sion, or fixation, done for prolapse. Two were suspended for sterility and neither got pregnant. So here are a thousand puerperal women, whose uteri were never replaced or pessaried when found retroverted, of whom two had suspensions —and in neither of whom it need have been done.

To sum up this review of our recent study, we feel that we cannot in justice to our own experience hold any other view than that retroversion is a normal position for the women in whom it occurs, and that unless complicated by such conditions as endometriosis or tender prolapsed ovaries, causing dyspareunia, it is no more likely to produce symptoms than the anteverted organ; and that operating on it when it is uncomplicated by such conditions is unlikely to relieve the symptoms blamed on it. Vogt *et al.*[4] have practically reached the same conclusion in their statement that "operation failed to relieve symptoms in three-quarters of the patients".

TABLE XII.

LATE PROLAPSE ACCORDING TO POSITION OF UTERUS AT 10TH DAY AND 6TH WEEK

At 10th day		*At 6th week*			
		Retrov.	*Antev.*	*Not. exam.*	*Total*
Retrov.	1	—	—	1	1
Antev.	20	—	10	11	21
No. exam.	9	—	3	5	8
Total	30	—	13	17	30

Perhaps the results of this study of 1,118 parous women do not entirely justify us in stating that the retroverted uterus is a normal position of that organ in those women in whom it occurs. Perhaps our experience has been exceptional. But if there is any truth at all in our findings, it does justify us in affirming that the whole case of the retroverted uterus should be restudied by others and that in the meantime most of what is said about it in the textbooks should be taken with a large grain of salt.

TABLE XIII.

RETROVERSION IN PROLAPSE CASES REQUIRING OPERATION

Degree	*No. of cases*	*Retrov.*	*% retr.*
1st	73	24	32.8
2nd	83	19	22.8
3rd	44	2	4.5
Total	200	45	22.5

I am greatly indebted to Dr. H. B. Atlee, Chief of the Department of Obstetrics and Gynæcology, Dalhousie University, for his suggestions and advice in the preparation of this paper, and also to Miss Jean Peabody, University Statistician, for her excellent arrangement of the statistical material.

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THE ELECTROCARDIOGRAPHIC RESPONSE TO THE STANDARD 2-STEP EXERCISE TEST*

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WHEN THE EQUILIBRIUM of the coronary circulation is disturbed so that the blood supply to the heart muscle is inadequate for the needs of the moment, electrocardiographic changes, with or without cardiac pain, may result. In most instances, the diagnosis of coronary artery disease rests essentially on an adequate history of the patient's symptoms. It is frequently difficult, however, to establish this diagnosis, because of an atypical history and a normal resting electrocardiogram.

In order to secure objective evidence for the diagnosis of angina pectoris,[1 to 8] in patients suspected of having coronary artery disease, various methods have been devised to induce coronary insufficiency. The 2-step exercise test was first used as a means of estimating cardiovascular function by determining the response of the blood pressure and pulse rate to a standardized form of exertion.[1] Subsequently, it was modified, and the electrocardiogram was used to obtain objective evidence of the presence of coronary insufficiency.[2]

In the single 2-step exercise test the work of the heart is increased by the performance of a standard amount of work in 1½ minutes. In some individuals suspected of having coronary

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artery disease, the work thus imposed upon the heart was found to be insufficient to produce the electrocardiographic changes characteristic of coronary insufficiency. The double 2-step test was, therefore, introduced for use among those patients believed to have coronary artery disease, whose single 2-step test was normal. In the double 2-step test the patient performs twice the amount of work as in the single test and in twice the time—3 minutes.[9]

Although the effects of various degrees of exercise upon the electrocardiogram in normal persons have been determined by several investigators,[2, 3, 10 to 16] the amount of exercise employed has varied widely, as have the methods of recording. It has been shown that electrocardiographic changes can be obtained in normal persons[17 to 21] following excessive exertion.

