The Electrocardiogram During Exercise

Findings in Bipolar Chest Leads of 1,449 Middle-Aged Men, at Moderate Work Levels

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Electrocardiographic (ECG) recording during exercise, employed for years by work physiologists, has only recently arrived on the scene of cardiovascular investigations in clinical, epidemiological, and sports medical areas. This has come about from interest in the import of ECG events observed during activity, from the improved safety provided by monitoring performance tests, and from technical innovations which have led to more convenience and better quality in recordings.

The extension of investigations in this area and certain reasons of expediency have led to use of many nonstandard testing and monitoring procedures. These include nonstandard configurations of ECG electrodes across the chest, the upright posture, FM radio transmission of the ECG, numerous other developments in instrumentation, and different modes of imposing work stress.

Standardization of method in exercise electrocardiography is not yet possible or desirable, because of rapid developments in quantitative cardiography and work physiology.1 Though it is not clear whether most of the nonstandard methods now used are desirable for the long run, they are nevertheless in use, and some quantitative base for the diagnostic and prognostic information sought from these methods is of interest.

This report concerns a specific application in which nonstandard electrocardiography during exercise was employed, between recordings of conventional standard supine resting and post-exercise electrocardiograms. The results apply to middle-aged working men, walking on a treadmill at an energy expenditure comparable to other common stress tests, in an examination situation with practical limitations of time, and in which two common types of simple bipolar chest ECG leads were employed.

An earlier report from this laboratory2 described the characteristics of S-T segment display in some of the multiple chest electrode configurations which have been employed for ECG monitoring (fig. 1).

Method

Each of two bipolar leads used has an exploring electrode at the standard left chest position C5 (V5) while the lead called "CM3" has a reference electrode on the upper part of the manubrium sternum and that called "CC5" employs a reference electrode in the same but opposite position on the right chest (fig. 2).

Records were made in 1,449 men, ages 45 through 64 years, part of a sample of railway workers under long-term observation within the context of a study into the influence of occupational activity on the attack rate of coronary heart disease. Details of the statistical sampling procedure are given elsewhere.3, 4 The overall response rate of the sample, 60 to 75%, precludes claims that this population is representative of anything other than a large group of middle-aged volunteers, actively employed in clerical and yard positions on rail lines operating in the northwest quadrant of the United States.

Specifically excluded from the exercise test (in addition to nonrespondents to the survey invitation) were subjects with clinically manifest coronary heart disease in the form of documented myocardial infarction, angina pectoris with an abnormal resting ECG, or severely disabling illness of any kind. Included in the exercise test

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Differences in magnitude and contour of S-T segment depression in one case recorded with different lead configurations. CH, forehead to chest; CR, right arm to chest; CC, right to left chest; CB, right back to chest; CM, sternum to chest; CS, right subclavicle to chest; O, right subclavicle to left back; X, right-to-left chest; A, manubrium to sacrum; B, right lower-to-left lower chest; CN, lower neck to chest; V, Wilson leads; RV, modified Wilson leads; R, right-to-left chest; L, ear-ensiform-precordial system.

Figure 1

Recordings were made in an air-conditioned converted Pullman car laboratory at the worksite of the men at the conclusion of the medical examination and the conventional supine resting ECG. During the recording the subject stood quietly before exercise, and after 15 seconds, 1½ minutes, and 2½ minutes of a 3-minute treadmill walk at 3 miles per hour, on a 5% grade. The average oxygen consumption of men at this work level is approximately 1.4 L per minute.

A Sanborn model 100 direct-writer (time constant verified at greater than 2 seconds), with

Electrode positions for the two bipolar leads CM5 and CC5.
direct cable-coupling or FM radio telemetry was used (time constant of the entire telemetry-recording system was verified at 1.6 seconds). No important difference in the quality of the records was obtained at this level of work between these two recording modes.

