THE TREATMENT OF CARDIAC INSUFFICIENCY BY A NEW METHOD OF EXERCISE WITH DUMB-BELLS AND BARS

THE CIRCULATORY REACTION TO EXERCISE AS A TEST OF THE HEART'S FUNCTIONAL CAPACITY *

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Brilliant as has been the advance in our knowledge of the pathology and diagnosis of cardiac disease during the last decade, therapeutics in this field are practically the same as they were twenty years ago, and consist chiefly in rest, diet, and digitalis.

The possibility of developing the inherent power of the heart muscle was affirmed many years ago by Oertel, who used the very arduous exercise of hill climbing for this purpose. Since then the Nauheim school has been the chief exponent of the treatment of cardiac insufficiency by exercise and baths. The literature on these methods is meager, and judging from the scarcity of published reports, but few physicians in this country have been enough impressed with their value to give them a trial. Possible reasons for this are the elaborate outfit required for certain of them, lack of knowledge of the various special exercises, and more than anything else, perhaps, our inability to form an accurate estimate of the patient's cardiac efficiency. No method of increasing the strength of the heart muscle can be carried out in any but the most empiric way, nor can the results be correctly appraised if we do not first possess a fairly reliable test for determining the heart's functional capacity.

Before treating patients with cardiac insufficiency by the new method of exercise referred to in our title, it seemed essential, therefore, to investigate the various tests for cardiac efficiency which have been proposed, although the validity of each has been questioned and no one has met with general acceptance.

In 1905, Gräupner originated a test consisting in deductions made from frequent observations of the pulse and systolic blood pressures after measured amounts of work, performed by means of an ergometer (that is, a form of stationary bicycle). His plan seemed peculiarly well adapted to our ends, for the exercises we used were of a kind

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that permitted a fairly accurate estimation of the amount of work performed. So we carried out Gräupner's test in 150 experiments on fifteen normal people, using our exercises instead of the ergometer.

EXPERIMENTS ON NORMAL PEOPLE

The pulse rate, systolic and diastolic pressures[1] were first taken. Then a measured amount of work was performed and the pulse rate and blood pressures were taken immediately after the cessation of work, and every one or two minutes thereafter, by the same observer. Then the same procedure was repeated with an increased amount of work.

Charts 1 and 2 show the type of reaction we invariably found. Directly after a moderate amount of work, the systolic blood pressure was raised and the pulse accelerated, both then rapidly falling to and below the figures noted before the work began. The rise was proportional to the amount of work, the time in which it was performed and to the individual's physique and muscular training. As soon as the work exceeded a certain amount, which varied for different individuals, we regularly found that the systolic blood pressure did not reach its highest point immediately after work, but a minute or so later at a time when the pulse rate had dropped back toward normal. The amount of work sufficient to produce this delay in the systolic blood pressure's reaching its maximum was generally accompanied by hyperpnea (in one person by vertigo and nausea), and the subject of the experiment was conscious that he had done a hard bit of work, sometimes unpleasantly so.

The physiologic explanation of this phenomena is still obscure. We know that during exercise the pressure in the aorta mounts rapidly, making the emptying of the left ventricle increasingly difficult. The exercise continuing, the pressure falls slowly, thereby relieving the strain on the ventricle. Just what part dilatation of the skin vessels or the splanchnic area plays in causing this fall we no not know, but it is evidently a defensive reaction to prevent the left ventricle from becoming insufficient.

Gräupner[2] measured the blood pressure at frequent intervals in patients with cardiac insufficiency during and after increasing quantities of work, and showed that when the work reached a certain amount the pressure fell slowly, and, the work stopping, there ensued the delayed rise we have observed. He noted also that the harder the work, the more marked the subsequent delay, until, finally, in heavy

2. Gräupner: Deutsch. med. Wchnschr., 1906, No. 26, p. 1028.

1. After making numerous measurements of the diastolic pressure we found them of no value for our purpose and so omitted them.

