The safety assessment of isokinetic training in patient with heart failure

Ocena bezpieczeństwa treningu oporowego izokinetycznego u chorych z niewydolnością serca

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SUMMARY

Introduction: Among the scientific reports of the beneficial effect of endurance and resistance exercises there is little information on programming and safety of isokinetic resistance training used in patient with heart failure (HF).
Material and methods: 18 males with stable systolic HF were assigned into two groups: S-strenght training, W-endurance training and were subjected to 12-week pilot isokinetic training with a gradually increasing load. Analyzed: subjective and objective patients' responses to the effort, heart rate, systolic and diastolic blood pressure before and directly after the effort and after 5 minutes of the restitution (HR, sBP, dBP) in each of the exercising group for 12 weeks (1-12W).
Results: The highest increase of the exercise parameters in group S in comparison to the output value of the day: HR – 10 beats per minute (4W), sBP –12 mmHg (10W), dBP- 8 mmHg (11W); in group W: HR – 11 bpm (2W), sBP – 18 mmHg (2W), dBP – 8 mmHg(12W).
In weeks 2 and 3 there was a more significant response to the load in group W: the sBP increase of 18 and 13 mmHg ($p<0,05$). In the course of 12 weeks, in both groups the significant decrease of parameters was documented ($p<0,05$).
Conclusions: The normal cardiovascular response to exercise, achieved an hypotensive effect to isokinetic exercise. The lack of incident in the 18 male participants in the course of training in both groups confirms the safety, efficiency and expediency of the method.

Key words: heart failure, cardiac rehabilitation, isokinetic training, safety of the training

STRESZCZENIE

Wstęp: Wśród doniesień naukowych o korzystnym wpływie ćwiczeń oporowych u pacjentów z niewydolnością serca (NS) niewiele jest informacji dotyczących bezpieczeństwa treningu oporowego izokinetycznego.
Materiał i metody: 18 mężczyzn ze stabilną, skurczową NS (51-78 lat, LVEF% 20-40), podzielono na 2 grupy: S – trening siłowy, W – trening wytrzymałości siłowej i poddano 12-tygodniowemu pilotażowemu treningowi izokinetycznemu, ze stopniowo wzrastającym obciążeniem. W celu oceny bezpieczeństwa treningu izokinetycznego analizowano wartości tętna, ciśnienia tętniczego skurczowego oraz rozkurczowego krwi, przed i bezpośrednio po wysiłku (HR, sBP, dBP) oraz po 5 minutach restytucji, w każdej z ćwiczących grup, w okresie 12 tygodni (1-12 T).
Wyniki: Najwyższy przyrost parametrów wysiłkowych w grupie S w porównaniu do wartości wyjściowych danego dnia: HR – 10ud/min (4T), sBP – 12 mmHg(10T), dBP – 8 mmHg (11T); w grupie W: HR -11ud/min (2T),sBP -8mmHg (2T), dBP – 8 mmHg (12T). W 2 i 3 tygodniu większa istotna reakcja na obciążenie wystąpiła w grupie W: wzrost sBP o 18 i 13 mmHg ($p<0,05$). W przebiegu 12-tygodni w obu grupach wykazano istotne obniżenie się parametrów hemodynamicznych pomimo wzrastającego obciążenia ($p<0,05$).

Wnioski: Prawidłowa reakcja układu krążenia na wysiłek, uzyskany efekt hipotensyjny ćwiczeń izokinetycznych i bezincydentalny przebieg treningu w obu ćwiczących grupach, potwierdzają bezpieczeństwo, skuteczność i celowość zastosowanej metody.

Słowa kluczowe: niewydolność serca, rehabilitacja kardiologiczna, trening izokinetyczny, bezpieczeństwo treningu

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INTRODUCTION

Contemporary rehabilitation takes into account mainly the atrophy and weakness of skeletal muscles in planning training programs for patients with heart failure (HF).