Eighty-eight per cent of the records were of adequate quality for eyeball classification of S-T and T findings from the CM5 lead, while 43% were adequate from the CC5 lead. The coding was found to be reasonably reproducible with one observer (intra-observer agreement in repetitions on presence or absence of a finding was 90%; agreement to agreements plus disagreements).

Specialized methods of improving the ECG signal in respect to the record “noise,” and new electrodes have now considerably improved both the yield of technically good records, even during much higher work levels, and the ability to quantify the ECG findings.

The ECG items classified in the resting and in each exercise record are listed in table 1.

Results

Manubrium-C5 Bipolar Lead (CM5)

Table 2 presents findings for this lead in 725 consecutively examined working men, ages 45 through 64 years. Records subjectively considered adequate for eyeball classification were obtained in 636 (87.7% of the total). Sixty-six men (10.4% of men with technically good records) had one or moreodable findings on the standing control record (S-T depression or elevation, negative T waves, bundle-branch block, frequent extrasystoles, or atrial fibrillation). Conversely, 570 men (89.6% of men with technically good records) had “normal” standing control records prior to exercise.

Of the 570 men with technically adequate and normal control records, 126 (22.1%) developed a codable ECG finding during the 3-minute walk, and 102 (17.9%) developed some codable item of S-T depression, principally at the latest recording of the 3-minute test. Two men (0.4% of 570) developed some codable item of S-T elevation; one man (0.2%) developed a transient complete right bundle-branch block during effort, and three men (0.5%) developed a bigeminal rhythm or runs of two or more ventricular premature beats. Seventeen men (3.0% of 570) developed isolated premature beats to the extent of 10% or greater of recorded heart cycles, and one man (0.2%) developed a codable negative T wave (in the absence of any codable S-T depression).

In table 3 is the distribution of S-T displacement (absolute rather than relative to the resting level) for the population under the conditions described. Fewer than 1% of this

<table>
<thead>
<tr>
<th>Code</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>IV--0</td>
<td>J point depression</td>
</tr>
<tr>
<td>1</td>
<td>J point depression</td>
</tr>
<tr>
<td>2</td>
<td>J point depression</td>
</tr>
<tr>
<td>3</td>
<td>J point depression</td>
</tr>
<tr>
<td>4</td>
<td>J point depression</td>
</tr>
<tr>
<td>5</td>
<td>J point depression</td>
</tr>
<tr>
<td>6</td>
<td>Segment elevation</td>
</tr>
<tr>
<td>7</td>
<td>Segment elevation</td>
</tr>
<tr>
<td>V--1</td>
<td>T wave negative</td>
</tr>
<tr>
<td>2</td>
<td>T wave negative</td>
</tr>
<tr>
<td>3</td>
<td>T wave negative</td>
</tr>
<tr>
<td>4</td>
<td>T wave low or notched</td>
</tr>
<tr>
<td>VII--1</td>
<td>Complete left bundle-branch block</td>
</tr>
<tr>
<td>2</td>
<td>Complete right bundle-branch block</td>
</tr>
<tr>
<td>VIII--1</td>
<td>10% premature beats</td>
</tr>
<tr>
<td>2</td>
<td>Bigeminy or runs of premature beats</td>
</tr>
<tr>
<td>3</td>
<td>Atrial fibrillation</td>
</tr>
</tbody>
</table>

\[ \geq 0.2 \text{ mv ischemic (horizontal or downward slope)} \]
\[ \geq 0.1 \text{ but } < 0.2 \text{ mv ischemic (horizontal or downward slope)} \]
\[ \geq 0.05 \text{ but } < 0.1 \text{ mv ischemic (horizontal or downward slope)} \]
\[ < 0.05 \text{ mv ischemic (horizontal or downward slope)} \]
\[ \geq 0.2 \text{ mv junctional (upward S-T slope)} \]
\[ \geq 0.1 \text{ but } < 0.2 \text{ mv junctional (upward S-T slope)} \]
\[ \geq 0.1 \text{ but } < 0.2 \text{ mv junctional (upward S-T slope)} \]
\[ \geq 0.2 \text{ mv} \]
working group had "ischemic type" of S-T depression during work at this level while 17.2% had J-point S-T depression of 0.1 mv (1 mm) or more. About 3% had J depression of 0.2 mv (2 mm) or more.

