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Research paper

Exercise-Based Cardiac Rehabilitation in Patients With Coronary Heart Disease

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Abstract

Objective**:** to develop a method of physical training programs and select a physical cardiac rehabilitation program in case of severe coronary heart disease (CHD). Materials and Methods: 370 men with CHD with an average age of 54,0 ± 1,6 years were examined. 230 patients were divided into 8 groups, depending on the severity of the disease and the training mode. The complex physical rehabilitation programs included controlled exercise on a cycle ergometer with low intensity using the developed method. The control group of 140 patients did not undergo the recommended programs of physical rehabilitation. All patients underwent cycle ergometry, electrocardiography, echocardiography, blood pressure monitoring. The parameters of hemodynamics, tolerance to physical activity, lethality in the first three years were studied. Results: Inclusion of controlled exercise in the program of cardiac rehabilitation with the low-intensity cycle ergometer increased the maximum oxygen consumption by the myocardium, improved the cardiac contractile function and prognosis reducing the lethality during the first three years of observation. Combination of exercise of low and high intensity under rehabilitation programs of patients with CHD is not appropriate due to the high risk of hypertensive reactions.
Conclusions: exercise using a cycle ergometer and the developed method can be used in patients with severe CHD at the hospital and subsequent stages following hospital-based rehabilitation increasing the time but not the power of the exercise.
Early exercise activization by patients using the developed method reduces the time spent at the hospital. It is used to prevent hypokinesia complications.

Keywords: *cardiac rehabilitation, coronary heart disease, physical training, cycle ergometer training.*

1. Introduction

Coronary heart disease (CHD) morbidity remains high including people of productive age [1,2,3,4]. Significant parameters of temporary and persistent disability make improvement of complex physical rehabilitation programs involving physical training necessary [5,6,7]. Optimal and individually adjusted physical activity results in rare and weak angina attacks, improved tolerance to physical activity, increase myocardial contractility, improve maximal oxygen uptake, contribute to tissue metabolism and normalize the exchange rate of lipids [8,9,10,].
Physical activity is contraindicated in angina at rest, unstable angina, aneurysm, low threshold of pain and other signs of severe CHD. Physical rehabilitation often requires complex technical and methodological support [11,12,13]. According to the above, the pressing issue of modern cardiology includes searching new forms of physical cardiac rehabilitation, which will be not just effective but also safe for patients due to individually-based control of physical activity depending on the disease severity and functional state of the body. It is important that rehabilitation programs can be implemented both in and out of hospitals [13-15,18-21].

2. Materials and Methods

Examination and treatment results of 370 men with CHD accompanied with exertional angina and post infarction cardiosclerosis (mean age of 54.0±1.6 years) were analyzed. 230 patients whose complex rehabilitation program included controlled exercise load using on a cycle ergometer were distributed into 8 basic groups (table 1, table 2) depending on t. The control group included 140 patients (table 3) who didn't follow the recommended programs of physical rehabilitation due to their social, domestic and psychological traits. Gender and age were comparable between the groups. To participate in the programs of physical rehabilitation, the patents were divided into conditionally 'strong' and 'weak' based on case history, clinical picture and load test results. History of extensive or complicated myocardial infarction, depression of ST for over 1 mm at the last load stage, systolic blood pressure (SBP) less than 140 mm Hg at the last load stage or decreased blood pressure by 10-15%, and power of the last load stage of less than 600 kgm/min were selected as criteria for distributing into the 'strong' or 'weak' groups. When two or more above signs were present, the patient was claimed 'weak' (I, II, III, IV groups), otherwise he was 'strong'(V, VI, VII, VIII groups) [16,17,18].

Table 1: Characteristics of 'weak' groups of patients with CHD

Parameter	Groups			
	I	II	III	IV
Number of patients	42	44	26	41

Age. years		53.4±0.7	56.0±1.3	54.9±1.6	55.6±0.9
Disease duration. years		4.7±1.2	4.3±1.1	6.2±1.3	5.1±1.0
History of myocardial infarction (MI) (abs. %) including Small-focal myocardial infarction Over 1 MI and/or cardiac aneurism		25(59.5%) 2(4.8%) 9(21.4%)	22(50%) 6(13.6) 3(6.9%)	12(46.2%) 4(15.4%) 3(11.5%)	21(51.3%) 12(29.3%) 2(4.8%)
Functional class (abs. %)	1	4(9.5%)	4(9.1%)	3(11.5%)	2(5%)
	2	2(4.8%)	6(13.6%)	15(57.7%)	16(39%)
	3	25(59.5%)	24(54.6%)	8(30.8%)	23(56%)
	4	11(26.2%)	10(22.7%)	0(0%)	0(0%)
DP. max (double product) (prior to rehabilitation		234.0±9.6	220.0± 9.7	232.0 ±12.3	245.0±9.2
Wmax kg m. /min. (prior to rehabilitation)		481.0±29.9	454.0±29.4	520.0±31.0	618.0±26.3
Depression of ST≥1ммat the peak of load (abs. %) (prior to rehabilitation)		35(83%)	36(82%)	12(46.2%)	26(63.4%)
Number of exercises		27.0±1.3	28.0±1.0	26.0±2.0	26.0±0.7