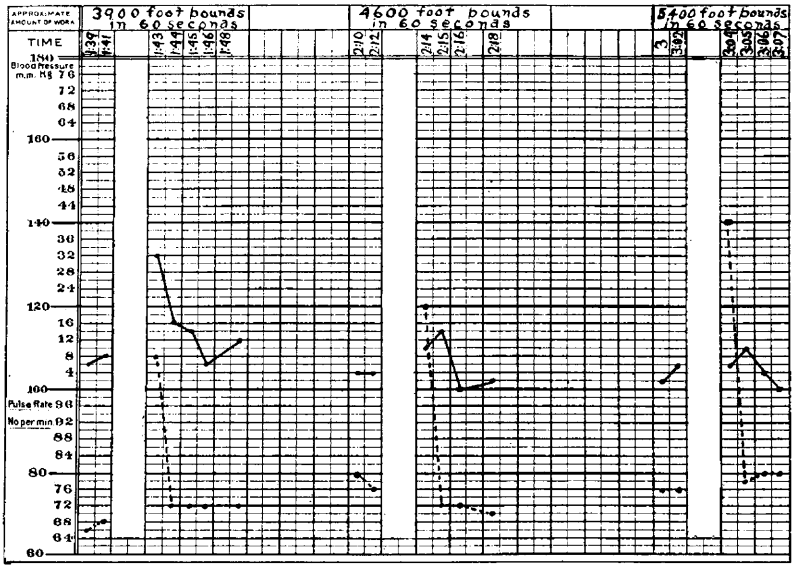

Chart 1.—Type of reaction in normal persons after measured amount of work.

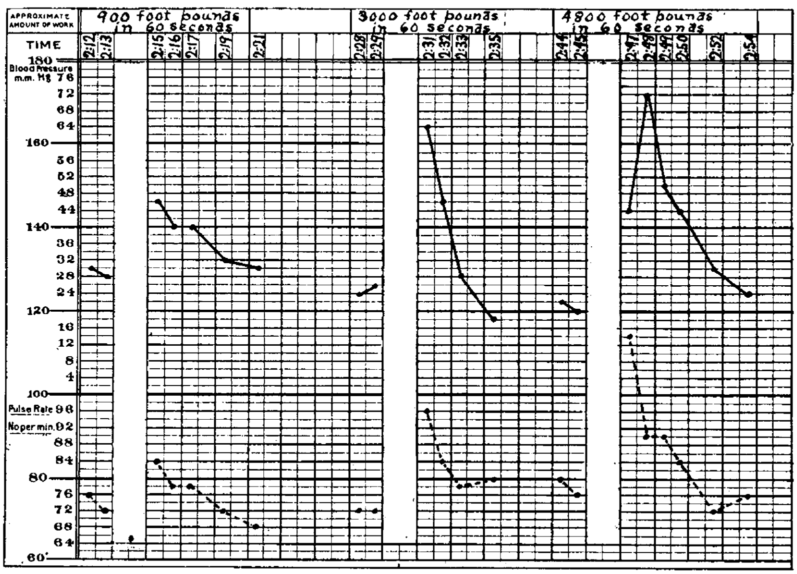

Chart 2.—Reaction noted in normal persons after moderate amount of work.

work the pressure immediately after was lower than before, and slowly returned to and above the original level.

The exercise incident to an active physical life must frequently produce this delayed rise and the fact that damage is rarely done to the heart shows the efficiency of this protective mechanism. We found that one week's training of a normal person would increase markedly the quantity of work he could do before a delayed reaction was produced.

TEST FOR ESTIMATING THE HEART'S FUNCTIONAL CAPACITY

As a result of our experiments on normal people we were inclined to believe that in certain deductions made from the pulse and blood-

