Work and Heart Disease

I. A Physiologic Study in the Factory

By Amasa B. Ford, M.D., and Herman K. Hellerstein, M.D.

Sixty-two factory workers, 36 with heart disease, and 26 healthy control subjects, were studied during a typical day's work. Observations of energy expenditure, pulmonary ventilation, pulse rate and electrocardiogram are reported and analyzed in relation to the type of work, the influence of heart disease, and possible objective evidence of fatigue.

NEW understanding of the natural history of heart disease and better methods of treatment are reducing the aura of fear traditionally surrounding the cardiac patient. At the same time, modern technology is steadily lowering the physical demands of factory work, so that it is now evident that a majority of urban patients with heart disease can work safely.1 The physician, who is increasingly called upon to prescribe activity for his patients with heart disease, needs specific information about the stress of daily activities on which to base his advice. Artificial work situations, such as the Master 2-step test or treadmill exercise, involve high-energy expenditure for short periods of time and cannot simulate actual working conditions unless the doctor has specific knowledge of the demands of the patient's job.2,3

Many measurements of the energy cost of individual activities and a few studies of energy expenditure during several hours or days have been collected by Passmore and Durbin.4 However, these studies are of normal people in other countries and under other economic conditions. No studies have been published of working energy expenditure of patients with heart disease. The present study therefore was designed to measure the energy expenditure of factory workers with heart disease, to observe various aspects of cardiovascular function under actual working conditions, and to compare in each particular the workers with heart disease with their healthy co-workers.

METHODS AND MATERIAL

Subjects. Sixty-two subjects were studied on the job. Thirty-six had recognized heart disease and 26 were normal control subjects. A control subject was matched to each cardiac subject whenever a healthy worker of comparable age and skill could be found performing the same job in the same industrial plant.

The subjects with heart disease were employees of 3 large Cleveland manufacturing firms and had come to the attention of the industrial physician in the course of employment physical examinations, illness at work, or from reports of private physicians following illness. The diagnosis of heart disease was confirmed by a complete medical history, physical examination and standard 12-lead electrocardiogram. Twenty-four of the 36 patients with heart disease were evaluated at the Work Classification Clinic of the Cleveland Area Heart Society where additional laboratory studies including fluoroscopic examination, ballistoeardiogram and the Master 2-step exercise test were made.

All the subjects were men, except for 1 woman, who had arteriosclerotic heart disease. Twenty-five patients had arteriosclerotic heart disease, of whom 20 had old myocardial infarcts confirmed by electrocardiogram. Four subjects had hypertensive cardiovascular disease, 5 rheumatic heart disease, 1 syphilitic aortitis and aneurysm, and 1 possible congenital heart disease. It is probable that most of the employees with symptomatic coronary artery disease in these 3 industries were studied. Undoubtedly many individuals with varying degrees of hypertension and some with asymptomatic rheumatic heart disease were not included. Twelve of the cardiac subjects fell into class I of the New York State Heart Association,5 19 into class II and 5 into class III. Ten of the 36 patients were taking digitalis at the time of

From the Department of Medicine, School of Medicine, Western Reserve University, and the University Hospitals of Cleveland, Cleveland, Ohio.

This study was supported in part by grants from the Cleveland Area Heart Society.
Table 1.—Types of Jobs Studied