MATERIAL

This report is based on a study of 311 normal subjects who performed the single and double 2-step exercise tests. Most of the subjects were employees of the Mount Sinai Hospital; others were attending physicians. Of the 311, 151 were males and 160 were females. Their ages ranged from 17 to 57 years. None of the subjects gave a history of past or present cardiac complaints. They all appeared to be healthy, and were essentially normal on physical examination. Their blood pressures were not higher than 140/90 mm. Hg. Fluoroscopy revealed no evidence of any cardiac abnormality. Control electrocardiograms, including standard, unipolar extremity and six unipolar precordial leads, were within normal limits.

Persons with chest complaints, however vague, or with a history even remotely suggestive of rheumatic fever or any other cardiovascular disorder, were excluded from this study. The sex and age distribution of the 311 persons is recorded in Fig. 1.

METHOD

Each person was seen on two occasions, with an interval of at least 24 hours between the two. On the initial visit a history was obtained, a physical examination and fluoroscopy were done, and a control electrocardiogram, consisting of the standard, unipolar extremity and multiple precordial leads, was recorded. The subject then performed the single 2-step exercise test, making the required number of trips up and down the steps in 1½ minutes. The number of trips is determined from previously prepared tables and is dependent on the weight, age and sex of the individual.[2, 9] Immediately upon the completion of the exercise, the electrodes not having been removed, standard leads I, II, and III, and unipolar lead V_4 or V_5 were taken, and were repeated after 1, 2, and 5 minutes. On the second visit a control electrocardiogram, consisting of standard leads I, II, and III and unipolar lead V_4 or V_5, was again recorded. The subject then performed the double 2-step test. Immediately thereafter, the electrocardiograms were recorded as after the performance of the single test. In no instance did pain occur, nor did the test have to be discontinued because of dyspnœa or inability to complete it. The electrocardiograms were taken on the direct writing Sanborn Visocardiette. Each record was analyzed for RS-T segment deviations, P and T wave changes, QRS complexes, arrhythmias and rate.

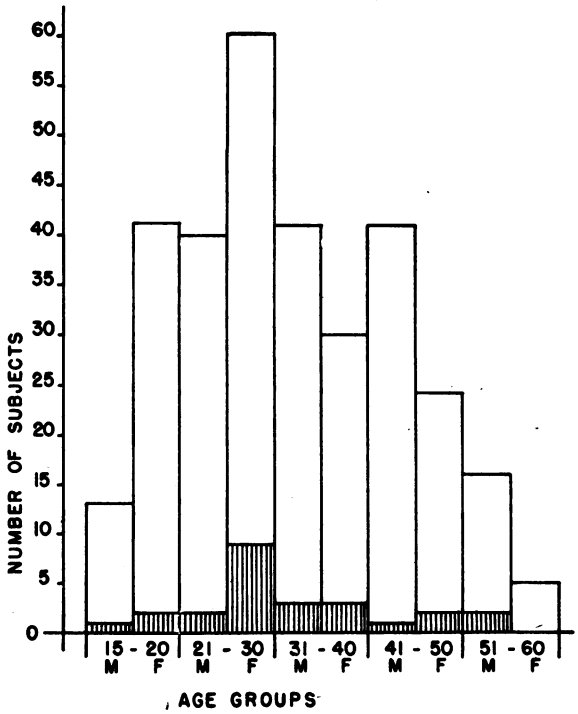

Fig. 1.—Age and sex distribution of the 311 persons studied. Shaded area indicates the number of persons in each group, who either had a positive single or double 2-step test, or both.

RESULTS

1. RS-T SEGMENT CHANGES

Of the 311 normal subjects tested, 10 (3.2%) showed RS-T segment depressions of more than 0.5 mm. after completion of the single 2-step test. In 4 of these the RS-T segment was depressed 1.0 mm. or more. After the performance of the double 2-step test, 22 (7.1%) had RS-T segment depressions of more than 0.5 mm.; in 3 of these the depression was greater than 1.0 mm. In no instance was the RS-T segment deviation greater than 1.5 mm., using the P-R interval as the base line (Fig. 2). The RS-T segment depressions were usually more pronounced in leads V_4, V_5 or II than in leads I or III.