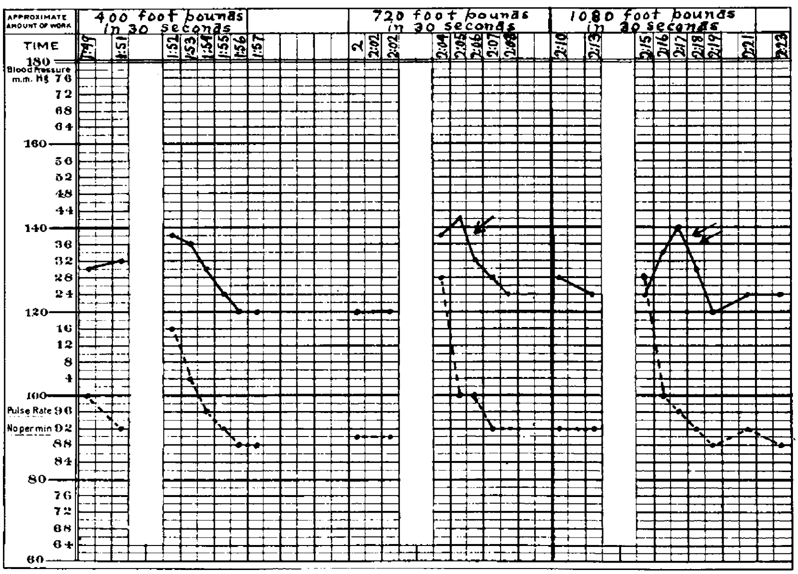

Chart 3.—Effect of overtaxing left ventricle.

pressure reactions to a measured amount of work, we possessed a valid test of the heart's functional capacity, even though we had no proved physiologic basis for this assumption. As soon as the quantity of work was sufficient to produce a delayed reaction, we considered that we had overtaxed the heart's reserve force at that particular time and secured a measure of its efficiency. As shown in Chart 1, if 3,900 foot-pounds of work performed in 60 seconds is followed by a rapid fall in blood pressure, and 4,600 foot-pounds of work in 60 seconds is followed by a delayed reaction, the functional capacity of that heart may be expressed as an ability to supply the amount of blood to the muscles necessary for doing between 3,900 and 4,600 foot-pounds of work in 60 seconds.

The validity of this test of the heart's functional capacity unexpectedly received confirmation during the study of five patients suffering from angina pectoris. While estimating their cardiac efficiency we found in four of them that just as soon as work sufficient to cause a delayed rise in blood-pressure was given, a slight anginal attack was produced. After resting some minutes each patient was then given work increased by several hundred foot-pounds. A more marked delay in the blood-pressure rise and a more marked anginal attack was produced. In other words the overtaxing of the left ventricle was evidenced clinically not only by the blood-pressure reaction but almost simultaneously by the angina. Chart 3 depicts this incident in one of the angina cases.

Accordingly we adopted this method of frequent pulse and blood-pressure determinations following a measured amount of work, as a guiding principle in the treatment of cardiac insufficiency, and it has worked out so well that we feel the validity of this criterion of the heart's efficiency has been practically established.

The pulse and blood-pressure curves we obtained after measured amounts of work differ in several very important points from Gräupner's results and these differences do much to invalidate Gräupner's conception of the essentials of his test. Our conclusions as to the import of the pulse and blood-pressure curves are naturally quite different from his, so different that our test cannot properly be called the Gräupner test. In a later article we shall discuss this matter at greater length.

METHOD OF EXERCISE

The new method of exercise which we have been trying out this past year is new only in its application to cardiac insufficiency. It was devised many years ago by the senior author, Dr. Teschner, and has been used by him constantly in the practice of orthopedics. Several of his patients were suffering also from chronic valvular disease with cardiac insufficiency and he noted a marked improvement in their circulatory symptoms, attributable apparently to these exercises, so we were encouraged to experiment with them on a series of patients suffering from various cardiac disorders.

The apparatus used consisted of dumb-bells weighing from 3 to 25 pounds each and steel bars varying from 10 pounds upward in weight, with which different movements of flexion and extension were carried out. It was possible to measure the approximate number of foot-pounds of work performed in each exercise.

In treating our patients we followed this routine; 50 or 100 food-pounds of work was given with a pair of 5 pound bells by pushing them alternately above the head. The pulse and blood pressure were taken before and every minute after the exercises. If they showed a normal type of reaction, in a few minutes another piece of work was given, increased by 50 or 100 foot-pounds through using heavier bells. Sooner or later, we reached an amount of work which was followed by a delayed rise in blood pressure and we knew that the functional capacity of the patient's heart had then been exceeded. We found that many of our patients showed a cardiac efficiency of only a few hundred foot-pounds, which contrasted strikingly with the efficiency of a normal heart, which may measure as much as 7,000 foot-pounds performed in two minutes.

The daily exercise of our patients was arranged as follows: Having found in a given patient that 800 foot-pounds produced a delayed rise, his future work was limited to 700 foot-pounds for a period of seven days. Each day he was given this 700 foot-pounds to do from four to six times, with five or ten minutes rest in between, so that about an hour was used for the exercise period. At the end of seven days the heart's functional capacity was again tested and, if it had increased, the work for the next week was kept just below the amount that produced a delayed reaction.