<table>
<thead>
<tr>
<th>Job Category</th>
<th>Subcategories</th>
</tr>
</thead>
<tbody>
<tr>
<td>Miscellaneous</td>
<td>(4 cardiaes, 2 controls)</td>
</tr>
<tr>
<td></td>
<td>Boxmaker</td>
</tr>
<tr>
<td></td>
<td>Laundry crib supervisor</td>
</tr>
<tr>
<td></td>
<td>Planning clerk</td>
</tr>
<tr>
<td></td>
<td>Tool crib attendant</td>
</tr>
<tr>
<td>Bench Workers</td>
<td>(8 cardiaes, 7 controls)</td>
</tr>
<tr>
<td></td>
<td>Assembler</td>
</tr>
<tr>
<td></td>
<td>Clutch tester</td>
</tr>
<tr>
<td></td>
<td>Electronics tester</td>
</tr>
<tr>
<td></td>
<td>Gauge setter</td>
</tr>
<tr>
<td></td>
<td>Light assembler (2 subjects)</td>
</tr>
<tr>
<td></td>
<td>Millwright</td>
</tr>
<tr>
<td></td>
<td>Stamper</td>
</tr>
<tr>
<td>Foremen</td>
<td>(7 cardiaes, 5 controls)</td>
</tr>
<tr>
<td></td>
<td>Foreman</td>
</tr>
<tr>
<td></td>
<td>Inspector</td>
</tr>
<tr>
<td></td>
<td>Lead man (foreman)</td>
</tr>
<tr>
<td></td>
<td>Maintenance supervisor</td>
</tr>
<tr>
<td></td>
<td>Shift foreman</td>
</tr>
<tr>
<td></td>
<td>Supervisor (2 subjects)</td>
</tr>
<tr>
<td>Machine Operators</td>
<td>(7 cardiaes, 5 controls)</td>
</tr>
<tr>
<td></td>
<td>Drill press operator (2 subjects)</td>
</tr>
<tr>
<td></td>
<td>Scarfing machine operator</td>
</tr>
<tr>
<td></td>
<td>Set-up burnishing press</td>
</tr>
<tr>
<td></td>
<td>Stub lathe operator</td>
</tr>
<tr>
<td></td>
<td>Tool grinder</td>
</tr>
<tr>
<td></td>
<td>Turret lathe operator</td>
</tr>
<tr>
<td>Maintenance Workers</td>
<td>(7 cardiaes, 4 controls)</td>
</tr>
<tr>
<td></td>
<td>Janitor</td>
</tr>
<tr>
<td></td>
<td>Maintenance electrician</td>
</tr>
<tr>
<td></td>
<td>Matron</td>
</tr>
<tr>
<td></td>
<td>Painter</td>
</tr>
<tr>
<td></td>
<td>Plant guard</td>
</tr>
<tr>
<td></td>
<td>Stationary engineer</td>
</tr>
<tr>
<td></td>
<td>Welder</td>
</tr>
<tr>
<td>Warehousemen</td>
<td>(3 cardiaes, 3 controls)</td>
</tr>
<tr>
<td></td>
<td>Stock picker</td>
</tr>
</tbody>
</table>

...the study. The average age of the cardiac subjects was 51 years, with a range of 24 to 70 years, while the control group averaged 42 years, ranging from 18 to 65 years.

The subjects were found to be working in every major department of the 3 companies. These plants manufacture light and medium weight metal products, including electric motors and switches, automobile and airplane parts, bearings, and non-ferrous metal products. They employ a total of 8,500 people and are representative of the type of industry that employed one third of the working population of Cuyahoga County (Cleveland) in a 1946 survey. The types of jobs varied considerably in skill and energy expenditure (table 1).

Methods. Each subject reported to the company dispensary 15 minutes before the shift on a typical working day. The purpose and methods of the study had been explained to each subject. Height and weight were measured, and 4 copper electrodes were taped in place on the chest in the V1 and V5 positions on right and left sides. Lead wires passed through the shirt collar to a socket attached to the subject’s belt, where they could be connected to a Sanborn direct-writing electrocardiograph when desired. A pedometer was adjusted and fastened to the subject’s belt. An Air Force half-face oxygen demand mask was carefully fitted and arranged to permit inhalation of room air. From the mask expired air passed through a Plexiglass valve and rubber tubing to the Kofranyi-Michaelis respiratory meter. The meter, which together with mask and tubing weighs 3.6 Kg., was either worn like a knapsack or placed on a table during sedentary observations. While the subject was becoming accustomed to the mask, observations were made of blood pressure and electrocardiogram. A 5-minute aliquot of expired air was then collected, and pulmonary ventilation was read from the meter to determine resting oxygen consumption. Respiratory rate was measured during the collection period. The mask and meter were then removed, but the electrodes were left in place, and the subject was accompanied to his place of work.

