The Effect of Exercise on Postural Changes in the Electrocardiogram

By Samuel Bellet, M.D., and Laurian Roman, M.D.

Postural Changes in the electrocardiogram are of considerable interest and have been the subject of numerous communications by many investigators.1–7 Recently, study of the exercise electrocardiogram with the subject in the upright position has stimulated our additional interest in these phenomena.8,9

The present investigation was undertaken to evaluate the incidence and significance of postural electrocardiographic changes in normal subjects and in patients with myocardial abnormality, and the effect of exercise upon these changes.

Methods

The methods employed have been discussed in detail in previous reports.8,9 Briefly, a standard 12-lead electrocardiogram was taken in the recumbent position; an electrocardiogram (lead II, V₄, and V₉) was then taken in the upright position and these leads were recorded continuously in sequence during the two-step test. These leads were then recorded immediately after exercise and at intervals of 1, 3, and 5 minutes in the standing position and then in the recumbent position. Although various criteria have been employed in defining postural changes, only the more significant ones, which may simulate ischemic response to exercise, were employed in this study—namely, the development in one or more leads of an ischemic ST depression of 1 mm. or more, a functional ST depression of 2 mm. or more, or frank inversion of the T wave.

The following groups were studied: (1) normal subjects (college students), age 17 to 25 (250 subjects); (2) industrial workers, age 30 to 65 (776 subjects); and (3) patients with coronary disease (70 subjects).

Results

The results are shown in tables 1, 2, and 3. From these, it is apparent that ST-T postural changes are much more frequent in subjects with coronary artery disease (18.5 per cent) and in normal subjects with a positive electrocardiogram exercise test (10.7 per cent) than in normal subjects with a negative electrocardiogram exercise test (3.4 per cent). Details of the total of 55 subjects (normal and angina patients) with postural ST-T changes are presented in table 2.

Of the total number of 1,096 subjects studied (normal and angina patients), 152 had positive exercise tests; details of the electrocardiographic findings in this group are presented in table 3.

Discussion

Cause of Postural Changes

Postural changes are manifested in the electrocardiogram by a shift of the QRS axis to the right, an increase in the amplitude of the P wave, a shortening of the P-R interval, ST-segment depression, and flattening or inversion of the T wave.2,3 The factors that alone or in combination are responsible for postural changes follow: (a) The shift in the QRS axis and at times the T axis are due to a change in the position of the heart.2,7 (b) ST-T changes are predominantly a consequence of an increase in the sympathetic tone in the standing posture. These changes may persist for a time even after the return to the horizontal position.1–4,6,7 The increase in sympathetic tone results from reflexes originating predominantly in the aortic arch and carotid sinus with resulting peripheral vasoconstriction; this helps to maintain an adequate blood pressure in the upper part of the body in spite of gravitational forces. The increase in sympathetic tone produces an in-
crease in catecholamine liberation, which has been shown to occur with the assumption of the upright position.\textsuperscript{10}

The relationship of postural changes to an increase in sympathetic tone has been demonstrated by many studies.\textsuperscript{2, 4, 5, 7, 11-16} Nordenfelt\textsuperscript{1} has shown that the postural electrocardiographic changes can be prevented by administration of ergotamine. Wagner et al.,\textsuperscript{6} Yu and Bernard\textsuperscript{14} and others have shown that the injection of epinephrine produces ST-T changes and even inverted T waves.

**Postural Changes in Coronary Artery Disease**

The more frequent occurrence of significant postural changes in subjects with coronary heart disease and in apparently normal subjects with positive exercise tests is of considerable interest; this fact is readily understood if we consider the mechanisms of postural changes.

The catecholamine liberation produced by assuming the standing position increases the cardiac output, oxygen consumption of the myocardium, and coronary blood flow. In normal subjects, the increase in oxygen consumption is usually accompanied by an adequate increase in coronary blood flow. In some subjects, however, after sympathetic stimulation, the oxygen supply in certain unfavorably located cell groups is not sufficiently large to compensate adequately for the increase in oxygen consumption; thus, because these cells may become hypoxic and the lactic acid concentration in the coronary venous blood may be increased\textsuperscript{11} changes in ST-T segment may result. These changes are more likely to occur in patients with angina or coronary heart disease in whom the oxygen supply to large areas of the myocardium is significantly impaired.