As the patient's heart increased its efficiency, and the increase was often surprisingly rapid, various other exercises were added to the initial one of pushing dumb-bells above the head, exercises which utilized the trunk muscles and enabled us to increase markedly the number of foot-pounds performed without tiring excessively any one group of muscles. These were the swing, in which a bell is swung from the floor above the head and down again, the elbow and wrist being fixed, and bar work in which a steel bar is pushed above the head, the patient standing, or lying on the back. Each movement was repeated from 10 to 20 times, the patient being carefully instructed not to hold his breath while exercising on account of the pressor effect of a closed glottis. The time consumed in each form of exercise varied between 30 and 120 seconds. Patients were frequently conscious of improvement after six treatments. We usually gave them from twenty to thirty treatments. Sometimes we were in doubt as to whether a delayed reaction had occurred, generally in patients with fibrillating hearts. A repetition of the exercise with a slight increase of work would always clear this up. Sometimes the pressure after work was found to be lower than before. This is to be regarded as an extreme type of delayed reaction and means that the heart has been decidedly overtaxed by the preceding work. The production of one or two delayed reactions in a patient with cardiac insufficiency never seemed to have any harmful result.

The time required for the pulse rate and blood pressure of a delayed reaction to return to the previous level was a distinct aid in estimating the condition of the heart muscle. In one of our patients, who subsequently died with double mitral, double tricuspid and double aortic lesions, and a cardiac efficiency of but 200 foot-pounds in thirty seconds, ten to twenty minutes would almost always elapse before the return to normal of a delayed reaction.

PATIENTS SELECTED FOR TREATMENT

We selected for treatment ambulatory patients with chronic valvular or myocardial disease and varying stages of decompensation. Any suggestion of an acute process, any history of recent emboli or a persistently high blood pressure was considered to be a contraindication for the exercise treatment. Many of the patients had entered the hospital suffering from an acute insufficiency and had had the usual treatment of rest, diet, and digitalis. As soon as they were able to be up and walk around, they were given the exercises.

PATIENTS WITH MITRAL LESIONS

Table 1 summarizes our results in six of these patients. Three patients whose histories follow showed marked improvement.

TABLE 1.—Summary of Results in Six Patients with Mitral Disease

No. and Name	Age	Initial Cardiac Capacity foot-pounds	Final Cardiac Capacity foot-pounds	Initial Lung Capacity cu. in.	Final Lung Capacity cu. in.
1 T.	40	150	520	70	96
2 F. D.	53	150	600	70	110
3 J. T.	28	?	?	162	180
4 B.	31	75*	...	...	...
5 P.	55	120	280	50	62
6 D.	24	100-200	525	?	?

* Exercise discontinued after five lessons.

Three patients whose histories follow showed marked improvement.

Case 1.—M. T. (Patient 1), a woman, aged 40, had been sick intermittently for a year, suffering from dyspnea and swelling of the feet and abdomen. On her second admission to the hospital she was cyanosed and orthopneic, her legs were much swollen, the liver extended six inches below the costal margin, there was free fluid in the abdomen and a small amount in each pleural cavity. Her heart showed a double mitral lesion and auricular fibrillation. After being treated with digitalis she was able in a few weeks to get around the ward. Several weeks later the exercise course was begun and she received fifty-eight treatments.

Twice the exercises were suspended and she was given digitalis (12 drams of the tincture altogether). After these two interruptions she improved steadily.

The edema of the legs subsided, the swelling of the liver lessened, and her strength returned. Her cardiac efficiency increased from 150 foot-pounds to 520 foot-pounds, and her respiratory capacity from 70 cubic inches to 96 cubic inches. Today (four months after stopping the exercises) she is doing her housework and feels "better than she has for years."

Case 2.—F. D. (Patient 2), a laborer, aged 53, had suffered from dyspnea and swelling of the ankles for a month before admission. On entering the hospital he was cyanosed and orthopneic. There was pretibial edema, fluid in the right pleural cavity and the liver was enlarged. His heart showed a mitral regurgitation and auricular fibrillation. Twenty-five ounces of clear fluid was taken from the right chest, and he received altogether, 9 drams of tincture of digitalis. Seven weeks later his exercise was begun. He had twenty-six treatments and improved markedly. His cardiac efficiency increased from 150 foot-pounds to 600 foot-pounds, and his lung capacity from 70 to 110 cubic inches. He went to work immediately after discharge, and did light work steadily for six weeks and then his dyspnea and swelling of the ankles returned. His breakdown was due to his shoveling snow for six hours one night after working all day. He recovered after three weeks stay in the hospital and began work again.