Beneficial effects of physical training, including resistance training, in patients with heart failure (HF) was documented in literature many times [1-5]. Considered as safe and effective, properly planned resistance exercises can improve the patients' muscle strength and endurance, increase the cardiovascular efficiency, reduce pro-inflammatory enzyme concentration and hyperactivity of the autonomic system. It has been found to improve frame of well being [4, 6, 7].

In a stable HF patient, the most commonly used form of training is the supervised, constant or interval endurance training (aerobic) with resistance elements, including dynamic resistance training- practiced on a specialized equipment and the use of weights, dumbbells, elastic bands and supplementary the breathing-relaxation training [4, 8, 9, 10].

There is less formal information relating to isokinetic resistance exercises. The reason can be expensive equipment, low bandwidth, the need for a complicated use of a computer program requiring trained personnel and precise interpretation, also the lack of unequivocal safety and programming guidelines of this exercise form in patients with cardiovascular disease. There are few reports which proved that both short-term tests evaluating the strength and endurance abilities of skeletal muscle under isokinetic conditions and traditional physical exercise with supervised resistance training are not harmful to the circulatory system [5, 11, 12, 13, 14].

There is a need to use the information available to develop a theory for the use of isokinetic exercise in rehabilitation using the strength and endurance improvements noted within the guidelines of resistance training.

METHODS

The project has obtained the consent of Bioethics Committees of University School of Physical Education in Wroclaw and Wroclaw Medical University and the approval and funding from the Polish Ministry of Science and Higher Education.

This study included 18 males with stable systolic HF of ischemic etiology, treated at the Clinic of Cardiology of the Center for Heart Disease and Heart Failure Outpatient Clinic by the 4th Military Academic Hospital in Wroclaw. The participants were randomly assigned into two subgroups: group S: qualified to strength training (n=9), group W: qualified to endurance training (n=9) (Tab. 1).

Inclusion criteria were: male gender, age 50-80 years, NYHA I/II/III, LVEF%<45%, stable course of disease during the recent month, optimal pharmacotherapy. Exclusion criteria were: NYHA III/IV and IV, unstable course of disease within the last 3 months, angina pectoris limiting exercise, paroxymal atrial fibrillation, dissecting aneurysm of aorta or the left ventricle, pulmonary embolism, deep vein thromboembolism, valvular insufficiency qualifying to cardiosurgical treatment, uncompensated metabolic disorders, severe renal failure, dysfunctions of skeletal and joint system and/or nervous system limiting motor abilities, systemic and fever illness, lack of consent for the examination.

Men with HF participating in the research project were treated pharmacologically according to the recommendations of the European Society of Cardiology [15].

Prior to the study and training, the subjects were familiarized with all the procedures and gave written, informed consent to participate in the experiment. Each patient was subjected to a thorough medical assessment, taking into account the history and physical and clinical examination and physiotherapy examination (resting EKG, echocardiographic trial, spiroergometric test, 6-minute walk test - 6MWT, the function of the flexors and the extensors muscles of the knee joint in both legs under isokinetic conditions (180^0/s and 60^0/s) also psychological examination.

Functional examination of the knee joint extensors and flexors under isokinetic conditions and 12-week resistance training was performed with an aid of Biodex System 3 Multi Joint isokinetic dynamometr (Biodex Medical System, NY- USA). Each participant was seated in the test chair and the examined thigh, along with pelvis and thorax, were stabilized with belts. The extent of knee flexion and extension was determined individually, and both limbs were weighted at a 30^o flexion. Each test was proceeded by a warm-up in the form of three submaximal, and one maximal movements.

Each participant completed a 12-week isokinetic resistance training program(including 3 sessions per week, 45-60 minutes each) comprised of preliminary phase (determination of hemodynamic parameters, instructions, respiratory and stretching exercises), main phase (strength/ endurance training of bilateral knee joint extensors and

Table 1. The characteristics of male heart failure patients participating in the study.