Seven of the 10 persons with RS-T segment depressions of more than 0.5 mm., after the single 2-step test, showed similar changes after the double 2-step test (Fig. 3). In the 4 persons in whom the RS-T segment depressions had

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been more than 1.0 mm., after the single 2-step test, the RS-T segment depression was less than 1.0 mm. after the double 2-step test. Three persons showed no significant RS-T depression after the double 2-step exercise test, but did have a depression of 0.5 to 1.0 mm. after the single 2-step test.

Of the 22 persons who showed RS-T segment depression of more than 0.5 mm. following the double 2-step test, 15 had no significant RS-T segment depression after the single 2-step test

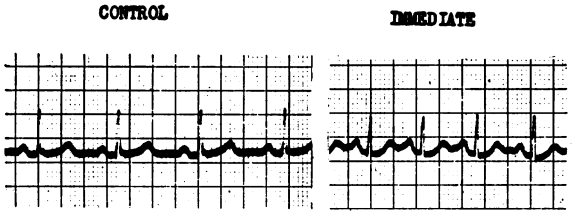

Fig. 2.—H.F., a 25 year old male. Lead II, single 2-step test. Note P wave beginning on downstroke of T wave in the immediate record. This illustrates the necessity for employing the PR intervals as the base line.

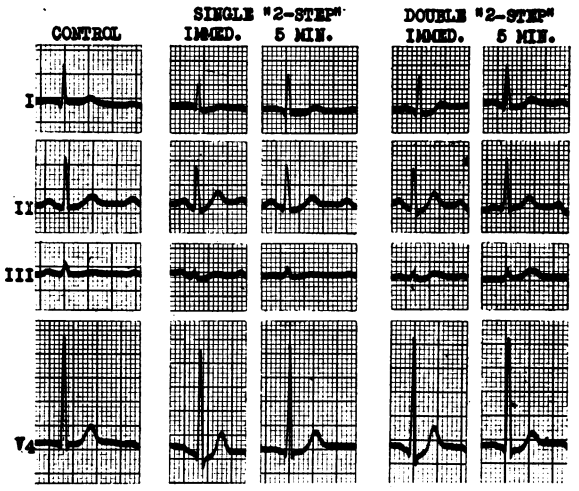

Fig. 3.—R.M., 38 year old normal male. RS-T segment depressed in I, II, and V-4 immediately after the single and double 2-step tests.

(Fig. 4). In the remaining 7 persons, both the single and the double 2-step tests revealed an RS-T segment depression of more than 0.5 mm. Thus, the RS-T segment was depressed more than 0.5 mm. in 25 of the 311 subjects tested, (8.0%) either after the single or double 2-step test or both.

In only five instances, two after the single 2-step test and three after the double test, did the RS-T segment deviations persist for more than 2 minutes. In every instance the 5 minute record was normal.

In no instance did the RS-T segment become elevated after exercise in the leads recorded. In 12 persons the RS-T segment, which was elevated 0.5 mm. or more prior to the exercise test, returned to the base line immediately after completion of the test; after 5 minutes it resumed its original position.

2. T Wave Changes

The T wave changes following the single or double 2-step exercise test were minimal. In no instance did an upright T wave in the control leads I, II, V_4 or V_5 become inverted following the exercise. In many records slight alterations in the height of the T wave were encountered. These changes were as frequent among the subjects who showed RS-T segment depressions as among those who did not, and were usually seen in the precordial leads. In 7 instances, in which there were no RS-T segment deviations follow-

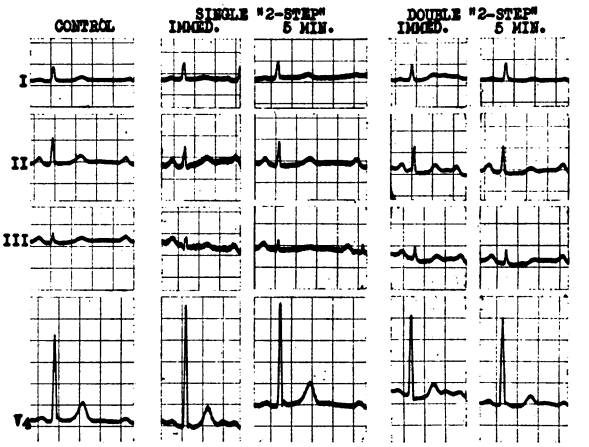

Fig. 4.—J.S., 40 year old normal female. Single 2-step test negative. RS-T segment depressed in II and V-4 immediately after the double 2-step test.