Case 3.—J. T. (Patient 3), a barber, aged 28, had a history of dyspnea, swelling of the ankles and occasional pulmonary infarction extending over three years. He had a double mitral lesion and auricular fibrillation. He improved markedly in the exercises and remained well for three months. Then he had another pulmonary infarct and decompensation followed.

Three patients did not do well. In one the treatment had hardly started (but five lessons were given) when we had to stop. Another improved slowly and then retrograded. This latter patient left the hospital against advice two weeks after treatment was discontinued, but returned in ten days and died twelve hours later. The necropsy showed an enormous heart with double mitral, double tricuspid and double aortic lesions. A third patient, a woman aged 55, with chronic bronchitis, a double mitral lesion, auricular fibrillation, and rather high blood pressure, improved slightly and then retrograded. She suffers now, two months after her last treatment, from recurring hydrothorax, shortness of breath and pretibial edema.

TABLE 2.—Summary of Results in Patients with Myocarditis

No. and Name	Age	Initial Cardiac Capacity foot-pounds	Final Cardiac Capacity foot-pounds	Initial Lung Capacity cu. in	Final Lung Capacity cu. in.
1 P. R.	39	700	3,000	215	278
2 K.	64	3,000 1,400 400	4,800	172	178
3 O. B.	54	800	1,600	?	?
4 D.	56	?	?	...	...

PATIENTS WITH MYOCARDITIS

Case 4.—P. R. (Patient 1, Table 2). This was a most interesting case in a laborer, aged 39, with splendid muscular development, who contracted bronchitis on Oct. 17, 1914. For two weeks he complained of cough, weakness and shortness of breath. On Oct. 29 he lifted one end of a cask weighing 1,200 pounds. He was immediately conscious of palpitation, and on trying to work again became very short of breath. He was helped to his home and the next day was admitted to the hospital. He was orthopneic, markedly cyanosed, and his ankles were swollen. His heart was rapid, regular, and showed at the apex a gallop rhythm and systolic murmur. The lungs were clear. He was given 0.0005 of strophanthin intramuscularly and later received digitalis, 5 drams of the tincture, altogether. On November 5 he was up in a chair and the digitalis was stopped. Four days later his exercises were begun. He received thirty-four altogether, and improved remarkably, his cardiac capacity increasing from 700 foot-pounds in forty-five seconds to 3,000 foot-pounds in seventy-five seconds. Today he is doing light work and feels well.

Chart 4 represents his electrocardiograms, the first taken November 7, two days after stopping digitalis. His exercises were begun on November 9 and on December 3 the second electrocardiograms were taken. On November 7, T_1 and T_2 were directed downward. On December 3, T_1 and T_2 were directed upward. Also P was much higher on December 3 than on November 7. The initial reversal of T_1 and T_2 may have been, as A. E. Cohn has pointed out, a digitalis effect, or it may have indicated, as Einthoven holds, a damaged heart muscle. The change in the T waves following the exercises and the marked