Parameter		Group			
		Strength (n = 9)		Endourance (n = 9)	
		$\bar{x} \pm s$			
age [years]		65 ± 6		67 ± 9	
BMI [kg/m²]		31 ± 5		27 ± 2	
LVEF [%]		33 ± 4		33 ± 7	
peak VO_2 [ml/kg/min]		15.9 ± 3		16.3 ± 3	
Feature N		Strength (n = 9)		Endourance (n = 9)	
		%	N	%	%
NYHA Class	I	0	0	3	33
	II	6	67	5	56
	III	3	33	1	11
Hypertention by WHO	II	6	86	7	88
	I	1	14	1	12
Miocardial infarction		5	56	7	78
PCI/PTCA	1	4	44	3	33
	2	1	11	1	11
CABG		3	33	4	44
Diabetes		2	22	4	44
Asthma/COPD		2	22	1	11
Atrial fibrillation (CRT)		3	33	2	22

flexors with 2-minute restitution between consecutive series, determination of hemodynamic parameters) and a final phase (determination of hemodynamic parameters, respiratory and relaxation exercises, fatigue and dyspnea assessment with the Borg scale). The distribution of training burden on group S and W amounted to 120-90-60°/s and 300-240-180°/s respectively.

The training protocol was designed and implemented by the physiotherapy team from the Faculty of Physiotherapy of the University School of Physical Education in Wroclaw.

The examination and training took place under medical supervision. The heart rate and blood pressure of each participant was monitored for the patient's safety in following the cardiac rehabilitation guidelines [16]. The maximum heart rate (HRmax) was used as the basic parameter limiting the maximum safe intensity of physical exercise. The HRmax was determined individually for each patient during CPX. The safe heart rate limits during exercise were considered as follows: up to 50% of HRmax during training weeks 1-4, up to 60% of HRmax in weeks 5-8, and up to 70% of HRmax in weeks 9-12. The maximum limit of subjective fatigue rate declared during training was set at 7–8 points of the simplified 10-point Borg scale [17].

Statistical methods: All statistical calculations were performed using Statistica 8 PL software package (StatSoft®). Continuous variables were presented as arithmetic means and standard deviations, and categorical variables as frequency distributions. The time variability of changes was analyzed by means of the χ^2 test. The significance of differences in mean values of parameters determined in two independent groups was tested with the Mann-Whitney U test. The significance of all tests was assumed at $p<0.05$.

RESULTS

The 12-week isokinetic resistance training was completed by all 18 participants. None of these patients had worsening HF in the course of training. None of the participants registered any adverse reaction to the effort such as palpitation, angina pain, shortness of breath inadequate to the effort, fainting etcetera. There were isolated cases of decrease in blood pressure or heart rate recorded as a result of the exercises. These values did not exceed established safety standards. None of individual training was interrupted due to health reasons. The subjective fatigue assessment declared after physical exertion was set at minimum 3 and maximum 8 of the Borg scale, however, the higher ratings were documented in the group W.

