Changes of Mean Spatial QRS and T Vectors and of Conventional Electrocardiographic Items in Hard Anaerobic Work

By K. A. Kahn, M.D. and E. Simonson, M.D.

In 35 normal men, conventional and vectorial electrocardiographic items were studied after severe, anaerobic exercise over a recovery period of 8 min. The changes, especially of the T vector, are pronounced, but are different from those observed in coronary insufficiency. The hypothesis is advanced that the changes in anaerobic exercise are due to general myocardial hypoxia, in contrast to the localized ischemia in coronary insufficiency.

Despite voluminous literature on exercise tolerance tests, little attention has been paid to the electrocardiographic response, particularly of spatial vectors, of the normal individual under conditions of anaerobic work. Kimura and Simonson1 demonstrated differences in the changes of mean spatial QRS and T vectors between aerobic and anaerobic work; however, the series was small. The present study consists of a statistical analysis of electrocardiographic changes, both of conventional items and spatial vectors, after anaerobic work.

Method and Subjects

Thirty-seven trained young men in good physical condition were judged to be normal after a complete medical history, physical examination and screening laboratory examination. They were exercised on a motor driven treadmill for 3 to 5 min. at a speed of 7 to 8 m.p.h. and at 6° to 10° grades depending upon individual endurance. Standard and six or more precordial leads were taken with a direct writing electrocardiograph in the supine position in basal condition, 1 and 4 min. after exercise in all subjects. In 25 of the subjects tracings were also taken 8 min. after exercise. All precordial leads were taken at a horizontal plane through the fifth intercostal space anteriorly in the conventional vertical lines of the precordial lead positions V1-6; Vr, and V6r were taken when necessary to determine the location of the T transition zone.

The electrocardiograms were analyzed for several conventional items (rate, P-R interval, QRS interval, height of T-V2, QRS axis, and T axis). In addition, mean QRS and T vectors were obtained from conventional scalar electrocardiogram leads utilizing a spatial vector analyzer.2 The azimuth (H°), elevation (V°), and magnitude (Mag) were determined for the mean QRS and T vectors. The reference scale for azimuth H° ranges from 0° (left) to ±180° (right), +90° indicating frontal and −90° posterior direction. Values for elevation range from 0 to 180°, 0° indicating caudad, and 180° cephalad direction. In addition, the angle between the resultant QRS and T vectors (ΔH°) and their projections in the horizontal plane H°T − H°QRS (ΔH°) were obtained. The magnitude is given in terms of standardized mm. (1 mm. = 0.1 mV.).

Utilizing the rest values as a control, the relative changes after exercise were evaluated with routine statistical procedures.

Results

The statistical analysis of conventional items is found in table 1 and of vectorial items in table 2. Graphic presentation of QRS and T axis deviations is shown in figure 1, and of vectorial items in figure 2. The values in tables 1 and 2 are expressed as differences between rest (control) and post-exercise tracing. Time after anaerobic exercise is indicated as 1, 4, and 8 min. post exercise, respectively. The absolute mean values of all items analyzed, before (control) and after exercise, are shown in table 3.

The results in the conventional items (table 1), in terms of mean changes, may be itemized as follows: 1. The P-R interval is shortened by a mean value of .0105 after 1 min. of exercise, which is highly significant, but recovers nearly to the initial value within 4 min. The slight differences at 4 min. (.0014) and at 8 min. (.0036) are not statistically significant. 2. The QRS interval is not significantly affected.
ELECTROCARDIOGRAPHIC CHANGES IN ANAEROBIC WORK

TABLE 1.—Changes of Conventional Electrocardiographic Items (Differences from Resting Electrocardiogram)

<table>
<thead>
<tr>
<th>Time after work (min.)</th>
<th>Statistic</th>
<th>Number of subjects</th>
<th>Intervals</th>
<th>Axis</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>PR</td>
<td>QRS</td>
</tr>
<tr>
<td>1</td>
<td>Mean</td>
<td>37</td>
<td>-.0105</td>
<td>-.0027</td>
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<tr>
<td></td>
<td>S.D.</td>
<td></td>
<td>.018</td>
<td>.013</td>
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<tr>
<td></td>
<td>t</td>
<td></td>
<td>3.46</td>
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<td>4</td>
<td>Mean</td>
<td>37</td>
<td>.0014</td>
<td>-.0065</td>
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<tr>
<td></td>
<td>S.D.</td>
<td></td>
<td>.019</td>
<td>.014</td>
</tr>
<tr>
<td></td>
<td>t</td>
<td></td>
<td>.430</td>
<td>2.708</td>
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<tr>
<td>8</td>
<td>Mean</td>
<td>25</td>
<td>-.0036</td>
<td>-.004</td>
</tr>
<tr>
<td></td>
<td>S.D.</td>
<td></td>
<td>.024</td>
<td>.014</td>
</tr>
<tr>
<td></td>
<td>t</td>
<td></td>
<td>.751</td>
<td>1.414</td>
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</tbody>
</table>