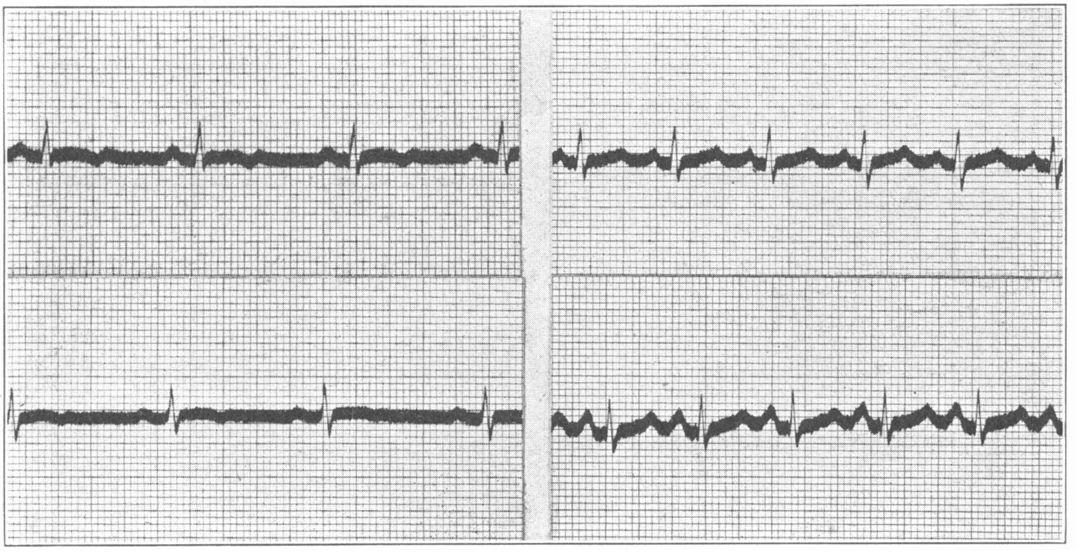

Chart 4.—Electrocardiogram of Patient P. R.. Leads 1 and 2 (at left) taken Nov. 7, 1914, two days after stopping digitalis. Leads 1 and 2 (at right) taken Dec. 3, 1914.

clinical improvement may have been due either to the exercises or to the release of the heart from digitalis influence. In regard to the significance of the increase in the height of P, it may be said that cases of compensated mitral stenosis generally show a large P wave.

Case 5.—K. (Patient 2, Table 2), was a business man, aged 64, who had no symptoms referable to his heart, but complained of occasional attacks of vertigo, acompanied by increased blood pressure. His electrocardiograms showed some heart muscle involvement, chiefly left ventricle hypertrophy. He was given a course of twenty-one exercises to see if we could influence the form of the cardiogram. The estimation of his cardiac efficiency showed a peculiar result. The first day it was 3,000 foot-pounds in sixty seconds. Two days later it was 1,400 foot-pounds in sixty seconds, and two days still later it was but 400 foot-pounds in thirty seconds. He felt perfectly well and we could not explain this surprising decrease. From that time on by carefully grading his exercise, his cardiac efficiency increased steadily until it reached 4,800 foot-pounds in sixty seconds. His electrocardiograms showed no changes.

CASE 6.—O. B. (Patient 3, Table 2), was a retired business man, aged 54, suffering from angina pectoris. He complained of shortness of breath and slight anginal attacks generally caused by walking or mental excitement. He was overweight; examination of his heart was negative and his Wassermann test was negative. His cardiac efficiency increased from 800 foot-pounds to 1,600 foot-pounds, but his angina was not improved. His electrocardiogram showed slight changes.

CASE 7.—D. (Patient 4, Table 2), was a woman, aged 56, suffering from dyspnea on exertion. She was obese, weighing 218 pounds. Her heart showed an auricular fibrillation but no murmurs. Her blood pressure ranged between 180 and 210 mm. Hg. The urine was negative. She showed no improvement after twenty-eight exercises.

PATIENTS WITH AORTIC REGURGITATION

We treated three patients with this lesion, all young men under 25 with high initial cardiac capacities and with no evidence of insufficiency except shortness of breath on exertion. They improved much

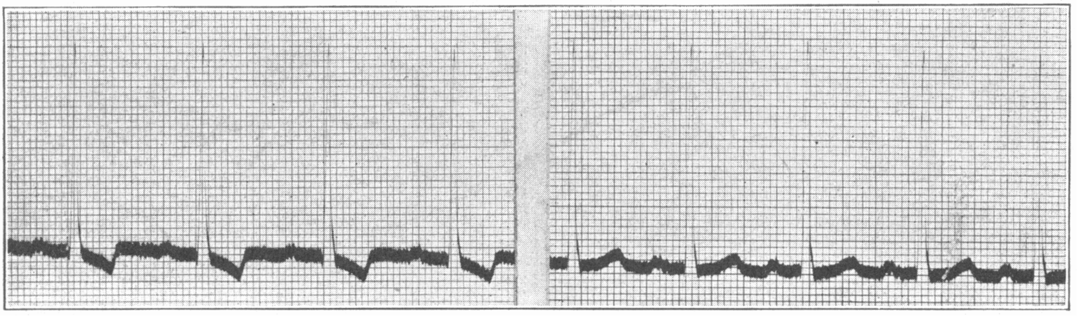

Chart 5.—Electrocardiogram in case of aortic regurgitation. Lead 1 (at left) taken before the exercise course. Lead 2 (at right) after exercise course.

more quickly than did the patients with mitral disease, feeling decidedly better after four or five treatments. Their youth, the slight degree of decompensation, and the intenser effect of exercise on the left ventricle, explain the rapidity of their improvement.