Table 2: Characteristics of 'strong' groups of patients with CHD

Parameter		Groups			
		V	VI	VII	VIII
Number of patients		15	23	26	13
Age. years		52.0±2.0	53.3±2.0	52.2±1.2	54.6±1.2
Disease duration. years		4.1±1.0	3.7±0.8	5.1±0.8	3.7±1.3
History of myocardial infarction (MI) (abs. %) including Small-focal myocardial infarction Over 1 MI and/or cardiac aneurism		3(20%) 2(14%) 0(0%)	5(21.7%) 5(21.7%) 1(4.4%)	11(42.3%) 3(11.5%) 2(7.7%)	2(15.4%) 1(7.7%) 0(0%)
Functional class (abs. %)	1	8(53%)	9(39.1%)	9(34.6%)	9(69.2%)
	2	6(40%)	13(56.5%)	10(38.5%)	4(30.8%)
	3	1(7%)	1(4.4%)	7(26.9%)	0(0%)
	4	0(0%)	0(0%)	0(0%)	0(0%)
DP. max (double product) (prior to rehabilitation		300.0±6.7	320.0±12.9	280.0±12.0	323.0±13.1
Wmax kg m. /min. (prior to rehabilitation)		626.0±33.0	791.0±38.7	672.0±35.5	712.0±49.0
Depression of ST≥1ммat the peak of load (abs. %) (prior to rehabilitation)		6(40%)	2(8.8%)	5(19.2%)	2(15.4%)
Number of exercises		24.0±1.0	25.5±2.5	25.0±3.8	24.0±1.5

Table 3: Characteristics of the control group of patients with CHD

Number of patients		140
Age. years		54.0±1.6
Disease duration. years		4.8±0.8
Myocardial infarction (abs. %)	Small-focal	34(24.3%)
	Large-focal	27(19.3%)
Over 1 myocardial infarction and/or cardiac aneurysm		15(10.7%)
No myocardial infarction		64(45.7%)
Functional class (abs, %)	1	32(23%)
	2	28(20%)
	3	63(45%)
	4	17(12%)
DP. max (double product) (prior to rehabilitation		271.0±10.6
Wmaxkgm. /min. (prior to rehabilitation)		620.0±32.0
Depression of ST≥1ммat the peak of load (abs. %) (prior to rehabilitation)		42(30%)
Number of exercises		No

Patients from the basic groups underwent an exercise tolerance test prior to and after training, patients from the control group had the test once. The double product (DP) which is the product of heart rate (HR) and systolic blood pressure (SBP) (HR x SBP/100), HR and SBP at maximum load (MHR and MSBP), Wmax maximum load power (kgm/min) were analyzed. The mentioned parameters were registered and analyzed in incremental cycle ergometer exercise in the sitting position: step duration is 5 min, rest pause duration is 5 min., 1 step power is 25 W with every subsequent step increasing by 25 W whereas in patients of functional classes 3 and 4 step 1 amounted to 10 W. The study was terminated in case of pains, pronounced dyspnea, ST segment depression of at least 1 mm and over, SBP decrease by 10–15% from baseline and general fatigue. HR (beats per minute), BP (mm Hg), 12-lead ECG were registered, and indicators of central hemodynamics were determined at the peak of load, during every minute of load and rehabilitation periods. Systolic volume (SV), cardiac work (CW), total peripheral vascular resistance (TPVR), mean blood pressure (MBP) as diastolic blood pressure plus 1/3 of pulse pressure were calculated.

The left ventricular cavity was measured using echocardiography in the supine position. End-systolic (ES) and end-diastolic (ED) dimensions of the left ventricle and left ventricular AP diameter shortening were determined.

Describing the developed method of low intensity training with cycle ergometers. Patients received training with a cycle ergometer in the supine position. Training load power was 90-120 kgm/min (15-20 W). Pedal rotation rate was 55-65 rotations per minute. Pedal axis height above the couch level was 2/3 of the entire femur length. Individual intensity of training load was determined using the HR training range, which amounted to 50-60% for *low-intensity exercise using a cycle ergometer*. For *high-intensity exercise using a cycle ergometer*, it was 75-85% of maximum HR determined on the individual basis according to the result of ECG-controlled initial loading test. The training activity included a warming up, basic part and warm-down.