**Transthoracic Bipolar Lead (CC5)**

In table 4, results in the CC5 lead are examined with less confidence because the numbers are fewer. More than half the CC5 records during work were too "noisy" to attempt classification of S-T-T findings by eye.

A total of 724 men of the same general population, though different men, were tested consecutively with the CC5 lead. In only 311 (43.0%) were the records subjectively considered suitable for S-T-T coding, though all served their original principal purpose of obtaining a work heart rate.

Of the 311 men 33 (10.6%) had a codable ECG finding in the standing rest control record prior to the treadmill test. Of the 278 men (89.4% of 311) who had no codable resting item, 40 (14.4% of 278) had codable findings during exercise. Twenty-five (9.0%) were codable owing to S-T depression, two (0.7%) owing to S-T elevation, one man (0.4%) had only a negative T wave during exercise; three men (1.1%) had bigeminal rhythm or

**Table 2**

*Findings in a Chest-Manubrium ECG Lead (CM5) Used for Monitoring During Treadmill Exercise among 725 Consecutively Examined Rail Employees, Men Ages 45-64*

<table>
<thead>
<tr>
<th>No. of men</th>
<th>% of 725 men</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total examined with lead CM5</td>
<td>725</td>
</tr>
<tr>
<td>Technically adequate records obtained during work</td>
<td>636</td>
</tr>
<tr>
<td>Technically adequate records and entirely &quot;normal&quot; standing rest control</td>
<td>570</td>
</tr>
<tr>
<td>Technically adequate records, &quot;normal&quot; standing rest control and some codable finding during work</td>
<td>126</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Findings in 126 men with “positive” tests during exercise</th>
<th>No. of men</th>
<th>% of 570 men*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Codable S-T depression during work</td>
<td>102</td>
<td>17.9</td>
</tr>
<tr>
<td>S-T elevation ≥ 0.1 mv</td>
<td>2</td>
<td>0.4</td>
</tr>
<tr>
<td>Negative T wave without S-T depression</td>
<td>1</td>
<td>0.2</td>
</tr>
<tr>
<td>Complete right bundle-branch block</td>
<td>1</td>
<td>0.2</td>
</tr>
<tr>
<td>Bigeminy or ventricular tachycardia</td>
<td>3</td>
<td>0.5</td>
</tr>
<tr>
<td>≥ 10% extrasystoles</td>
<td>17</td>
<td>3.0</td>
</tr>
</tbody>
</table>

*All the men having technically adequate records and "normal" standing rest control.

**Table 3**

*Distribution of Maximum S-T Displacement in a Chest-Manubrium Lead (CM5) During Exercise Among 570 Rail Employees, Men Ages 45-64, Having Technically Good and "Normal" Standing Rest Control Records*

<table>
<thead>
<tr>
<th>Class</th>
<th>No. of men</th>
<th>% of 570 men</th>
</tr>
</thead>
<tbody>
<tr>
<td>S-T depression classes</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1. ≥ 0.2 mv
2. ≥ 0.1 but < 0.2 mv
3. ≥ 0.05 but < 0.1 mv
4. ≤ 0.05 mv
5. ≥ 0.2 mv
6. ≥ 0.1 but < 0.2 mv

ischemic type
ischemic type
ischemic type
ischemic type
junctional type
junctional type

1
1
2
0
16
82

1.0
1.0
0.4
0.0
2.8
14.4

S-T elevation classes | | |

1. ≥ 0.1 but < 0.2 mv
2. ≥ 0.2 mv

segmental elevation
segmental elevation

2
0

0.4
0.0

No codable “J” or segment displacement

466
81.8

*Circulation, Volume XXXIV, December 1966*
Table 4

Findings in a Bipolar Transthoracic ECG Lead (CC₅) Used for Monitoring During Treadmill Exercise among 724 Consecutively Examined Rail Employees, Men Ages 45-64 Years