Chart 5 shows the electrocardiograms of one if these patients, taken before and after the exercise course. He had received no digitalis for months before the first electrocardiogram. It shows an inverted T_2 wave which becomes erect in the second one, at which time he showed a marked clinical improvement. R_2 and R_3 were taller in the first, than in the second electrocardiogram.

Chart 6, represents the electrocardiograms of another aortic patient taken before and after eleven treatments with exercise. They show a marked increase in the height of R_1 and an increase in the negativity of R_3. The average height of R_1 in the first was 10 mm., in the second 25 mm. R_3 in the first measured —6 mm., in the second, —15.

The electrocardiograms of a third patient showed an increase of R_2 from 18 mm. to 27 mm., and of R_3 from 8 mm. to 16 mm.

These last two patients showed an increase in the height of the R waves accompanying clinical improvement, while Patient 1 showed a decrease in the height of his R waves.

We took electrocardiograms of all our patients before and after the exercise treatment, and the four described are the only ones showing decided changes. But one patient showed changes pointing to an increased left ventricular hypertrophy.

SUMMARY OF HEART CASES

Nine of the thirteen patients treated showed marked improvement attributable apparently to the exercises, for with one exception, no other treatment was given during the exercise course. Three of the

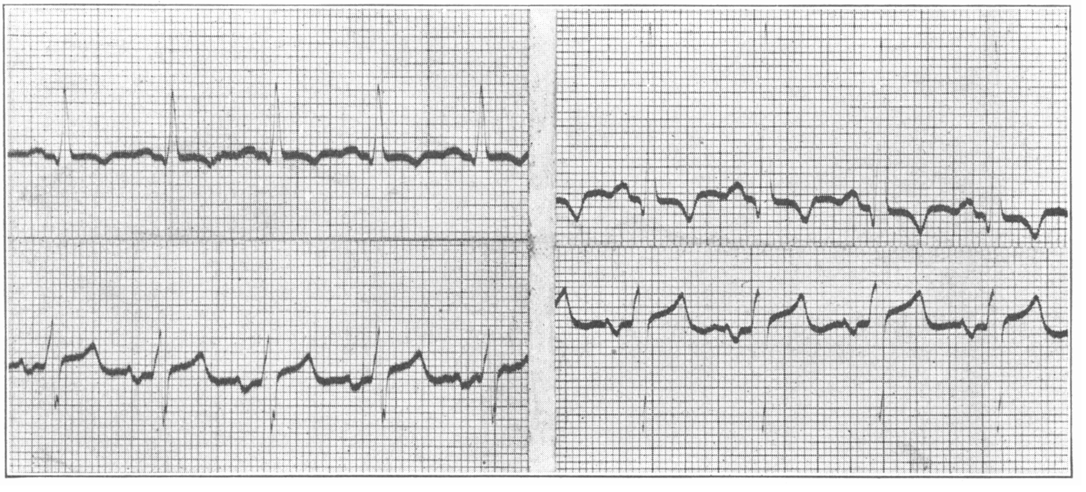

Chart 6.—Electrocardiogram in case of aortic regurgitation (at left) before exercise, and (at right) after exercise.

patients, who did not improve suffered from mitral disease with marked decompensation and showed very low initial cardiac and respiratory capacities.

PHYSIOLOGY OF EXERCISE

The marked increase in the heart rate and raising of the systemic blood pressure caused by exercise in general are undoubtedly the chief physiologic factors in producing the many beneficial effects of muscular activity. Increased ventilation of the lungs also plays an important rôle.