A detailed log was kept of the exact duration of each activity in which the subject engaged during the day. Five-minute samples of expired air were collected for the purpose of measuring energy expenditure during each activity, after at least 5 minutes of performing that activity while wearing the mask and meter. Electrocardiograms and respiratory rate were recorded as the sample was being taken, and blood pressure was measured either during or immediately after the determination. At least 3 observations were made on any activity that occupied more than an hour of the subject’s time. Five to 9 (average, 7) samples of expired air were collected during the day. The specific requirements of the study took about an hour from the regular working time, but in no case did a worker fail to meet a quota for the day or show other objective evidence of hampered efficiency or productivitv on account of the study.
WORK AND HEART DISEASE I.

Table 2.—Average Rates of Energy Expenditure (Calories Per Minute)

<table>
<thead>
<tr>
<th></th>
<th>36 Cardiacs</th>
<th></th>
<th>26 Controls</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Average</td>
<td>S.D.</td>
<td>Average</td>
</tr>
<tr>
<td>At rest</td>
<td>1.30</td>
<td>0.25</td>
<td>1.40</td>
</tr>
<tr>
<td>During shift</td>
<td>1.97</td>
<td>0.48</td>
<td>2.13</td>
</tr>
<tr>
<td>During actual work</td>
<td>2.29</td>
<td>0.64</td>
<td>2.51</td>
</tr>
</tbody>
</table>

Samples of expired air were transferred immediately from the butyl rubber collecting bag to glass sample tubes, where they were stored under positive pressure of mercury and thus transported to the laboratory. Analyses for carbon dioxide and oxygen content were performed with the Scholander micro gas analyzer. Duplicate determinations gave a mean difference of 0.03 volume per cent (S.D. of the difference = 0.06 volume per cent) for carbon dioxide and 0.03 volume per cent (S.D. of the differences = 0.07 volume per cent) for oxygen. The volume measurements of the respiratory meter, compared with a 100-liter Tissot spirometer at rates of flow of from 10 to 50 liters per minute, gave a mean error of 1.3 per cent of the total. The maximum resistance to breathing offered by the meter at these flows was 2.0 cm. of water. Oxygen consumption (milliliters per minute) was taken as 10 times the product of ventilation (liters per minute) and oxygen utilization (per cent of oxygen in room air minus per cent of oxygen in expired air), and converted to energy expenditure (in kilogram calories per minute) according to the data of Catheart and Cuthbertson. All volumes were reduced to standard conditions (0 °C, 760 mm. Hg, dry). Rates of energy expenditure were expressed without deduction of a basal or resting value. Energy expenditure was not divided by body surface area, since these quantities have not been shown to bear a constant relationship during different types of activity.

Observations

Energy Expenditure

The average rate of energy expenditure of workers with heart disease was 1.97 calories per minute or a total of 997 calories during the 8½-hour work shift (table 2). A higher rate of energy expenditure, 2.29 calories per minute, obtained during actual working time. The figures for the control subjects were higher but were not significantly different as judged by the t test, and a probability level of 5 per cent (t = 1.06, p = <0.4).

Table 3.—Age and Blood Pressure

<table>
<thead>
<tr>
<th></th>
<th>36 Cardiacs</th>
<th></th>
<th>26 Controls</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Avg. S.D.</td>
<td>Avg. S.D.</td>
<td>p</td>
</tr>
<tr>
<td>Age (years)</td>
<td>51 9.4</td>
<td>42 12.3</td>
<td>&lt;.02</td>
</tr>
<tr>
<td>Systolic blood pressure at rest (mm. Hg)</td>
<td>136 22</td>
<td>122 18</td>
<td>&lt;.05</td>
</tr>
<tr>
<td>Diastolic blood pressure at rest (mm. Hg)</td>
<td>81 10</td>
<td>81 13</td>
<td>—</td>
</tr>
<tr>
<td>Maximum systolic blood pressure at work (mm. Hg)</td>
<td>153 29</td>
<td>134 20</td>
<td>&lt;.02</td>
</tr>
<tr>
<td>Maximum diastolic blood pressure at work (mm. Hg)</td>
<td>89 10</td>
<td>88 13</td>
<td>—</td>
</tr>
</tbody>
</table>