TABLE 2.—Changes of Vectorial Electrocardiographic Items after Anaerobic Exercise

<table>
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<tr>
<th>Time after work (min.)</th>
<th>Statistic*</th>
<th>Number of subjects</th>
<th>QRS complex</th>
<th>T wave</th>
<th>H°</th>
<th>V°</th>
<th>Mag.</th>
<th>H°</th>
<th>V°</th>
<th>Mag.</th>
<th>ΔA</th>
<th>ΔH°</th>
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</thead>
<tbody>
<tr>
<td>1</td>
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<td>37</td>
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<td>4.70</td>
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<tr>
<td></td>
<td>s</td>
<td></td>
<td>20.09</td>
<td>19.57</td>
<td>2.7</td>
<td>14.41</td>
<td>20.71</td>
<td>1.91</td>
<td>19.47</td>
<td>27.69</td>
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<td>2.40</td>
<td>1.18</td>
<td>.16</td>
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<td>8.24</td>
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<td>-5.89</td>
<td>-3.24</td>
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<td>-7.46</td>
<td>.04</td>
<td>4.92</td>
<td>19.97</td>
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<td>21.58</td>
<td>20.87</td>
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<td>14.06</td>
<td>19.97</td>
<td>1.54</td>
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<td>.0077</td>
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<td>10.36</td>
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<td>.22</td>
<td>9.20</td>
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<td></td>
</tr>
<tr>
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<td>s</td>
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<td>11.32</td>
<td>24.24</td>
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<tr>
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<td>.651</td>
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<td>1.808</td>
<td>.660</td>
<td>1.966</td>
<td>3.013</td>
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<td></td>
</tr>
</tbody>
</table>

* Significance Criteria (t). X = 37: 2.029 = 5%; 2.722 = 1%; 3.589 = 0.1%. N = 25: 2.064 = 5%; 2.797 = 1%; 3.745 = 0.1%.

TABLE 3.—Mean Values of Electrocardiographic Changes after Anaerobic Exercise

Cardiac rate is markedly accelerated; the recovery within 8 min. is incomplete. 4. The T axis (fig. 1) shifts markedly to the right (18.44°) immediately after exercise. It then slowly recedes until at 8 min. the average deviation is +5.56° which is close to the 5 per cent level of significance. 5. The QRS axis deviates continuously to the right through the 8 min. recovery. The average change of 5.43° 1 min. after exercise is statistically not significant, but by 8 min. the progressive shift reaches a deviation of 8.16°, which is significant at the 5 per cent level. 6. The amplitude of T-V2 immediately increases by 6.5 mm. and then gradually recedes to 1.5 mm. increment at 8 min. These changes are highly significant and we feel constitute the most remarkable finding in this study.

Changes in vectorial items (table 2) are itemized as follows: 1. QRS items (H°, V°, Mag.) show no marked changes. There is a backward
rotation of QRS-H° during the first recovery minute of −7.9° within the 5 per cent significance level. This parameter then returns slowly but not completely to the initial value; however, the difference at four and eight minutes is statistically not significant. 2. T-H° shows a highly significant forward rotation of 20.3° and then gradually recedes to 10.4° after 8 min.; this deviation from the initial axis is still highly significant. 3. T-V° is deviated inferiorly by 11.5° at 1 min. and then returns to normal at 8 min. After 4 min. it is still significantly deviated by −7.46°. 4. T-Mag increases in the first minute to +2.6 mm. which is about 165 per cent of the initial value. It then returns towards normal, almost reaching the baseline by 8 min. (table 2 and fig. 2). These changes, of course, form the basis for the increase of T-V. 5. ΔA° is not appreciably altered, but ΔH° increases by over 25° immediately after exercise and then slowly recedes toward normal (fig. 2).

Scatter diagrams comparing T-V and heart rate, and T-V and maximal oxygen debt failed to show evidence of any correlation. The serum potassium failed to show any appreciable variation.