In our system of exercises the pulse rate is increased and the blood pressure raised for very brief periods of time. The respiration is quickened likewise for a few seconds. Whether this transient excitation of the circulatory system repeated six or seven times in the course of an hour would have any appreciable general effect on a normal person was a question which suggested itself when making our earlier experiments to secure a valid test of the cardiac efficiency. Accordingly we gave the exercises to six normal people for a month, using heavier weights, and found to our surprise that the benefit to their health (appetite, digestion, sleeping and general efficiency), was marked and unmistakable. The improvement in the heart patients must have been due to the same physiologic cause. To be more specific, the raising of pressure in the aorta improves the coronary circulation and peripherally it causes a more rapid blood flow through each organ. Also the help to the venous circulation afforded by alternate relaxation and contraction of the muscles is considerable. The lymphatic flow in particular is aided by this muscular action, thereby bringing more quickly the end-products of metabolism to the blood stream and so to the excretory organs. Also the increase in lung capacity which our exercises seem peculiarly adapted to bring about, aid materially in improving the heart action and the pulmonary circulation. This increase amounted to 36 per cent. in four of our patients with mitral disease. The psychical effect on a cardiac patient of actually doing physical work and feeling better rather than worse for it, must not be overlooked.

It is hardly probable that our results were due in any way to increasing the cardiac hypertrophy already existing in our patients. Failure to demonstrate any changes in the electrocardiograms indicating increased hypertrophy with one exception, and the absence of change in the physical signs, and the fact that the actual total working time of each patient was not over five to eight hours for the entire course, all militate against such a supposition.

COMPARISON OF OUR EXERCISES WITH RESISTANCE GYMNASTICS

Resistance gymnastics is the chief form of exercise used today in cardiac insufficiency and forms an important part of the Nauheim treatment. A comparison with our system of exercises might be of interest.

The most striking feature of the exercises we advocate is their concentration. Each series of movements lasts from thirty to one hundred and twenty seconds and is followed by a rest from five to ten minutes. It would be quite possible to spread the work over from ten to fifteen minutes so that the patient would accomplish the same number of foot-pounds in the longer period of time. This we have done but found there was a much slighter effect on the pulse and blood pressure. If the rise in blood pressure and increase in heart rate are the essential physiologic causes of the benefit derived from exercise, then our present concentrated form of exercise must be far more efficient than any other, *provided always* that we can guard against too high a blood pressure and too rapid a pulse. We feel convinced that our test, the validity of which we took such pains to establish, protects us against such danger.

On reading the description of resistance gymnastics in the last edition of Schott's "Treatment of Chronic Diseases of the Heart," one is impressed with the extreme gentleness of the exercise, and the impossibility of measuring the work performed, slight though it is. On page 253, there is a chart showing the effect of the exercises on a low blood pressure. The systolic pressure taken before exercise by palpation is 115 mm. and pulse 82. Taken after 25 minutes of exercise the pressure is 120 (by palpation) and the pulse 72. It is needless to say that a variation of 5 mm. in the systolic pressure is trivial and will be found in any normal person who is sitting quietly in a chair. Also the margin of error in taking blood pressure by palpation frequently amounts to more than 5 mm. On page 55, a chart is reproduced showing that the same exercises *reduce* high blood pressure. Before exercise the systolic blood pressure was 175 and pulse 81; after thirty minutes of exercise the pressure was 160 mm. and pulse 62. If readings are made every five minutes on a patient with hypertension, sitting quietly in a chair, they will be found to vary as much as 10 mm. If a patient talks they will vary much more.

We have given our exercises cautiously to ten patients with high blood pressures and found that invariably a very small amount of work caused a *rise* of pressure which was followed by a fall to and below the preexercise figure.

That any form of exercise can raise a low pressure and lower a high pressure, the readings being taken at synchronous periods during or after exercise, is physiologically incomprehensible.

The only reasonable explanation of the charts just described is that they represent normal variations in blood pressure and would have been found whether or not the resistance exercises were carried out.

The good results unquestionably obtained at Nauheim, must be caused by the effervescing baths, for charts published in the above-mentioned work show a more marked pressor effect from the baths than from the resistance gymnastics.

CONCLUSIONS

1. The validity of the postexercise blood-pressure test of the heart's functional capacity has been established.

2. Although our experience is limited to a small group of patients, we feel that our system of exercise affords a valuable adjunct to the means already at our disposal for treating cardiac insufficiency.

We are much indebted to Dr. H. B. Williams for doing the electrocardiographic work. We wish also to express our appreciation of the very material help rendered by Dr. H. S. Valentine and Dr. F. W. Fiedler in carrying out the work recorded above.

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