The energy cost of individual jobs increased as the work involved the use of progressively larger muscle groups (fig. 1). There was a progression from sedentary to ambulatory work and from hand work to work involving leg, trunk and shoulder muscles. The same pattern was evident among the control workers. In both groups there was considerable overlap among categories of work. In many supervisory and maintenance jobs, walking made up the bulk of the energy demand. Twelve subjects walked more than 5 miles during the shift, and 2 walked more than 10 miles. Although the walking was usually intermittent, it required an average energy expenditure of 2.79 calories per minute. The energy cost of this factory work was remarkably low. Only in the maintenance and warehouseman groups were there a few individuals whose average rate of energy expenditure equalled twice the resting level.

Maximum rates of energy expenditure varied from individual to individual but were seldom excessive (fig. 2). The noncardiac workers had slightly higher maximum energy expenditures (average peak of 3.45 calories per minute) than did those with heart disease (average peak of 3.04 calories per minute). However, when each subject was compared with his matched control, the differences were not statistically significant (t = 1.56, p = <0.2).
Different jobs required different patterns of energy expenditure. In each job the magnitude and duration of energy expenditure and sequence of tasks were consistent and were not modified by the presence of heart disease in the worker. Two basic patterns were observed: (1) a low rate of energy expenditure maintained fairly steadily and (2) high peaks of energy expenditure alternating with inactive periods (fig. 3). The majority of jobs studied resembled the low steady pattern. Only 13 subjects had peaks of energy expenditure above 4.0 calories per minute. The workers took an average of from 9 to 10 breaks during the shift, for an average total of 1 3/4 hours. This time includes breaks, rest periods and meals, but not time away from work necessitated by the study procedures. Again, no significant difference in the frequency or duration of rest periods was noted in a comparison of the cardiac workers with their controls.

Specific types of heart disease showed no influence on the amount or pattern of energy expenditure when paired subjects and controls were compared within diagnostic categories. In the largest category, that of arteriosclerotic heart disease with previous myocardial infarction, the average rate of energy expenditure was identical for the 23 patients and 17 controls, namely 1.84 calories per minute. The other diagnostic categories were too small (1 to 5 pairs) for significant comparison.

Physiologic Parameters of Cardiovascular Function

The data were next analyzed for evidence of stress, which might distinguish the subject with heart disease from his healthy co-worker or which might be considered injurious to the cardiac patient.

Blood Pressure. The average systolic blood pressure at rest and at work was higher in the cardiac group than among the controls, but the diastolic blood pressures were nearly identical. The differences in systolic pressure were statistically significant, probably as a result of the significantly greater age of the group with heart disease rather than the inclusion of patients with hypertension, since there were only 3 of the latter (table 3).

None of the cardiac subjects developed a working blood pressure higher than 184/100 mm. Hg, except 2 patients with hypertension and 2 with aortic insufficiency who developed systolic pressures above this level. The subject whose blood pressure rose to 184/10 mm. Hg at work was a 62-year-old man who had previously recovered from a myocardial infarction and who died suddenly 3 months after the study. None of the control subjects developed a working blood pressure higher than 162/108 mm. Hg except 3 who were found to have previously unrecognized hypertension at rest (diastolic pressure over 100 mm. Hg).

The average maximum increase of blood pressure was 17 mm. Hg systolic and 8 mm.
Hg diastolic for the cardiac subjects and slightly less for the controls (table 3). The highest blood pressures recorded during the working day coincided with maximum energy expenditure in only 26 per cent of the total cases and in only 1 of 13 subjects whose blood pressure during work rose above 150 mm. Hg systolic or 100 mm. Hg diastolic. During performance of factory work in the study, therefore, the blood pressure response elicited was small in the normotensive cardiac subject and the controls.