In patients with angina, it has been shown that sympathetic activity is increased.\textsuperscript{11, 13, 17} Gazes et al.\textsuperscript{13} and Richardson et al.\textsuperscript{17} have found that in angina patients, after exercise, circulating catecholamines increased significantly in contrast to normal subjects in whom no increase was found. This increased sympathetic reactivity found in coronary patients may be an additional factor in the increased frequency of postural changes observed in this group.

It has recently been shown that shifting the patient from the horizontal to the upright position produces an immediate decrease in inferior vena caval flow of 40 to 50 per cent of the resting horizontal value with a subsequent return to the steady state of approximately 80 to 90 per cent within a period of 5 to 8 minutes. The minute cardiac output follows a similar pattern, but the decrease is relatively less marked.\textsuperscript{18} These factors would tend to reduce the amount of coronary blood flow, and would tend to produce elec-

### Table 1

<table>
<thead>
<tr>
<th>Group</th>
<th>Total no. subjects</th>
<th>Total no. postural changes</th>
<th>Positive test Total</th>
<th>Positive test Postural changes</th>
<th>Negative test Total</th>
<th>Negative test Postural changes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>1026</td>
<td>42 (4.1%)</td>
<td>103</td>
<td>11 (10.7%)</td>
<td>923</td>
<td>31 (3.4%)</td>
</tr>
<tr>
<td>Angina</td>
<td>70</td>
<td>13 (18.5%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Table 2

<table>
<thead>
<tr>
<th>Types of ST-T Postural Changes in 55 Subjects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inversion of T wave</td>
</tr>
<tr>
<td>Ischemic depression, $\geq$ 1 mm.</td>
</tr>
<tr>
<td>Junctional depression, $\geq$ 2 mm.</td>
</tr>
<tr>
<td>Total</td>
</tr>
</tbody>
</table>

### Table 3

<table>
<thead>
<tr>
<th>Incidence of Electrocardiographic Changes in Subjects with Positive Exercise Tests</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ischemic ST depression, $\leq$ 1 mm., with or without T inversion</td>
</tr>
<tr>
<td>Junctional depression, $\leq$ 2 mm.</td>
</tr>
<tr>
<td>Multiple premature ventricular contractions</td>
</tr>
<tr>
<td>T Inversion only</td>
</tr>
<tr>
<td>Total</td>
</tr>
</tbody>
</table>

*Bellet, Roman

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trocardiographic changes, particularly in the presence of coronary artery disease. The difference in the incidence of postural changes in normal subjects as contrasted to those with coronary artery disease and latent coronary insufficiency has not been previously emphasized. Lepeschkin and Surawicz\textsuperscript{19} observed an increased incidence in subjects with positive exercise tests and those with coronary disease, but the exact description and discussion of the T and ST changes was not given.

**Effect of Exercise**

Another item of interest is the effect of postural changes on the exercise electrocardiogram recorded in the standing position. In the great majority of cases, postural changes which affect the repolarization process are represented by alterations in the T wave (fig. 1); only in about 10 per cent of our cases were postural changes expressed by an ischemic ST depression similar to that observed in positive exercise tests (table 2). Conversely, a positive exercise test was manifested by ischemic ST-segment depression in most instances and solely by T changes in only 8.5 per cent of our cases (table 3). Therefore, only a small range of possible confusion exists between these two categories of electrocardiographic findings. Furthermore, careful examination of the tracings can prevent such confusion; in subjects with an inverted T wave or ST depression, or both, as a result of postural changes, only a significant increase in T inversion or ischemic ST depression is considered evidence of a positive test\textsuperscript{9} (figs. 2 and 3).

Recently, Lachman et al.\textsuperscript{20} published observations concerning postural changes in the radioelectrocardiogram which are worthy of comment. They found ST-T postural changes in 16 per cent of 200 normal subjects ages 15 to 30 years. This percentage was higher than ours (4.1 per cent) and that observed by Lepeschkin and Surawicz (3 per cent).\textsuperscript{19} The difference is probably explained by the criteria for postural changes and more particularly by the leads employed by Lachman et al. Among the criteria for significant postural changes that present false-positive evidence of ischemic changes, the above authors included even simple flattening of the T wave and small junctional depression of the ST segment. These do not represent significant “ischemic type” changes. Most important was the electrode placement; instead of using the

![Figure 1](http://circ.ahajournals.org/)

*W.G. (40 steps). An 18-year-old normal student (lead II). Note the postural changes: the inverted T wave, which appeared on standing, persisted during the period of exercise. The T waves were less inverted at 70 seconds and immediately after exercise.*
Figure 2.