5-minute warming-up was 60 kgm/min (10 W), 30-minute basic part was 90-120 kgm/min (15-20 W), 5-minute warm-down took place in the lack of resistance in pedaling. In any training regimen, the total duration was 40 minutes.

Characteristics of training regimen. Programs and regimen of physical training are presented in Table 4.

Table 4: Physical exercise regimen in groups

Group	Type of physical exercises	Exercise intensity. HR training range	Number of exercises
'Weak' groups			
I	***Low-intensity cycle exercise in the prone*** position	50-60% of HR max	3 times per week (every alternate day)
II	***Low-intensity cycle exercise in the prone*** position	50-60% of HR max	6 times per week (daily and every alternate day without an exercise)
III	Mixed cycle exercise in the prone position: 2 low-intensity exercises and 1 high-intensity exercise	50-60% of HR max 75-85% of HR max	3 times per week (every alternate day)
IV	Controlled walking	Average walking rhythm (50-60) steps per minute	Daily
'Strong' groups			
V	***Low-intensity cycle exercise in the prone*** position	50-60% of HR max	3 times per week (every alternate day)
VI	***High-intensity cycle exercise in sitting*** position	75-85% of HR max	3 times per week (every alternate day)
VII	Mixed cycle exercise in the prone position: 2 low-intensity exercises 1 high-intensity exercise	50-60% of HR max 75-85% of HR max	3 times per week (every alternate day)
VIII	Controlled walking	Average walking rhythm (50-60) steps per minute	Daily

While training patients from groups I and II (with more severe clinical and functional condition), they used a developed method of low intensity cycle training with the training range of 50-60% of HR max in the supine position. Group I had training 3 times a week every alternate day. Group II had training 6 times a week. Some patients with a very weak functional condition are given supplementary doses higher than the maintenance dose if they have cardiac pains during training.

'Strong' patients from group V had low-intensity cycle training with the training range of 50-60% of HR maxin the supine position every alternate day. The patients required no additional drug-induced support of training load.

Patients from group IV with milder signs and higher tolerance to physical load had an intense cycle training with the training range of 75-85% of HR max 3 times a week every alternate day.

Groups III and VII had training 3 times per week every alternate day such as two low intensity exercises with the training range of 50-60% of HR max and every third intense exercise with the training range of 75-85% of HR max. During the intense training, some patients were given nitrates to improve load tolerance. Patients from group III with a more severe course of the disease and 'weak' functional condition needed it more frequently.

Groups IV and VIII had moderate (50-60 steps per minute) controlled walking daily as a method of physical rehabilitation, the exercise lasted 30 minutes [1]. During the study, the effectiveness of the developed method of exercising using a cycle ergometer with various intensities, structures and exercise frequency.

3. Results

Changes in measures based on the data of the final stress testing are presented in table 5. Groups I and II had similar and significant increase of DP, MHR, whereas growth of peak systolic blood pressure (MSBP) wasn't statistically reliable.

Table 5: Dynamics of the parameters that characterize exercise tolerance

Group No.	DP (M±m)	P	MHR (M±m)	P	MSBP (M±m)	P	Wkgm/min (M±m)	P
I	35.0±3.5	≤0.01	14.0±2.5	≤0.01	5.0±3.0	≥0.05	162.0±14.3	≤0.001
II	30.8±4.0	≤0.01	11.6±1.6	≤0.01	6.4±3.3	≥0.05	135.0±12.7	≤0.001
III	33.4±8.3	≤0.01	9.5±2.4	≤0.05	11.6±4.0	≤0.05	92.4±16.8	≤0.01
IV	2.2±6.4	≥0.01	-0.1±2.2	>0.05	5.5±3.6	≥0.05	5.9±17.9	≥0.01
V	38.7±7.8	≤0.01	15.3±2.3	≤0.01	5.3±3.3	≥0.05	120.0±36.2	≤0.01
VI	14.0±8.5	≥0.01	6.0±3.0	>0.05	-2.6±2.8	≥0.05	96.0±13.2	≤0.01
VII	33.3±7.8	≤0.01	8.3±2.6	≤0.05	11.4±5.1	≤0.05	104.9±15.6	≤0.01
VIII	-29.8±16.5	≥0.01	-7.5±3.8	>0.05	-10.3±6.6	≥0.05	23.0±23.0	≥0.01

Notice: P – Student's t-test confidence

In Group III, growth of DP and Wmax was similar to one in Groups I and II, whereas growth of MHR was less and MSBP was higher than in groups I and II. Thus, when using the method of low-intensity exercise using a cycle ergometer, the DP growth was due to improved MSBP values. When using the mixed method, Group III had improved MHR and MSBP (2 low-intensity trainings and 1 high-intensity training). It must be noted that during the initial load test the rate of found hypertensive reactions to physical load in Groups I, II and III was 40%, it dropped to 9% after a number of exercises in Groups I and II, and amounted to 19% in Group III.