**Pulse Rate.** The average pulse rate increased from 84 per minute at rest to an average of 102 per minute during work. Sinus tachycardia (over 110 per minute) occurred in 17 subjects (10 controls and 7 cardiac subjects). In 7 subjects the sinus rate reached 120 per minute or more. Three were control subjects, all of whom had resting pulse rates of over 100 per minute, 2 had hitherto undetected hypertension, and the third was obese. Two of the 4 cardiac subjects had high resting pulse rates. A third subject developed the highest pulse rate observed (136 per minute). He was a 59-year-old man with rheumatic heart disease and predominant aortic stenosis, classified II C; he died suddenly 4 months after the study. The marked tachycardias were disproportionate to the rate of energy expenditure, since they occurred at rates of 1.8 to 4.3 calories per minute. This type of factory work therefore elicits only a moderate increment in pulse rate. Under the conditions described, a working pulse rate in excess of 120 per minute suggests an undetected or inadequately treated cardiovascular abnormality, sustained anxiety or limited cardiovascular reserve.

**Respiration.** The average respiratory rate in the cardiac group was 16.4 per minute at rest and 22.7 per minute during maximum exertion, while the average pulmonary ventilation rose from 8.7 liters per minute to 16.9 liters per minute. The figures were slightly higher for the control group, but the differ-

![Fig. 3. Pattern of energy expenditure during shift for 2 types of job: A. Steady low rate. B. Intermittent high rate.](image)

![Fig. 4 Top. Pulse rate and oxygen consumption, 144 observations on 26 control subjects.](image)

![Fig. 5 Bottom. Pulse rate and oxygen consumption, 157 observations on 36 subjects with heart disease.](image)
the difference was not significant (3.17 ml. of oxygen at rest, 4.00 ml. of oxygen at work). As with pulmonary ventilation, high individual values occurred during high rates of energy expenditure.

Correlation of Physiologic Rates

As the energy expenditure of the human organism increases, the rates of the rhythmic physiologic processes that facilitate the transport of oxygen and the release of energy also rise. It is of interest to examine the cardiac subjects for inappropriate response of such subsidiary mechanisms as heart rate, pulmonary ventilation, or oxygen utilization at a given level of exertion.

Pulse rate in general increases as energy expenditure rises. At rates of over 5 calories per minute the correlation is good enough that pulse rate has been proposed as an index of energy expenditure.\(^{10}\) Figures 4 and 5 show clearly that at oxygen consumptions below 1 liter per minute (approximately 5 calories per minute), there is extremely poor correlation between pulse rate and oxygen consumption, both for control and cardiac subjects. At these relatively low levels of exertion other factors such as emotion, temperature and interindividual variation probably influence pulse rate so greatly as to make it useless as a criterion of energy expenditure. In the present study the maximum pulse rate coincided with the maximum rate of energy expenditure in only 35 per cent of the cases.

Pulmonary ventilation also increases with oxygen consumption. Here, as may be seen in figure 6, the correlation is excellent in the range of the current observations, and may be described by a straight line of the form

\[ y = a + bx \]

where \( y \) is oxygen consumption (ml. per minute), \( x \) is pulmonary ventilation (L. per minute), and \( a \) and \( b \) are constants. The regression line has been calculated by the least-squares method and plotted through the points. We also know from the method of calculation used (indirect calorimetry) that

\[ m = 10xz \]

where \( z \) is oxygen utilization (ml. of oxygen

---

Fig. 6 Top. Pulmonary ventilation and oxygen consumption, 144 observations on 26 control subjects (\( y = 40.6x - 76.6 \)).

Fig. 7 Bottom. Oxygen utilization and oxygen consumption, control subjects (\( y = 766z/40.6 - 10z \)).
absorbed per 100 ml. of air breathed). Substituting, we can express the relationship of oxygen consumption to oxygen utilization as

\[ y = \frac{10a}{10z-b} \]

This curve has been plotted against the actual data for the control subjects in figure 7. In the range studied, the percentage of oxygen extracted from air rapidly approaches a maximum at low rates of energy expenditure. Oxygen utilization would therefore be a poor index of energy expenditure.