ing the single or double 2-step tests, upright T waves in leads II, V_4, or V_5 became isoelectric immediately after the exercise. In 2 instances the T waves became diphasic in lead V_4, immediately after the double 2-step test. Similar changes occurred as frequently in the subjects with RS-T segment deviations. Because of normally wide ranges of direction and the amplitude of the T wave in lead III, the changes in this lead were not regarded as significant. The T waves in several instances were of increased amplitude following exercise. These changes were usually seen in leads V_4 or V_5 in the electrocardiogram recorded immediately after the exercise.

3. P Wave. P-R Interval and QRS Complex Changes

In a few instances the P waves showed a slight increase in amplitude in leads I and II, but generally they were not significantly altered

after exercise. There was no significant change in the P-R interval. The QRS complexes also were not significantly prolonged or shortened. Minor variations in amplitude of the QRS complexes were occasionally seen. Q waves were not observed after exercise if they were absent prior to it.

4. ARRHYTHMIAS

Immediately following the exercise a few instances of cardiac arrhythmias were encountered. These consisted of occasional auricular premature beats, rare ventricular premature beats, sinus arrhythmia, one case of an ectopic auricular rhythm and one case of transient right bundle branch block.

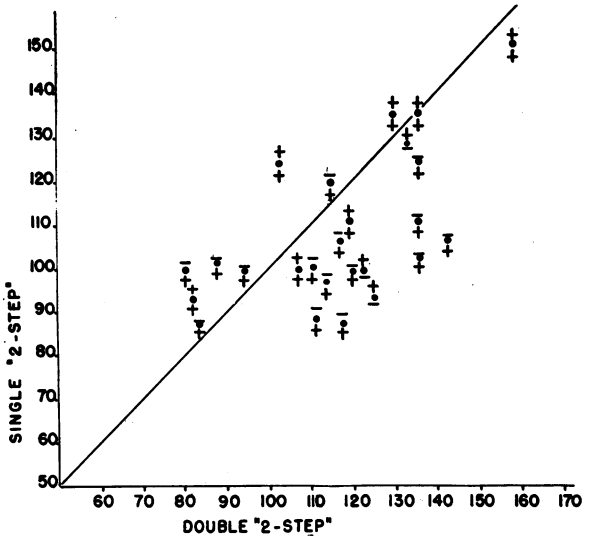

Fig. 5

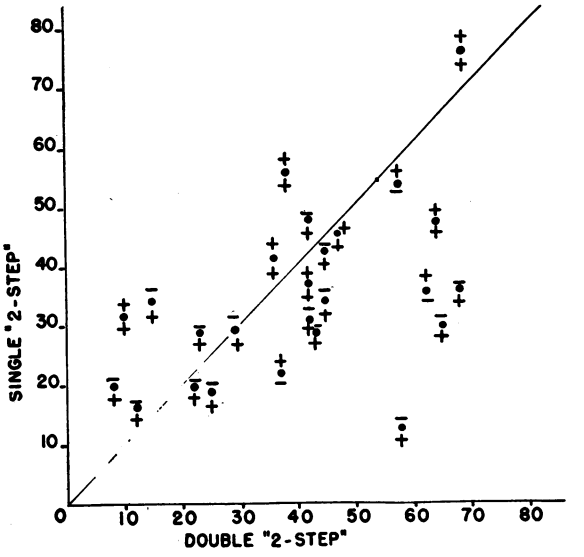

Fig. 6

Fig. 5.—Absolute cardiac rates (positive 2-step tests): Each point represents one person, and compares the rate immediately after the single 2-step test to the rate immediately after the double test. The sign above each point indicates whether there was an RS-T segment depression after the single 2-step test (+ indicates positive test); the sign below similarly shows the result of the double 2-step test. Fig. 6.—Change in rate (positive 2-step tests): Each point represents one person, and compares the increment in rate immediately after the single test to the increment in rate immediately after the double 2-step test. Symbols are similar to those employed in Fig. 5.