<table>
<thead>
<tr>
<th>No. of men</th>
<th>% of 278 men *</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total examined with lead CC₅</td>
<td>724</td>
</tr>
<tr>
<td>Technically adequate record obtained during work</td>
<td>311</td>
</tr>
<tr>
<td>Technically adequate records and entirely “normal” standing rest control</td>
<td>278</td>
</tr>
<tr>
<td>Technically adequate records, “normal” standing rest control and some codable finding during work</td>
<td>40</td>
</tr>
</tbody>
</table>

Findings in 40 men with “positive” test during exercise

<table>
<thead>
<tr>
<th>ECG item</th>
<th>No. of men</th>
<th>% of 278 men *</th>
</tr>
</thead>
<tbody>
<tr>
<td>Codable S-T depression during work</td>
<td>25</td>
<td>9.0</td>
</tr>
<tr>
<td>S-T elevation &lt; 0.1 mv</td>
<td>2</td>
<td>0.7</td>
</tr>
<tr>
<td>Negative T wave without S-T depression</td>
<td>1</td>
<td>0.4</td>
</tr>
<tr>
<td>Complete right bundle-branch block</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td>Bigeminy or ventricular tachycardia</td>
<td>3</td>
<td>1.1</td>
</tr>
<tr>
<td>≥ 10% extrasystoles</td>
<td>9</td>
<td>3.2</td>
</tr>
</tbody>
</table>

*All the men having technically adequate records and “normal” standing rest control.

runs of ventricular premature beats; and nine (3.2% of 278) had frequent isolated premature beats.

There were no ventricular conduction defects during exercise in those with technically adequate and normal resting control CC₅ records. However, the proportion of these findings was similar to the CM₅ examined group if the technically poor CC₅ records are considered in the analysis.

In table 5, among the 27 men with S-T-T displacement in lead CC₅, 25 (9.0% of 278) had codable S-T depression while two had S-T elevation of at least 0.1 but less than 0.2 mv (0.7% of 278). However, only four men (1.4% of 278) had S-T junctional (J) depression of as much as 0.2 mv, while none had ischemic type depression.

Overall Findings

In table 6 are pooled items for all men for those ECG findings largely unrelated to the lead system or technical quality of the records (since these items are easily identified even in “noisy” tracings) in order to boost the confidence levels for their prevalence estimates in a middle-aged group of working men. The 1,305 men who did not have ECG findings in the resting control record provide the

Table 5

Distribution of Maximum S-T Displacement in a Bipolar Transthoracic ECG Lead (CC₅) During Exercise Among 278 Rail Employees, Men Ages 45-64 Years, Having Technically Good and Normal Control Records During Standing Rest

<table>
<thead>
<tr>
<th>S-T depression classes</th>
<th>No. of men</th>
<th>% of 278 men</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. ≥ 0.2 mv</td>
<td>ischemic type</td>
<td>0</td>
</tr>
<tr>
<td>2. ≥ 0.1 but &lt; 0.2 mv</td>
<td>ischemic type</td>
<td>0</td>
</tr>
<tr>
<td>3. ≥ 0.05 but &lt; 0.1 mv</td>
<td>ischemic type</td>
<td>0</td>
</tr>
<tr>
<td>4. &lt; 0.05 mv</td>
<td>ischemic type</td>
<td>0</td>
</tr>
<tr>
<td>5. ≥ 0.2 mv</td>
<td>junctional type</td>
<td>4</td>
</tr>
<tr>
<td>6. ≥ 0.1 but &lt; 0.2 mv</td>
<td>junctional type</td>
<td>21</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>S-T elevation classes</th>
<th>No. of men</th>
<th>% of 278 men</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. ≥ 0.1 but &lt; 0.2 mv</td>
<td>segmental elevation</td>
<td>2</td>
</tr>
<tr>
<td>2. ≥ 0.2 mv</td>
<td>segmental elevation</td>
<td>0</td>
</tr>
</tbody>
</table>

No codable J or segmental displacement 251 90.3 |
denominator. Thirty men (2.3% of 1,305) had isolated extrasystoles in as many as 10% of recorded beats during exercise. Ten men (0.8% of 1,305) had bigeminal rhythm or runs of two or more ventricular premature beats. One (0.1%) developed complete right bundle-branch block and another atrial fibrillation during effort.