A higher percentage of hypertensive reactions in group III was associated with the inclusion of highly intense exercises resulting in the growth of MSBP.

No significant changes in measures were seen in group IV engaged in terrenkur. Slight positive trend was seen in some patients without ST segment depression at the peak of the initial loading test whereas patients with ST segment depression had more frequent worsening both in the clinical and functional condition.

A significant growth of DP, MHR, W max was seen in patients from functionally 'strong' group V engaged in low-intensity exercise, whereas changes in the MSBP was insignificant. Group IV had a significant growth of Wmax without dynamics of DP, MHR and MSBP. Groups VII faced a significant increase of DP, MHR, MSBP. As compared with group III, who followed the same program, but had significantly more severe clinical and functional condition prior to the training, no difference in the change of the analyzed parameters was found. The frequency and change in the

rate of load hypertension reactions was comparable between groups V, VII and I, II, III.

In group VIII, they had an inaccurate negative dynamic of DP, MHR, MSBP; Wmax had no dynamics. No difference was found in the change of the analyzed parameters among groups IV and VIII. However, the difference between clinical and functional state was significant and accurate prior to training.

Echocardiography-based study results. There was no echocardiography-based difference between the analyzed parameters among different groups prior to training. Thus, in the examined groups, echocardiographic parameters at rest didn't display the functional condition of patients. Comparison of the change in echocardiographic parameters among groups prior to and following training reveals as follows. The functionally 'weak' groups (I, II, III, IV) had a significant decrease of EDD by 0.24±0,08; $p \leq 0.01$ and a significant decrease of ESD by 0.56±0.1; $p \leq 0.00$. It indicates better contractility of left ventricular myocardium as its size decreases.

The functionally 'strong' groups (V to VIII) had increased EDD (0.17±0.9; $p \leq 0.1$) with an insignificant change of ESD (0.02±0,16; $p > 0,05$). No significant change was found in group VI with intense training. Training of low and high intensity combined (groups III and VII) resulted in positive dynamics in 'strong' group VII only. During the 1st year of observation, lethality was 2% in all basic groups of patients using the method and 7.9% in the control group ($p \leq 0.05$). During two years of observation, lethality was 4% in all basic groups of patients using the method and 15% in the control group ($p \leq 0.05$).

4. Discussion and Conclusion

The proposed method of training using low-intensity cycle ergometer in the supine position improved the functional reserves of the cardiovascular system against the background of maximum performed capacity.

This effect depended not on the initial functional condition of a patient (groups I and V). It also depended on the total number of procedures but not on their rate. Having training every day (group II) and three times a day (groups I and IV) produced a similar effect in a similar total number of procedures. Thus, this method can be used in hospitals and health camps.

No significant change of the parameters was found in patients from the functionally weak group IV who had controlled walking. Results for patients from group VIII with decreased parameters of MHR, MSBP and DP against the background of practically not changed maximal capacity display economization of cardiac activity in the 'strong' group.

The rationale for combination of low-intensity and high-intensity exercises was examined in groups III and VII. Though the combination leads to the growth of DP and Wmax, it is often the reason for the hypertensive reaction to the exercise which is an unfavourable sign.

Examination of the analyzed parameters for patients from group VI with a good functional condition who had high-intensity exercise using a cycle ergometer in the sitting position shows that the parameters of MHR, MSBP, DP are increased against the background of improved maximum load capacity. Thus, the myocardial contractility is improved in the lack of cardiac activity economization [16,17,18].

In our opinion, decreased lethality following training of low intensity is due to improved myocardial contractility against the background of increasing functional reserves of the cardiovascular system.

5. Conclusion

controlled physical exercises belong to an important component of cardiac rehabilitation programs in CDH;

Controlled low-intensity exercises using a cycle ergometer and the developed method in patients with CDH increase the myocardial contractility and improve the disease prognosis reducing lethality during the first three years of observation; low-intensity exercises using a cycle ergometer can be used in patients with severe signs of CDH;

combination of low-intensity and high-intensity exercises using a cycle ergometer in the rehabilitation programs of patients with CDH is unnecessary due to the high risk of hypertension and lack of positive influence on the prognosis; controlled walking improves economic efficiency of the cardiovascular system without a significant increase of the myocardial contractility.

Early load activization of patients using a cycle ergometer and developed method reduces the period of stay at a hospital. It prevents hypokinesia complications and promotes faster rehabilitation.

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