5. HEART RATE

A. *Persons without RS-T segment depressions after exercise.*—Among the 286 persons (572 tests) who had no significant electrocardiographic changes after the exercise tests, there was a tendency for the double 2-step test to produce a more rapid cardiac rate than the single 2-step test. Immediately after the completion of the single test the heart rate was between 131 and 162 in 5% of the cases and between 110 and 130 in about 25%. In no instance did the rate exceed 162 beats per minute. After the double 2-step test the heart rate was between 110 and 130 in about 30% of the cases and between 131 and 167 in approximately 10%.

Immediately after the single 2-step test 25% of the subjects showed an increase of 30 to 40 beats per minute over the control heart rate; 11% had an increase of 41 to 50 beats; and approximately 4% had an increase of 51 to 65 beats. In only 3 persons did the increase exceed 60 beats per minute. Immediately after the completion of the double 2-step test approximately 25% had an increase in heart rate of 30 to 40 beats per minute; 20% had an increase of 41 to 50 beats; and 8% had an increase of more than 50 beats per minute. In approximately 3% of this group the increase in the heart rate exceeded 65 beats per minute.

Within 5 minutes after the single 2-step exercise test approximately 14% of the 286 persons still had an increase in the heart rate of 10 or more beats per minute, as compared to the control rate. In approximately 7% the rate at 5 minutes was increased more than 15 beats per minute. Five minutes after the double 2-step test, 24% showed an increase in heart rate of 10 beats or more, and 11% showed an increase of 15 beats or more.

B. *Persons with RS-T segment depression after exercise.*—The absolute cardiac rates of the

25 persons with RS-T segment depressions of more than 0.5 mm. found immediately after the single and doube 2-step are plotted in Fig. 5. The double 2-step test tended to produce a greater increase in heart rate than the single test. Three of the 10 persons, who had an RS-T segment depression of more than 0.5 after the single 2-step test, had a heart rate of 110 to 130; 3 others had a rate of more than 130. Eight of the 25 persons with RS-T segment depressions following the double 2-step test had a heart rate of 110 to 130, and 7 had a rate of 131 to 166.

In Fig. 6 are plotted the *increase in rate* found immediately after exercise, and the control rates. Of the 10 cases who had RS-T segment depressions after the single 2-step test, 3 had an increase in rate of 31 to 40 beats, 3 of 41 to 50 beats, and 3 others of 51 to 80 beats per minute. Of the 22 cases with RS-T segment depression after the double 2-step test, 2 had an increase in rate of 31 to 40 beats, 7 an increase of 41 to 50 beats, and 5 an increase of 51 to 70 beats per minute. In two subjects, who had RS-T segment depressions after the single 2-step test only, there was an increase of more than 50 beats after the negative double test.

DISCUSSION

According to the criteria previously established, using the P-R interval of the electrocardiogram as the base line, a depression of the RS-T segment of more than 0.5 mm. in any lead with or without flattening or inversion of a previously upright T wave, constitutes a positive 2-step test.[2, 9] On this basis, 10 subjects (approximately 3.2% of the 311 examined) had a positive single 2-step test, and 22 (7.1%) had a positive double 2-step test. In 25 persons (8.0%) either the single test, the double test, or both were positive. Some authors believe that the criteria employed for the 2-step test should be altered,[11, 12, 14, 16, 19, 22, 23] and that a depression of the RS-T segment of less than 0.75 mm. should not be considered significant. However, if the criteria were changed, so that a depression of 0.5 mm. to 0.75 mm. were considered "normal", many patients with clinically diagnosed coronary disease would be included in the "normal" group. It is impossible, on the basis of the present study, to attempt to define new criteria of "normal or abnormal" responses to exercise.