Finally the paradox of a T-wave "anomaly" at rest, disappearing during effort, was tabulated. Forty-nine among 1,449 men (3.2%) had either a notched, flat, diphasic, or distinctly inverted T wave in the resting standing control record. Of these 49, 20 (40.8%) showed no such T abnormality during exercise.

**Discussion**

**Technique**

The C5-to-manubrium chest lead (CM5) yielded, under field conditions, twice the proportion of records susceptible to detailed S-T classification by eye as the transthoracic lead CC5. However, its use in a consecutive series of examinations followed use of the CC5 lead, and improvements over time in electrodes and other techniques perhaps exaggerate the superiority of the CM5 configuration. Nevertheless, in an earlier study with other variables kept constant, several bipolar leads were compared during increasing levels of physical work, from deep breathing to running at 7 mph (fig. 3). The CM5 lead was demonstrably superior to CC5 in regard to base-line shift (0.17 mv CM5 versus 0.32 mv CC5 mean peak-to-peak amplitude of shift) and in strength of the ECG signal compared to the base-line "noise" (9.6 signal-to-noise ratio in CM5 versus 3.8 in CC5). This superiority is based largely on the fact that few muscle potentials occur and motion is minimal, under the sternal reference electrode. These technical differences in lead systems have now been reduced as a result of newer developments in skin-electrode contact. A number of electrodes and lead configurations are under systematic study using more quantitative assessments of performance, by a U. S. Public Health Service Technical Group on Exercise Electrocardiography.

**Findings at Rest**

The identical total prevalence of codable ECG findings in the standing control records for the two lead systems (10.4 versus 10.6%) speaks for comparability of the two groups of railway workers tested consecutively.

In any search for lead configurations giving maximal and predominantly upright QRS deflections, the lead vector may be sufficiently posteriorly oriented to place the mean horizontal plane T vector near 90° from the QRS. Consequently, with very small posterior shifts of mean QRS which may occur on assumption of the upright posture, a small proportion of subjects develop notched, low amplitude, or negative T waves. The clinical significance of this phenomenon is not known. The problem must be considered if standardization of electrode position is desired and, as was found here, as many as 3.2% of 1,449 working men have such notched, flat diphasic, or distinctly negative T waves while standing at rest. Almost identical proportions of orthostatic T-wave findings are reported in several normal groups. The problem applies to conventional and other lead arrangements as well. A

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**Table 6**

<table>
<thead>
<tr>
<th>ECG item</th>
<th>No. of men</th>
<th>% of 1,305 men*</th>
</tr>
</thead>
<tbody>
<tr>
<td>≥ 1% of extrasystoles</td>
<td>30</td>
<td>2.3</td>
</tr>
<tr>
<td>Bigeminy or ventricular tachycardia</td>
<td>10</td>
<td>0.8</td>
</tr>
<tr>
<td>Complete right bundle-branch block</td>
<td>1</td>
<td>0.1</td>
</tr>
<tr>
<td>Atrial fibrillation</td>
<td>1</td>
<td>0.1</td>
</tr>
</tbody>
</table>

*All the men without these findings in the resting control record.
similar order of frequency of “abnormal” resting T waves has been found in this laboratory in precordial lead V5 on assuming the upright from the supine posture (unpublished observations). Semler has found this postural T wave less prevalent in a bipolar lead with the reference electrode under the right clavicle.7 Model studies here indicate that this produces a slightly more anteriorly directed lead vector.