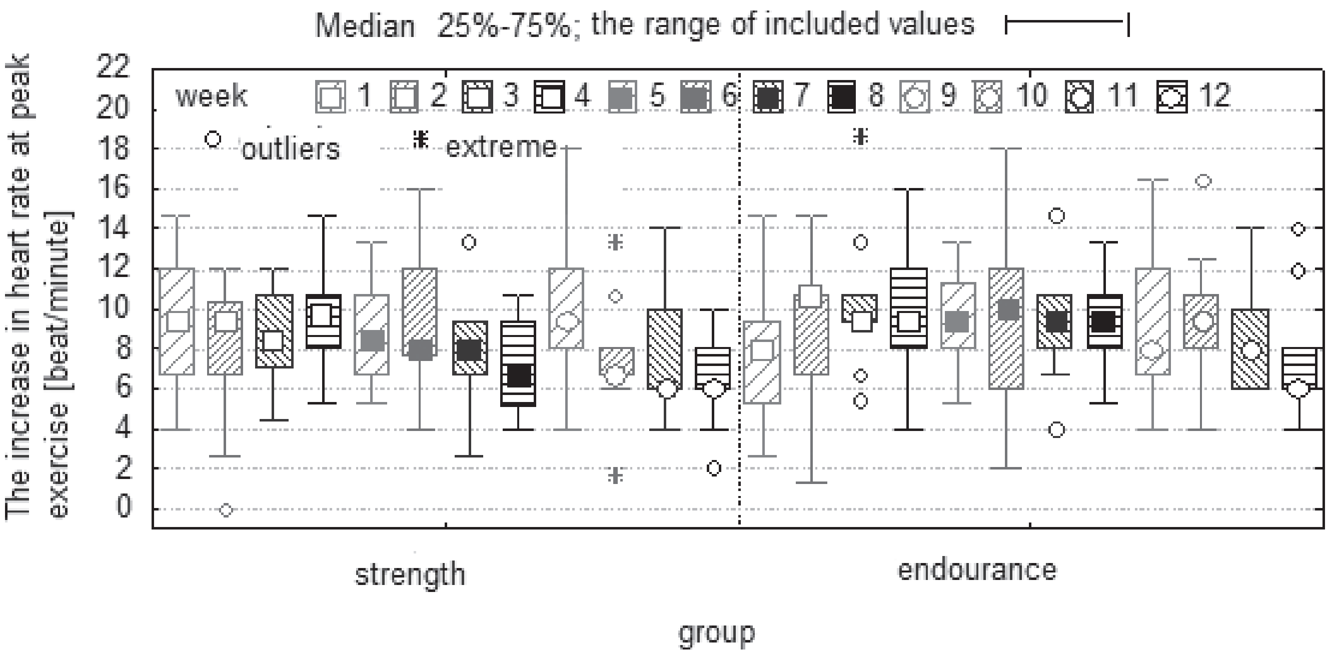

Figure 1. The increase in heart rate at peak exercise in group S and W, in the course of the 12-week training.

