the maximal exercise test at the 2-, 4- and 6-minute intervals.

Discussion

Four conclusions appear warranted from the present study. First of all, older American men who have no history of angina pectoris and no clinical evidence of cardiovascular disease can complete exercise of near maximal or maximal severity with a very small risk of serious complications. This is consistent with extensive previous experience in this laboratory and others.\(^1\) \(2\) \(5\) \(8\) Secondly, such exercise can be completed with a very low incidence (less than 1%) of ischemic or segmental ST depression of 0.1 mv or more in electrocardiographic records made 30 seconds or later following the conclusion of the test. Thirdly, a small percentage of subjects will exhibit such ST changes only with maximal exercise, having been able to complete the near maximal test (GXT) without recognizable abnormality. Fourthly, many of the subjects having ST-segment depression as a result of maximal exercise will
manifest this change only during exercise or within the first half minute following termination of the exercise. In this study, four of the 114 subjects (3.5%) showed such transitory ST-segment depression.

The relative safety of maximal and near maximal exercise testing in the older subjects volunteering for this study is reassuring. No significant complications during or after exercise were recognized in any of these 114 subjects ranging in age from 40 to 75 years. Similar conclusions have been reached following study of 226 volunteers of about the same age by Doan and associates. Sheffield, and associates reported no complications in 216 patients, including 38 patients with angina pectoris. Mason and his colleagues have likewise reported no significant morbidity and no mortality in near maximal testing in normal subjects and patients with angina pectoris.

This does not imply that such testing is completely without hazard. Violent activity is hazardous for subjects with coronary heart disease. There are several reported instances of death during or immediately after exercise for electrocardiographic testing. There are undoubtedly many others that have not been reported. Most of the tragedies have occurred when an acute myocardial infarction was not recognized prior to testing. It is therefore mandatory that the test be directly supervised by a clinician competent in electrocardiographic interpretation. In addition, we consider it essential to have resuscitation equipment, including electrical defibrillator, immediately at hand with personnel skilled in its use.

To our knowledge no serious complications of maximal or submaximal testing as herein described have been reported. We have, however, been impressed by the transitory ventricular arrhythmias associated with the MET, and by the prolonged feeling of weakness following it, occasionally accompanied by postural hypotension and faintness. Submaximal exercise testing, by comparison, is characterized by recovery of well-being within 4 to 6 minutes in normal subjects, and 4 to 15 minutes in patients with angina pectoris. Until several thousand experiences with both test levels in both normal and diseased subjects have been accumulated and analyzed, we believe that the availability of protective measures, the attitude of caution in administration, and the development of indications for testing with either level should be in proportion to the severity of stress involved. In the selection of a test for wide usage in screening population groups for coronary artery disease, subject acceptance must be given serious consideration. The GXT requires less of the volunteer's time at the test and he is required to demonstrate a lower level of motivation and cooperation than the MET requires. Simply stated, a higher percentage of average subjects is likely to complete a GXT than is likely to proceed through exercise stages to maximal exertion.

As reported earlier, the double Master test is for some persons a near maximal exertion. By controlling exercise rate in accordance with heart-rate response, patients with severe restriction of exercise capacity tend to be protected from overexertion. But we have found that for the average subject a more vigorous exercise level improves diagnostic yield, and the more moderate heart-rate response of the fit subject automatically calls for a proportionally higher work rate in the performance of a GXT.

One recent study has resulted in findings that appear to conflict seriously with the data of the present study. Doan and associates, reporting on maximal exercise tests in a volunteer population, found positive responses in 9.4% of persons in the fifth decade, 24.1% in the sixth decade, and 46.1% in the seventh decade. Examination of the maximal heart rates achieved in each study suggests that there were not significant differences in the work stresses involved; indeed, the rates were slightly higher in our study which found fewer positive responses. There are, however, four possible explanations for the differences found.

First, there is a difference in the compositions of population samples. Of the 226 subjects in the older age group studied by Doan
and associates,25 had significant cardiac abnormalities that were recognized prior to testing. These abnormalities included aortic stenosis, angina pectoris, arterial hypertension, left ventricular hypertrophy, and healed myocardial infarction.

Abnormal electrocardiographic responses in these 25 subjects increased the gross incidence of reported abnormal responses, yet these subjects are not comparable with the presently reported group from which all significant cardiac abnormalities were excluded. A similar exclusion of known abnormality from Doan’s study5 would leave 201 “normal” volunteers manifesting only a 9% incidence of electrocardiographic positive responses in subjects 40 years or older. This incidence is in the same order of magnitude as that found in our study (5%).