The postural effect is perhaps not so serious (1) if the testing posture is similar for rest, work, and recovery records, (2) if means are devised for quantitating the change in the S-T-T region between rest, exercise and recovery, (3) if S-T depression itself, in contrast to T-wave amplitude, is little affected, and eventually, (4) if orthogonal leads can be employed and vectorial changes in space analyzed.

Findings During Exercise

Similar prevalence of premature beats, a frequent finding during work (3.0 versus 3.2%), in leads CC5 and CM5 also suggests that the workers compared were not different. This in turn would confirm that the two-lead systems truly differ in regard to “sensitivity” of display of S-T segment depression phenomena, since codable S-T depression occurred in only 9.0% of CC5 records versus 17.9% of CM5 records. This difference in S-T display has been previously demonstrated in simultaneous records of the same individuals having S-T depression at rest2 and is shown in figure 1. It has recently been found in simultaneous records of cases with S-T depression during work.10 Though much of the lead differences in S-T display are attributable to differences in lead strength with regard to QRS forces, some is undoubtedly due to optimal lead orientation for S-T vector display.2

The frequently observed phenomenon of negative T waves at rest which become “normal” or upright during or immediately after exercise requires clarification best achieved through studies with orthogonal ECG leads and follow-up observation. In 40% of the cases of standing rest T anomalies in these simple bipolar leads, the “paradox” of T becoming upright was observed during effort. The clinical significance of this is not clear since in the other 60% of these cases the negative T wave persists or becomes more negative.

Standards

Within the conditions of this study, employing simple bipolar chest leads in middle-aged
working men, under a moderate work load comparable to clinical step tests (± 1.4 L O₂/ 
min), the following may be considered “ab-
normal” responses during effort, on the basis 
of a statistical approach to the total distribu-
tion in which findings in excess of the 95% 
upper limits are regarded abnormal:

1. Ischemic S-T depression of any percep-
tible degree (0.05 mv or more).
2. Junctional S-T depression of 0.2 mv or 
more.
3. S-T segment elevation of 0.1 mv or more.
4. Arrhythmias, ventricular conduction de-
fects, and 10% or more frequency of pre-
mature beats.

Significance and Conclusions

The use of simple bipolar chest leads in 
exercise electrocardiography may not, in the 
end, be preferable to conventional leads, or-
thogonal leads, or specially “distorted” leads.
At least in this country where conventional 
limb and Wilson chest leads are standard for 
rest and recovery periods, their use for 
monitoring during work, assuming technically 
good records are obtainable, is logical until 
information from other lead derivations is 
demonstrated to be comparable or super-
ior.⁶, ¹¹

Nevertheless, during this period of chang-
ing methodology and improving instrumenta-
tion, the empirically developed bipolar chest 
leads have given practical advantages of few-
er electrodes and cables, fewer artifacts dur-
ing motion, and displays of wave forms suf-
ficiently similar to the familiar central terminal 
left precordial leads to permit qualitative evalua-
tion of the ECG response to work.

The findings and suggested criteria for ab-
normal responses to moderate work in these 
leads recorded from middle-aged working men 
are similar to those derived from convention-
al leads in post-exercise records.⁸, ⁹, ¹¹–¹³ They 
would probably not apply to high levels of 
work load near maximal work capacity, during 
which greater changes, in a much higher pro-
portion of men, have been reported.¹¹, ¹⁴, ¹⁵

If the facts are considered that conventional 
Wilson chest lead V₅ probably gives 90% of 
the information obtainable from the exercise 
ECG response,¹⁶ and that some bipolar chest 
leads have greater lead strength and sensitivity 
to S-T depression display than V₅,² it is likely 
that this type of lead configuration is rather 
optimally sensitive for monitoring and screen-
ing purposes. If in addition the confirmatory 
information and extensive experience of Scan-
dinavian work physiologists,⁹, ¹⁷ and investiga-
tors in the space program and in physical 
education¹⁸ are considered, it appears that 
simple bipolar chest lead ECG systems may 
be practically and profitably employed in 
screening and monitoring programs until an 
acceptable standard quantitative approach 
is available.