In figure 8 pulmonary ventilation has been plotted against oxygen consumption for the subjects with arteriosclerotic heart disease, hypertensive cardiovascular disease and rheumatic heart disease, and the appropriate regression lines have been entered. None of the lines differs significantly from that calculated for the control subjects (fig. 6). The subjects with rheumatic heart disease have a somewhat higher pulmonary ventilation and lower oxygen utilization at a given level of oxygen consumption than do the normal subjects or the patients with arteriosclerotic heart disease. Such a tendency to inefficient extraction of oxygen has been shown to differentiates between normal subjects and mitral stenosis from normal subjects at an oxygen consumption of 1,500 ml. of oxygen per minute and may be the result of limited cardiac output. It should be emphasized, however, that in the present study, at low rates of energy expenditure, this difference is not statistically significant.

Thus, there is no evidence in the present study that workers with compensated heart disease are compelled to make any greater demands upon their reserves in terms of pulse rate, pulmonary ventilation or oxygen utilization in order to perform this type of factory work than are their healthy co-workers.

**Electrocardiographic Changes**

There were remarkably few electrocardiographic changes. The method of electrode placement yielded information only in the horizontal plane, i.e., on the \( x \) and \( z \) axis, equivalent to \( RV_s \), \( V_4 \), and \( V_8 \).

In the cardiac group at rest, 2 patients had atrial fibrillation, 4 had ventricular premature beats, and 3 had atrioventricular block (prolonged P-R interval, second-degree block with Wenckebach phenomenon, and complete block).

During work the premature beats persisted but did not increase in frequency; in 4 additional cases rare ventricular premature beats appeared. Three of these 4 subjects had shown an abnormal response to Master's exercise-tolerance test. The premature beats did not appear with maximum energy expenditure. Three subjects showed primary T-wave changes (change in angle QRS-T) during the working day. Two of the 3 subjects also had an abnormal blood pressure response. One of the 2 mentioned had an abnormal maximum pulse rate response and died later at home in bed.

In the subject with second-degree atrioventricular block, ventricular premature beats appeared and the Wenckebach phenomenon became more prominent. In the subject with third-degree atrioventricular block the rate increased from 56 to a maximum of 58 although the energy expenditure ranged from 1.87 to 2.49 calories per minute.

The control subjects all had regular rhythm. Two subjects had ventricular premature beats at rest, which in the case of 1 disappeared during work. Primary ST-T changes occurred in 3 cases at levels of energy expenditure of 1.8 to 2.8 calories per minute.
The electrocardiographic changes in cardiac and control groups were similar except for ventricular premature beats that appeared during work only in the cardiac group. The low incidence of ST-T changes at this level of work in these subjects is not surprising, since only 23 per cent had shown abnormal or borderline response to Master’s exercise-tolerance test, which requires a larger expenditure of energy.

**Fatigue**

Objective evidence of fatigue was sought in our data. A sustained elevation of the resting oxygen consumption and of the resting pulse rate have been observed to follow strenuous exertion, suggesting that basal physiologic mechanisms have been unable to meet the current demands of the body. The respiratory quotient has likewise been noted to drop during prolonged exercise, suggesting an exhaustion of the readily available carbohydrate stores of the body. Figure 9 summarizes the changes observed in these 3 parameters at rest at the beginning, middle and end of the work shift. Both cardiac and control subjects show a minor but not statistically significant elevation of oxygen consumption at midshifts, which may be attributed to the lunch or supper ingested by most of them just before the observations were made. Aside from this observation, there are no consistent changes in the resting oxygen consumption, pulse rate or respiratory quotient during the day in either cardiac or control group, and no significant differences between the 2 groups. Thus, as might be anticipated from the level of energy expenditure encountered, there is no evidence of fatigue in the over-all process of energy production. Other types of fatigue not measured by the methods of this study may, of course, have been present.

**Discussion**

How representative were the jobs studied? Although not selected for statistical purposes, the jobs appeared typical of those held by a third of the total working population of a large industrial city and by a large percentage of working cardiac subjects studied at the Work Classification Clinic of the Cleveland Area Heart Society. The jobs ranged from menial to managerial and from sedentary to active, and were distributed throughout all departments of these 3 metal-manufacturing plants.