N.G. (24 steps). From a 41-year-old woman with typical angina over a period of 2 years (lead II). In the recumbent position note the diaphasic T wave. In the upright position, note the appearance of a frankly inverted T wave with slight ST-segment depression; the ST-segment depression becomes more marked as

classical unipolar chest leads that we employed (the value of which has been established by long experience), the above authors used a bipolar chest lead, MV5, in which the exploring electrode is placed at the V5 position and the "remote electrode" over the sternal manubrium very close to the heart. The axis of this bipolar lead is such that even minor changes in the direction of the T vector (which occur often in the standing position) result in negative T waves in this lead. When the remote electrode was placed in a position below the lateral third of the right clavicle (similar to CR5), many of the postural changes disappeared. Thus, the type of electrode placement significantly influences not only the incidence of postural changes but also the criteria for a positive exercise test (fig. 4).

Summary

The electrocardiogram before, during, and after a double two-step exercise test was studied in the upright position in 1,026 subjects with no apparent heart disease and in 70 patients with angina. Postural changes were found much more frequently in subjects with angina (18.5 per cent) and in apparently normal subjects with positive exercise tests (10.7 per cent) than in normal subjects with negative exercise tests, in which postural changes were found in only 3.4 per cent. Probable causes for these findings are discussed.

The criterion for positivity in over 80 per cent of exercise tests, namely, an ischemic ST depression, is rarely seen as a postural change in normal subjects. On the other hand, isolated T-wave changes, which represent approximately 90 per cent of the postural changes of the repolarization period, are very rarely the sole criteria for a positive exercise test. Therefore, only a small area of possible confusion exists between postural changes and positive exercise tests. However, even in such the exercise continues. Note that following exercise the inverted T wave and the ST-segment depression persist even in the 5-minute postexercise tracing. These findings are typical of the postural changes observed in a patient with coronary artery disease.

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A.G., age 52, with evidence of coronary artery disease, chest pain had been present for the last 3 years (lead V). Note the upright T wave in the supine position. On standing the T wave becomes frankly inverted. During exercise the inversion of the T wave becomes more marked at 18 seconds and is accompanied by an ST-segment depression; this depression becomes more marked at 180 seconds. Note that the ST-segment changes become less marked in the tracing taken immediately after exercise, but the T-wave inversion persists in the tracings taken 1, 3, and 5 minutes postexercise in the standing position.

cases, careful examination of the tracings can resolve these difficulties.

References
10. Sundin, T.: The effect of body posture on the
Figure 4

G.W. This tracing is taken from a normal subject, age 20 years. This figure illustrates the differences in the postural changes between MV₅ (bipolar lead from apex to manubrium) and CV₅ (from apex to just below the level of the right clavicle). The findings in CV₅ are similar to those obtained with CR₅ and Vₐ. Note the diminished amplitude of the T wave in the recumbent position (MV₅). Note that immediately upon standing the T wave becomes inverted. This inversion persists although it is somewhat less marked during the period of exercise and in the period 1 and 3 minutes following exercise, but the same degree of inversion returns in the 5-minute postexercise tracing. CV₅ (right-hand series): note the absence of postural changes in the standing position and the presence of upright T waves during and in the period immediately after exercise. This figure illustrates the difference in the postural changes observed in the two types of bipolar leads—MV₅ and CV₅ (see text).


The baneful features of controversy develop chiefly, I believe, from the use of language which expresses emotional attitudes rather than intellectual considerations. If differences between investigators are discussed strictly on the intellectual level there is no reason for the development of a sense of injury, no reason for later enmity. Properly conducted, a polemic may leave both the original investigator and his critic with the conviction that they have been concerned with the advancement of science. The desire for conquest, the impulse to engage in triumphal exaltation is absent. Also the emphasis on observed facts may lead to further work of a more refined character, and thus to new and unanticipated discoveries.—WALTER BRADFORD CANNON: The Way of an Investigator: A Scientist's Experiences in Medical Research. New York, W. W. Norton & Company, Inc., 1945, p. 100.
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