The question of diagnostic discrimination 
between normals and subjects with coronary 
insufficiency is not examined in this present-
tion of distributions in a working popula-
tion. Semi-quantitative approaches similar to 
this one have indicated that the exercise ECG 
response at comparable work levels is not 
highly discriminatory.⁸, ¹⁹ Quantitation of the 
ECG response, at higher work levels, prom-
ises better discrimination and predic-
tion.¹¹, ¹⁴, ¹⁵, ¹⁷

The important question of response fidelity 
at the lower end of the recording system de-
termining the S-T response is not here con-
sidered. Berson and Pipberger²⁰ most recently 
examined this problem and found that the 
low-frequency cut-off of instruments with the 
deay time characteristics of those used in this 
study might result in 3% of the records having 
0.1 mv or more error in the S-T amplitude.
This error is dependent on the form of the 
QRS, whether predominantly up or down or 
equiphasic and the symmetry of the wave 
slopes. They proposed reducing these errors 
by one half through lowering the lower fre-
quency filter pass to 0.05 cps in the situation 
in which the amplitude decreases to one half 
when the frequency decreases to one half 
(6 db per octave roll-off).

Studies are now being made to synthesize 
the ECG curves faithfully by playing these
taped records through circuits with the inverse characteristics of the recording instruments. It is hoped thereby to obtain a better approximation of the instrument error in S-T segment displacement.

**Summary and Conclusions**

Nonstandard ECG leads and recording procedures are being applied in monitoring the ECG response during performance tests. Detailed systematic studies in well-defined populations with adequate control of the numerous variables of electrode position, body posture, the type, amount, and duration of work, recording intervals, and instrumentation are required before the “dynamic” ECG response may be interpreted with confidence.

This study reports the distribution of ECG findings during moderate treadmill exercise in a group of 1,449 working men in the railroad industry of ages 45 to 64. Two bipolar chest leads commonly used in work monitoring were compared, each with the exploring electrode at chest position C5, one with the reference opposite at C4R (CC5) and the other on the manubrium (CM5). Ninety-six per cent of the examined men, excluding those with manifest cardiac or other disabilities, were subjected to a 3-minute treadmill walk at 3 mph on a 5% grade, and the maximal codable S-T or other findings was used in the analysis.

About 90% of all men had standing control records free of any codable ECG finding. Less than 1% of these developed ischemic type of S-T depression during work. About 2% developed J (junctional) type of S-T depression of 0.2 mv (2 mm) or greater. Less than 1% developed significant ventricular blocks or arrhythmias, and about 3% developed frequent extrasystoles. Any of these findings during moderate exercise may then, on a statistical basis, be considered an “abnormal” response. The discriminative diagnostic power of the ECG responses during exercise is poor, however, and evidence about its predictive import for future disease risk requires careful quantitation and follow-up studies.

Standardization of methods for exercise electrocardiography is not yet possible because of rapid developments in theory and instrumentation. When it is not feasible to obtain good data from conventional limb and precordial leads, information from simple bipolar chest leads may be profitably utilized in screening and monitoring programs. This should be a temporary expedient, until a practical and acceptable quantitative approach is available for exercise electrocardiography.

**References**

ELECTROCARDIOGRAM AND EXERCISE


Twenty-five Years Ago

No nation can isolate itself. No progress is possible if the mind is shackled with the authority of this or that system, merely because it is national.

We should not be in the grip of the dead past, nor should we be awed by authority but we may not forget that the past has claims over us. The evolution of modern medicine is a series of successes over false beliefs. The present is the child of the past, and, to understand it properly, a historical outlook is essential. Physicians with such an outlook do not hanker after miracles and are not easily lured away from the scientific path by the false promises of pseudoscience, quackery and the fashionable cults of the day.—Editorial: About Ourselves. Indian Physician 1: 2, 1942.
The Electrocardiogram During Exercise: Findings in Bipolar Chest Leads of 1,449 Middle-Aged Men, at Moderate Work Levels
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