**DISCUSSION**

The increased height of precordial T waves and vectorial T changes constitute the most significant effects of anaerobic exercise. T-H° showed a marked forward rotation, the transition zone moving as far over as 94° (a 42° shift from resting value). Change of position cannot account for this as the QRS did not change concomitantly. It appears logical to assume that ventricular hypoxia is the cause of the electrocardiographic changes in anaerobic exercise. The T inversion in clinical ischemia appears to be at variance with this assumption. However, it should be pointed out that clinical ischemia is usually localized, while anaerobic exercise is more likely to produce a general myocardial hypoxia.

Cosby et al., utilizing the same type of vector analyzer, found a shift of the T vectors away from the ischemic zone in coronary insufficiency, corroborating earlier experience. The large precordial T waves may be due to posterior wall ischemia as demonstrated in episodes of coronary insufficiency and in the evolution of the posterior wall infarct.

Inasmuch as the bulk of the myocardium is situated posteriorly, general myocardial hypoxia may well tend to rotate the T vector anteriorly with an increase of T-V. The assumption of general hypoxia as basis for the increase
of the T wave is supported by observations of Britvan and Kydin\textsuperscript{7} of a pronounced increase in T waves during the early phase of experimental methemoglobinemia in dogs; in a later phase of methemoglobinemia the T waves became inverted. The decrease in T-V° is more difficult to explain because with a predominant posterior ischemia greater elevation is anticipated. However, this may be due to the inspiratory position of the diaphragm in severe exercise.

A second possibility would be the effect of changes of metabolites accumulated during anaerobic exercise, particularly lactic acid. Barker et al.\textsuperscript{8} found T depressions by feeding sodium bicarbonate and T increase by feeding ammonium chloride in experimental subjects. Perfusion experiments\textsuperscript{9} on animals have demonstrated that T increase is produced by lowering pH or by raising pCO\textsubscript{2}, and decrease of T is readily caused by raising pH and lowering pCO\textsubscript{2}.

A third possibility involves a temporary increase in intracellular potassium. Although venous serum potassium was not significantly changed in this series, the intracellular potassium concentration is not necessarily reflected. It is therefore conceivable that a potassium shift might have occurred causing the electrocardiographic changes noted. Of course, a combination of these three factors is quite possible.

It is of interest that the pattern of an abnormal electrocardiographic exercise test in coronary patients is not reproduced in normal subjects by severe, anaerobic exercise. In contrast, the abnormal metabolic and respiratory changes (oxygen debt, oxygen utilization, oxidative recovery, blood lactate) of cardiac patients in standardized moderate exercise can be reproduced by a higher work load in normal subjects (Simonson and Enzer\textsuperscript{10}). The difference in the metabolic changes between cardiac patients and normal subjects is quantitative, the difference in the electrocardiographic changes is qualitative. This agrees well with the assumption that the metabolic changes of patients and normal subjects in exercise are due to general hypoxia, which is more pronounced in patients and that the electrocardiographic changes in coronary insufficiency are due to localized myocardial ischemia.

**Summary**

Changes in conventional scalar electrocardiogram items and mean spatial QRS and T vectors were analyzed in 35 healthy young men 1, 4 and 8 min. after anaerobic work (running on a treadmill). The greatest changes occurred in the T vector (forward rotation and marked increase of magnitude). Significant changes of the QRS vector were limited to the azimuth (QRS-H°). Except for the QRS–Einthoven–axis, all changes receded slowly during the recovery period of 8 min., but the recovery of most items was not complete. The changes are dissimilar to those produced in patients with angina pectoris. Possible causative factors are discussed.

**SUMARIO IN INTERLINGUA**

Alterationes de aspectos del scalar electrocardiograma conventional e del vectores spatial medie QRS e T esseva analysate in 35 juvene adultos mascule in bon stato de sanitate, 1, 4, e 8 minutas post labor anaerobe (currer in un ambulator rolante). Le plus grande alterationes occurriva in le vector T (rotation in avante e marcate augmento del magnitude). Significative alterationes del vector QRS esseva restringite al azimuth (QRS-H°). Con le exception del axe QRS Einthoven, omne le alteraciones recedeva lentemente in le periodo recuperatorii de 8 minutas, sed le restablimente del majoritate del aspectos concernite non esseva complete. Le alterationes non esseva simile al alterationes occurrente in patientes con angina de pectore. Possibile factores causative es discutite.

**REFERENCES**

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