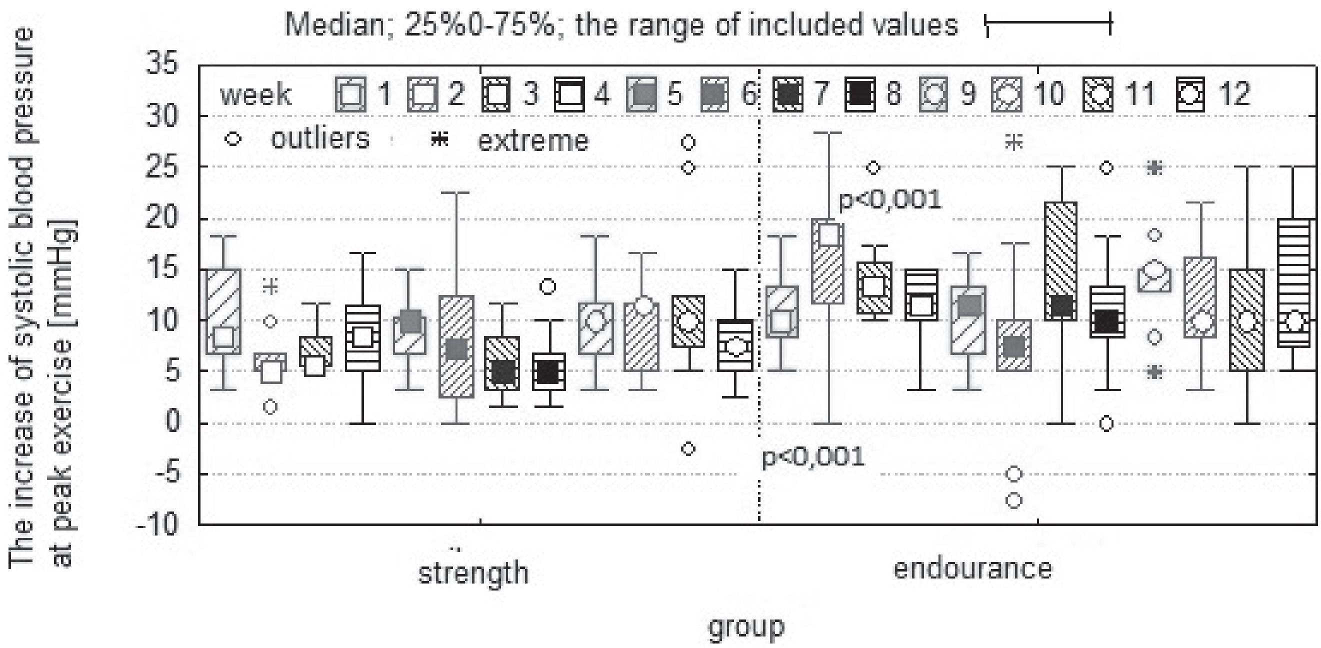

Figure 2. The increase of systolic blood pressure at peak exercise in group S and W, in the course of 12-week training.

In the study, weekly median values of heart rate, blood pressure, systolic and diastolic blood pressure before and immediately after finished effort in each of the exercising group was assessed. The analysis included the shaping of the hemodynamic parameters in response to physical effort.

Based on the weekly median values, including hemodynamic parameters changes during training units, it was noted that the maximum increase in heart rate at peak exercise was in group S 10 beats/minute and in group W 11 beats/minute. The change was observed in week 4 of the strength training and also in week 2 of the endurance training (Fig. 1).

The largest systolic blood pressure increase of 12 was noted in week 10 in group S, and in the group W in training week 2 it was 18 mmHg. In turn, diastolic blood pressure increased the most after effort in group S in week 11 (8 mmHg), and in group W in week 12 of training (8 mmHg) (Fig. 2, 3).

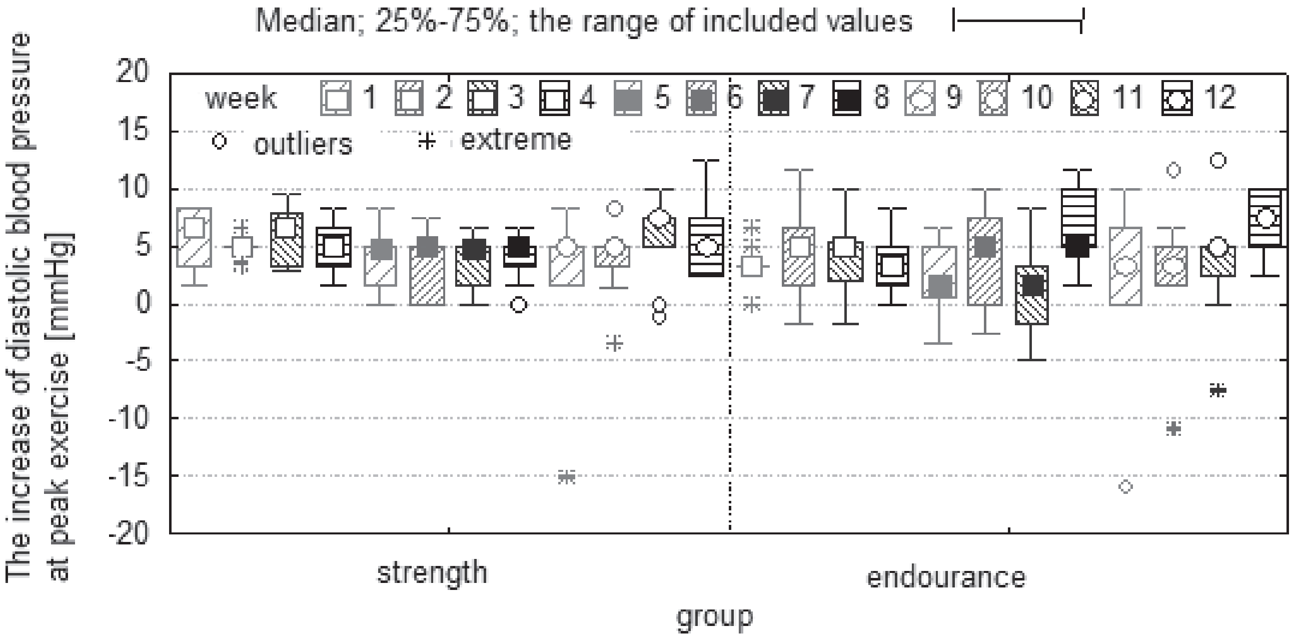

Figure 3. The increase of diastolic blood pressure at peak exercise in groups S and W, in the course of 12-week training.