There does appear to be a relationship between subject age and likelihood of positive response. Our own experience is in agreement with that of Mason and associates,2 Rumball and Acheson,3 and Doan and associates,5 in this respect. The incidence of positive responses in the present study is too low to allow a confident analysis with respect to age. It is interesting, however, that only three of 98 subjects less than 60 years of age presented any kind of electrocardiographic abnormality in response to maximal exercise, whereas three of 17 subjects over 60 exhibited ST-segment depression during or after exercise.

A second difference in the compared studies lies in the time, with respect to exercise, that the recordings were made. In the study of Doan and associates,5 almost all the “ischemic ST depressions” appeared during or immediately after exercise and returned to normal in 30 seconds of recovery. In the study by Sheffield and associates,1 only recordings made after 30 seconds of recovery were analyzed and reported. In the present study one of 114 normal subjects had ST depression 30 or more seconds after maximal exercise, although the overall incidence of abnormality was 5.2%. It was less than 1% for the near maximal (GXT) procedure.

A third possible cause of difference in findings is the recognized high incidence of interobserver variation in evaluating electrocardiograms. The reproducibility of human measurement of ST-segment depression by conventional means is known to be limited. The methods used in the present study were designed to minimize these differences. In addition, all records were independently reviewed by all three authors to ensure that no “doubtful” responses were overlooked.

Fourth, in addition to the three technical bases of different findings, it is possible that there are actual significant differences between the source populations of Birmingham and Seattle. Indeed, one of the major potential values of exercise electrocardiographic testing is that of epidemiological evaluation, both geographic and otherwise. It has been suggested on other grounds that important regional differences in the incidence of coronary heart disease are present in the United States. Until there is more technical uniformity in recording and higher precision of analysis, such applications will be difficult to interpret.

In view of the total experience reported to date and with attention to the factors discussed above, it would appear that the overall incidence of ST-segment depression in response to near maximal exercise testing (GXT) is between 1 and 3% in middle-aged and older American men. The incidence of such changes in response to maximal testing seems to be between 5 and 10%. It is important to recognize that such figures apply only to the incidence of ST-segment abnormalities. Other, more subtle, electrocardiographic changes, which may have equal significance, have not been included. The most important of these include (1) increased intraventricular depolarization time, (2) the development of sustained ventricular arrhythmias during and following exercise, (3) abnormal widening of the QRS-T angle, (4) J depression greater than 0.2 mV, (5) prolongation of the QT interval relative to the heart rate, and (6) changes in certain spatial values as derived from the vector electrocardiogram. Other measurements may have equal or greater significance. Analysis of
these and other changes by automatic data-
processing methods should permit clarifica-
tion of their relative importance in diagnosis.
At present, in our clinical practice, we regard
all such changes as indications of possible
abnormality, increasing the degree of suspi-
cion of coronary heart disease in the absence
of evidence of other types of cardiac ab-
normality.

The exact significance of electrocardiograph-
ic abnormalities following maximal or near
maximal exercise has not been established.
Most of the evidence linking ST-segment de-
pression to myocardial hypoxia is empirical.
It is also evident that the prognostic value of
such changes under the conditions existing
during or immediately following maximal ex-
ercise cannot be properly assumed to be the
same as more persistent changes occurring
after less strenuous exercise of shorter dura-
tion. We believe that the degree of coronary
flow restriction may be inversely proportional
to the severity of stress required to detect it.
It seems likely also that the duration of the
ischemic changes following termination of ex-
ercise will be found to have prognostic sig-
ificance.

Thus, there is a broad question of the de-
gree of applicability of a sign that has time-
proven usefulness under one set of conditions
(that is, ST-segment depression following the
relatively moderate exercise of a “two-step
test”) to a significantly different set of testing
conditions. If this question is frankly recog-
nized, it should be possible to begin answering
it by properly designed prospective studies.

Addendum

Since this report was submitted for publication an
additional 60 subjects, 51 over the age of 50, have
been studied with the MET. In this group multiple
electrocardiographic leads were recorded by direct
wire before, during, and after exercise. Postexercise
recordings were made in the sitting position. A
total of four positive responses (8.6%), two by criteri-
on I and two by criterion II, were found. In each
case the abnormality was manifested before exercise
was completed. In two the abnormality was transitory,
disappearing within 30 seconds after the termination
of exercise, and in the other two the abnormality
persisted for 6 and 8 minutes, respectively.

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