Alterations in the T waves of normal persons similar to those observed in this study, and increased amplitude of the P waves have also been noted by others after the 2-step test.[11, 16, 24] In no instance did an upright T wave become inverted following exercise.

In comparing the pulse rate after the single and double 2-step exercise tests, it is evident that the double 2-step test produces a tachycardia more often than does the single test. Five minutes after the completion of the exercise tests a greater percentage of cases still showed a tachycardia after the double than after the single 2-step tests. It is interesting to note that only 15% of the subjects without RS-T segment depression had a cardiac rate of 130 or more immediately after exercise. Yet 10 of the 32 tests, in which RS-T segment depressions appeared, were associated with cardiac rates of 130 or more.

Results at variance with those herein reported have been found in studies which employed various methods of non-standardized exercise tests, and in which a precordial lead was not utilized. For example, numerous investigators have pointed out that excessive exertion causes electrocardiographic changes in a large percentage of normal persons.[17 to 20, 25] Some have insisted upon exercise up to the point of cardiac pain, shortness of breath, or fatigue.[3, 10, 12] Others have shown that a decrease in the CO_2 combining power of the blood and an alkalosis develop in the presence of shortness of breath or hyperventilation, and that the RS-T segment depression and T wave inversion may result therefrom.[26, 27] It is unwise, therefore, to exercise the patients to the point of exhaustion. Such strenuous exercise may be dangerous to patients with coronary artery disease. It is, perhaps, also unwise to induce attacks of chest pain for diagnostic purposes, since the electrocardiographic changes are the same in the presence of coronary artery disease, whether or not chest pain develops during exercise. The 2-step tests employed in the present study are standardized according to the age, the weight and the sex of the patient. The amount of work done is simply and accurately determined and can be readily repeated when necessary. Neither the single nor the double test produces an undue strain upon the patient who undergoes it. None of the tests herein reported had to be discontinued because of shortness of breath or inability to complete them. The degree of exertion required by the tests is probably no greater than that required by daily, routine activities.

The use of a precordial electrode is of extreme importance for the study of RS-T segment changes, since this electrode, in the V_4 or V_5 position, most often records such changes after exercise.[8, 12, 16, 19, 21, 25, 28, 29] The Wilson unipolar precordial lead is preferred, since it best records the potenials as found immediately under the electrode. When a CF lead is employed, it will probably show a smaller degree of RS-T segment deviation, because any negativity recorded in the precordial lead may be offset by negativity recorded in the leg. The precordial lead V_5 should be used more often, since the frequent presence of a prominent S wave in lead V_4 may make the degree of RS-T segment depression extremely difficult to determine accurately.

The reports of conflicting results of 2-step exercise tests may be due to the difference in the time elapsed between the completion of the exercise and the recording of the electrocardiogram. In the present study, the RS-T segment changes were most frequently seen in the record taken immediately after exercise, and usually disappeared within 1 to 2 minutes afterwards. It is for this reason that all the electrodes should be maintained in position while the exercise is being done. An electrocardiograph of the amplifier type, preferably a direct writing instrument with instomatic control, should be employed. This permits the recording of leads I, II, III, and V_4 or V_5 within 20 to 35 seconds after the completion of the exercise. When longer periods of time elapse after the exercise, fewer instances of RS-T segment changes will be found.

The nature of the RS-T segment depressions after exercise in normal persons has been the subject of much controversy. In the presence of coronary artery disease the RS-T segment and T wave changes in induced coronary insufficiency have been attributed to predominant involvement of the subendocardial aspect of the heart.[30]

According to Ashman and Byer,[31, 32] utilizing the concept of ventricular gradient as put forth by Wilson, Macleod, Barker and Johnston,[33] some of the RS-T segment and T wave deviations after exercise are attributed to repolarization or regression deviations, causing a decrease in the manifest magnitude of the gradient. Normally in the human heart the presence of a ventricular gradient, which accounts for the upright T wave, is probably due to earlier repolarization of the subepicardial layers of the heart. According to these authors[31, 32] the tachycardia following exercise is responsible for reducing or abolishing the human ventricular gradient, so that the time difference of depolarization and repolarization of the endocardial and subepicardial aspect of the heart are almost equalized.