Table 2. The assessment of hemodynamic parameters variability in the groups S and W during the 12-weeks training using the χ2 test (indicated in bold probability <0.05)

Parameter $\bar{x} \pm s$		Group S		Group W	
		$\bar{x} \pm s$	P	$\bar{x} \pm s$	P
Heart rate [beats/minute]	reasting	65.0±5	0.073	64.8±5	0.001
	reserve	73.4±6	0.071	74.1±8	0.208
Heart rate change [beats/minute]	reasting	-3.8±6	0.101	-2.9±4	0.014
	reserve	-5.1±9	0.061	-1.5±7	0.001
Systolic blood pressure [mmHg]	reasting	115.4±11	0.000	113.5±12	0.000
	reserve	123.8±13	0.000	125.6±16	0.001
Diastolic blood pressure [mmHg]	reasting	74.5±7	0.000	68.8±5	0.001
	reserve	79.0±7	0.000	72.5±5	0.126
Systolic blood pressure change [mmHg]	reasting	-7.4±9	0.000	-5.4±8	0.033
	reserve	-9.8±13	0.000	-4.6±8	0.002
Diastolic blood pressure change [mmHg]	reasting	-7.0±7	0.006	-3.5±4	0.006
	reserve	-8.2±8	0.000	-1.8±6	0.037

When comparing the changes of hemodynamic parameters in both training groups it appeared that in week 2 and in week 3 of program bigger reaction in patients for loading was in group W, in which there was the increase in systolic blood pressure of 18 (p=0.001) and 13 mmHg (p=0.001) to the measured resting values.

Moreover, in the course of 12 weeks in the observation of both groups, a relevant reduction in resting heart rate, systolic and diastolic blood pressure values, and also significant lower values of these parameters at peak exercise, despite an increasing load was found (Tab. 2).

DISCUSSION

The correct cardiovascular hemodynamic response is one of the condition for patients with HF safety rehabilitation. Bearing in mind that till the 1980's (eighties of the twentieth century) patients with HF were excluded from rehabilitation. The detailed inspection of subjective and objective body reactions for the training load is very important in contemporary ambulatory programs. To provide an ideal positive hemodynamic reaction, the monitoring of the response of the left ventricle to physical effort, good frame of well being and the sense of security during training, the monitoring of blood pressure, heart rate and heart function is indicated [9,18].

In the case of HF patients, the process of improving cardio-respiratory and muscle efficiency should be implemented gradually, in accordance with the rules of cardiac rehabilitation. A minimal training load may not bring the expected results, while excessive exercise, inadequate to patient's ability, can lead to the exacerbation of clinical status, cardiac decompensation of the circulatory system, overloading of the motor system, and an unfavorable affect on their mental status. Especially in resistance training, in which the load may be a provocative factor in arrhythmias, excessive increase or decrease of heart rate and/or blood pressure or dyspnoea, the attention should be focused on supervision, frequent monitoring of the parameters, the observation and verbal contact with the patient.

The rehabilitation program described in the study was adapted individually to the patient and had the possibility of correction according to psychophysical changes. Each patient practiced individually. The physiotherapist was focused on the patient and oversaw the hemodynamic parameters changes and well-being of the patients. They also supervised the exercise form in main phase and the practiced exercises in the preliminary and final phases with the patient.

The hemodynamic responses and subjective answers to a given load was not cause for concern and did not deviate from the norm in the course of 12 weeks of used training.

No distressing symptoms were noted in the patients beyond the physiological fatigue and muscle pain characteristic for the long-term effort with the load. None of the participants had dyspnoea or HF exacerbation in the course of training. The increased heart rate and blood pressure at peak exercise did not exceed the training's limit values according to the PTK Standards , which was determined for each patient during cardiac stress test in strength and endurance training group [9].