The energy cost of the type of work studied is remarkably low in relation to other human activities. A champion athlete can maintain an energy expenditure of 26.5 calories per minute for several minutes during a 2-mile run or skiing. Taylor et al. found that a group of healthy but untrained young men could achieve a maximum rate of energy expenditure of approximately 18 calories per minute on a treadmill. These rates are obviously unrealistic in relation to the requirements of daily work. Passmore and Durnin, reasoning from their own data and those of German workers, conclude that 5 calories per minute during working hours \( \text{probably represents the upper rates of daily energy expenditure that can be maintained regularly in heavy industry.} \) Garry et al., using methods similar to those of the present study, have found the average rate of energy expenditure by coal miners during the underground shift to be 4.3 calories per minute. In the same study, clerks at the mine had an average working rate of
1.7 calories per minute. In the present study, the average rate of energy expenditure was more comparable to that of the clerks. During the working shift for the entire cardiac group the rate was 1.97 calories per minute, ranging from 1.54 calories per minute, for the miscellaneous group (planning clerk, tool and laundry crib attendant, etc.) to 2.35 calories per minute for the warehousemen (stock pickers). The energy requirements of these jobs therefore lie in the lower range of possible sustained-energy output. In fact, the workers may expend energy at a higher rate on the job than off. This surprising conclusion is based on the findings of Garry et al., that during the 8 nonworking waking hours 1,400 calories, or 2.96 calories per minute, were expended by coal miners and clerks, a rate which is higher than the average working rate for any of the groups in the present study. The low rates of energy expenditure at work are not attributable to heart disease as such, since no statistically significant difference in either average or maximum rate could be demonstrated when the cardiac subjects were compared with healthy men performing the same job. The subjects had not been downgraded to less difficult jobs because of the development of heart disease, according to the industrial physicians, consulting physicians and personnel managers.

Granted, then, that the energy demands of such factory work are not great, does the work nevertheless cause strain on the cardiovascular system of workers with heart disease? Certain individuals have been cited here who, in spite of the relatively light character of the work, developed heart rates of over 120 per minute or blood pressures of over 184 systolic or 90 diastolic, and electrocardiographic changes.

These physiologic alterations may have variable significance. When they occur singly and infrequently, as in the control group, they may be insignificant or secondary to obesity or benign essential hypertension. The concurrence of several abnormalities in the same subject is probably significant. Their occurrence in 2 subjects, who died unexpectedly within 4 months of the study, suggests encroachment upon a diminished cardiac reserve. It would be desirable, although not presently practicable, to monitor several parameters of cardiovascular function in the average cardiac patient at work. The Master 2-step test may be used to elicit such changes in the office or laboratory. It is important to recognize, however, that the Master step test calls for the expenditure of 8.5 calories per minute, a rate in excess of any peak observed in any of the workers studied. Certainly an individual with heart disease, who can make this exertion without developing excessive heart rate, blood pressure or abnormal electrocardiographic changes, would not be expected to show adverse effects during a job requiring average peaks of 3.45 calories per minute, or an average sustained effort of only 2 calories per minute. On the other hand, the cardiac patient who does show an abnormal step-test response may be able to perform safely at the rates of energy expenditure required by his job. The decision to return such an individual to work may be made in view of the fact that merely keeping him at home without further restriction probably will not reduce his energy below that required by work. The patient’s work may, of course, entail other forms of stress than those measured in calories, but emotional and personal problems may be aggravated and are seldom solved by keeping a worker idle.

**Summary**

Sixty-two subjects, 36 with heart disease and 26 healthy controls, were observed during a normal working day in 3 metal-manufacturing plants. The workers are considered representative of at least a third of the working population of a large industrial city. Their average rate of energy expenditure during the shift was of the order of 2 calories per minute, a low rate and one comparable to that observed during nonworking activities. The maximum rate of energy expenditure rarely exceeded twice the resting rate. A few subjects with heart disease developed disorders of cardiovascular function in terms of blood pressure, heart rate or electrocardiogram dis-
orders that may have had serious prognostic significance. Energy expenditure correlated well with pulmonary ventilation, and poorly with pulse rate at the levels observed. No objective evidence of fatigue was detected.