This explanation may account for some of the RS-T segment deviations in the tests which were associated with a marked tachycardia; but many persons who had a marked increase in the heart rate after the exercise did not show any RS-T segment or T wave changes. Moreover, in 2 persons who had a positive single 2-step test with a heart rate of less than 100, the double 2-step test was negative, though the heart rate was higher. It is thus evident that factors other than rate alone probably are effecitve.

Abundant clinical evidence in cases of coronary artery disease has demonstrated a definite relationship between central and reflex nerve stimuli and cardiac pain, indicating that the nerve supply to the coronary arteries plays a significant rôle. Persons with neurocirculatory asthenia and with emotional disorders may complain of symptoms suggestive of coronary disease and may have abnormal electrocardiograms. Following exercise in these young individuals it is possible that transient metabolic changes occur, which are predominant in the subendocardial aspect of the heart and produce RS-T segment depression and T wave changes.

When the history and routine physical examination give evidence of coronary artery disease and the resting electrocardiogram is abnormal, no additional tests are necessary. In fact, in the presence of an abnormal resting electrocardiogram, the exercise test should usually not be performed. However, although it is usually possible to make the diagnosis of coronary artery disease on the basis of a history and routine physical examination, a large number of patients, estimated at 25 to 60%, give an atypical history and have a normal resting electrocardiogram.[21, 34 to 36] In these cases objective functional tests may aid in establishing the diagnosis. The main purpose of the 2-step exercise test is to reveal objective evidence of coronary insufficiency in patients who are suspected of having coronary artery disease, but who have normal resting electrocardiograms. Since patients with neurocirculatory asthenia, and others with various emotional

disorders, may at times simulate the syndrome of angina pectoris, there is a distinct need for such objective diagnostic procedures.[37]

In a patient suspected of coronary artery disease the single 2-step exercise test should be performed first. Only if this test is negative should the double 2-step test be tried. It should be remembered that, with the double 2-step test, a higher percentage of positive tests may occur in persons without any history or evidence of coronary artery disease. The clinical applicability of the results of the present study lies in the prognostic significance of a normal electrocardiographic response to the 2-step tests. A follow-up study[38] of patients with negative single and double 2-step tests indicates that they are of favourable prognostic significance, as far as coronary artery disease is concerned.

The 2-step exercise tests should be regarded as an aid in the diagnosis of coronary artery disease, but should be interpreted only in the light of the patient's history and other physical findings. It is a functional test, which objectively records the patient's electrocardiographic response to exercise. There are many factors—functional, reflex, and organic—which may be responsible for a positive test.

SUMMARY

Since the purpose of the single and double 2-step tests is to reveal objective evidence of coronary insufficiency in patients with normal resting electrocardiograms who are suspected of having coronary artery disease, these exercise tests were performed on 311 normal individuals. The single 2-step test should be performed first; the double 2-step test is done only if the single test is negative.

After the single 2-step test, the RS-T segment was depressed more than 0.5 mm. in 3.2% of the cases; after the double 2-step test, it was depressed in 7.1%. The single or double 2-step tests, or both, were positive in 8.0% of the 311 subjects.

The RS-T segment depressions were most frequently recorded in the V_4 or V_5 electrode position. The electrocardiographic changes were most frequently seen immediately after the test exercise, and usually disappeared within 1 to 2 minutes. In no instance did a T wave, which was upright before the exercise, become inverted following it.

The absolute cardiac rates, as well as the increments in the rates, are reported.

The advantages of using a standardized exercise test are indicated. A direct writing electrocardiographic instrument is preferred, particularly one which permits instantaneous lead recording.

The results obtained with the 2-step exercise tests should be interpreted only in the light of the patient's history and the other physical findings.

We wish to express our appreciation to Mrs. Steven Ogden, Miss Edith G. Stern, Miss Janice Newman, Miss Ann Coleman, and Miss Nancy Miller for technical assistance.

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