The reduction of resting hemodynamic parameters in the course of 12 weeks and less hemodynamic response to load can indicate a positive adaptation of the cardiovascular system to this type of physical training.

Patients declared their subjective fatigue during the exercise. The rate at 6-8 points of 10 in a simplified Borg scale , which is evidence that the exercise practiced by them was not assessed as too light and fatigue-free. It is likely that a large positive significance can be related to 2-minute restitution breaks combined with breathing exercises used between sets at the each stage of training.

The safety of isokinetic exercises also was confirmed in studies by other authors [11,19]. Degache et al. [19] controlled the heart rate in response to the isokinetic effort recommending patients with HF making 3 movements of straightening and bending the lower limb in the knee joint at a speed of 60°/s, 90°/s, 180°/s and 240°/s, than 20 movements at a speed of 240°/s. The highest heart rate increase to 117,6+/- 22 beats/minute occurred in the last task, however the value was lower than the value recorded during spiro-ergometric tests. It was stressed that due to the nature of endurance exercise at a speed of 240°/s, it should be offered only to patients without arrhythmias and ischemic symptoms. However, presented in the training article program, it shows that the load imposed on the patient, including those with a strength-endurance nature, do not cause disorders in the cardiovascular system and are safe and well tolerated by patients. Just as in the previously mentioned studies, the authors suggested the need to formulate cardiac rehabilitation uniform rules for testing and training under isokinetic conditions.

In turn, in the Minotti et al publication [20] examining the effectiveness of aerobic training in 16 patients with HF in NYHA Class I-IV assessed also the safety of testing muscles under isokinetic conditions. Each patient during the test, which contained 15 repetitions of bending and straightening the knee joints in both lower limbs in strength conditions 90°/s and in endurance conditions 180°/s, achieved the regular heart rate increasing properly to the effort. In the test at 90°/s recorded the average increase in heart rate of 13 beats/minute and at 180°/s of 10 beats/minute. The authors suggest, however, that a positive response and a slight change in hemodynamic parameters may be the result of reduced muscle strength in patients with HF and therefore inaccurate task execution, not reflecting the real capacity of muscle and thus a small involvement by the circulatory system.

In the applied project nevertheless slight changes of hemodynamic parameters were achieved. These changes were analyzed not only after one study but after the 12-week training period. It can be assumed that the dynamic, alternating movements of the flexor and extensor muscle groups of the knee joint protected muscle groups against overload, and the regular physical activity provided a gradual reduction in vascular resistance, without excessive hemodynamic response. The reason of maintained hemodynamic parameters changes in safety limits could be a comfortable, resting and isolated sitting position during the training, as well as a beneficial nature of the resistance exercise in isokinetic conditions for the patients with HF.

The adaptive changes of the cardio-respiratory system are particularly relevant for the patients with HF. The carried out experiment confirmed that, in accordance with the principles of exercise physiology, properly selected physical training can result in heart rate decrease and also a decrease in blood pressure, both at rest and in response to submaximal physical effort. The decrease of resting heart rate is considered as the increase of the functional heart reserve. The level of systolic and diastolic blood pressure is reduced because of the intensification of the vagus nerve tension under the influence of the physical exercises which leads to arterioles enlargement, reducing the load on the blood vessels' walls [16].

CONCLUSIONS

The resultant hypotensive effect of exercise, the improvement of hemodynamic heart efficiency of isokinetic training course and lack of incidents, in both exercise groups, confirms the safety, efficiency and desirability of presented method in patients with HF. The small sample size of the trial connected with the pilot character of the study suggests the need for repetition of this training type on a larger population maintaining similar safety principles.

It should be remembered that the systematical, supervised rehabilitation of the patients with HF can attenuate disease symptoms and can motivate persons to participate in everyday physical activity and improve well-being during illness.

Ethical Approval: The project has obtained the consent of Bioethics Committees of University School of Physical Education in Wroclaw and Wroclaw Medical University (KB – 182/2006).

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