ACKNOWLEDGMENT

The authors wish to express their gratitude to Richard Mackey, Herbert Medoff, James L. Phillips, Frank Tiberio, and Norman Zucker for invaluable assistance in collecting and preparing the data, to the volunteer subjects and personnel of the Cleveland Graphite Bronze Company Division of Clevite Corporation, Jack and Heintz, Inc., and Thompson Products, Inc., and to Dr. Arthur Littell and Mr. Melvin Conway for assistance in the statistical analysis.

SUMMARIO IN INTERLINGUA

Sexanta-duo subjectos—36 con morbo cardiac e 26 normales a titulo de controlo—eseva observate in 3 fabricas metallurgic durante un typic die de travalo. Es opinate que le subjectos seligite eseva representative de al minus un tertio del population travaliante de un grande citate industrial. Le expensa medie de energia in le curso del jornata eseva del ordine de 2 calorias per minuta. Iste valor es basse in comparation con observationes in activitates altere que travalo. Le intensitate del expensa de energia attingeva rarmente maximos de plus que duo vices le valor de reposo. Plure subjectos con morbo cardiac disveloppava disordines del functiones cardiovascular—tanto in le pression de sanguine e le frequentia cardiaci como etiam in le manifestationes electrocardiographie—le quales es possibilemente de serie signification prognostic. Le expensa de energia se monstrava ben correlationate con le ventilation pulmonar, sed illo se trovara paucu correlationate con le frequentia del pulso a omne le nivelllos studiate. Nulle signos objective de fatiga eseva detegite.

REFERENCES
Work and Heart Disease: I. A Physiologic Study in the Factory
AMASA B. FORD and HERMAN K. HELLERSTEIN

Circulation. 1958;18:823-832
doi: 10.1161/01.CIR.18.5.823

Circulation is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
Copyright © 1958 American Heart Association, Inc. All rights reserved.
Print ISSN: 0009-7322. Online ISSN: 1524-4539

The online version of this article, along with updated information and services, is located on the World Wide Web at:
http://circ.ahajournals.org/content/18/5/823

An erratum has been published regarding this article. Please see the attached page for:
/content/19/2/313.3.full.pdf

Permissions: Requests for permissions to reproduce figures, tables, or portions of articles originally published in Circulation can be obtained via RightsLink, a service of the Copyright Clearance Center, not the Editorial Office. Once the online version of the published article for which permission is being requested is located, click Request Permissions in the middle column of the Web page under Services. Further information about this process is available in the Permissions and Rights Question and Answer document.

Reprints: Information about reprints can be found online at:
http://www.lww.com/reprints

Subscriptions: Information about subscribing to Circulation is online at:
http://circ.ahajournals.org//subscriptions/
insufficiency, for instance, in parents and children, in siblings, and in twins. In such observations the author sees further evidence that an inherited predisposition must be present for the acquisition of extraneous cardiovascular diseases.


Errata

Various authors have requested that the following changes be made in their published papers:


On page 572, text should read: "...an electrocardiographic analysis of sixty-five cases of mitral regurgitation."


On page 575, table 5, Lead V6, Group Range, 56.0 under LVII should be 36.0; table 5, Lead V1, No. pts., (INC) under RVH & IRBBB should be 1.

On page 576, table 6, Lead V5-V6, No. pts., 48 (N) and 17 (PRO) under Total should be 49 (N) and 16 (PRO).

On page 577, table 8, R/S Ratio in Lead V1, No. pts., 37 (N) under Total should be 27.

On page 578, table 9, R Wave in V1 + S Wave in V5-V6, No. pts., 18 (N) under Total should be 19.


On page 575, text should read: "...an electrocardiographic analysis of sixty-five cases of mitral regurgitation."


On page 831, line 13, should read "...workers may expend energy at a higher rate off the job than on it."