INFLUENCE OF THE EXERCISE-BASED REHABILITATION ON THE MORPHOFUNCTIONAL CONDITION OF THE PATIENTS OF MODERATE AND HIGH RISK WITH CORONARY HEART DISEASE

VPLYV CVIČEBNEJ REHABILITÁCIE NA MORFOFUNKČNÝ STAV PACIENTOV SO STREDNÝM A VYSOKÝM RIZIKOM ISCHEMICKEJ CHOROBY SRDCA

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ABSTRACT

Background: Telecardiorehabilitation (TCR) programs can address the low participation of patients with coronary heart disease (CHD) in cardiorehabilitation programs. However, most data on the effectiveness of TCR programs are based on studies involving low-risk patients. This necessitates the analysis of the impact of TCR programs on the condition of patients in moderate and high-risk groups.

Objectives: To research the influence of exercise-based rehabilitation on the morphofunctional condition of moderate and high-risk patients with CHD.

Research sample and method: The materials were obtained during the examination of 66 patients with CHD. Echocardiography was used to assess the structural and functional condition of the cardiovascular system. Surveys of all participants were performed at the beginning of the study and after three months.

Results: According to the echocardiographic study, after three months of training, patients in the intervention groups showed a statistically significant improvement in myocardial contractility, as evidenced by an increase in the ejection fraction, and a decrease in end-diastolic dimension, end-systolic dimension, end-systolic and end-diastolic left ventricular volumes.

Conclusions: The hybrid model of exercise-based rehabilitation (controlled classes in combination with home-based exercise using telerehabilitation technologies) showed a moderately positive effect on the morphofunctional condition of the left ventricle of patients with CHD, classified as moderate and high risk. The results obtained in the intervention groups did not have a statistically significant difference compared with the control groups' effects, which used a center-based model of cardiorehabilitation.

Key words: Coronary heart disease. Exercise-based rehabilitation. Physical therapy. Telecardiorehabilitation.

ABSTRAKT

Východiská: Telekardiorehabilitačné (TKR) programy môžu riešiť nízku účasť pacientov s ischemickou chorobou srdca (ICHS) na kardiorehabilitačných programoch. Väčšina údajov o účinnosti programov TKR je však založená na štúdiách zahŕňajúcich pacientov s nízkym rizikom. To si vyžaduje analýzu vplyvu programov TKR na stav pacientov v stredne a vysoko rizikových skupinách.

Ciele: Skúmať vplyv pohybovej rehabilitácie na morfofunkčný stav stredne a vysoko rizikových pacientov s ICHS.

Súbor a metódy: Dáta boli získané pri vyšetrení 66 pacientov s ICHS. Echokardiografia bola použitá na posúdenie štrukturálneho a funkčného stavu kardiovaskulárneho systému. Prieskumy všetkých účastníkov sa uskutočnili na začiatku štúdie a po troch mesiacoch.

Výsledky: Podľa echokardiografickej štúdie po troch mesiacoch tréningu u pacientov v intervenčných skupinách došlo k štatisticky významnému zlepšeniu kontraktility myokardu, o čom svedčí zvýšenie ejekčnej frakcie a zníženie end-diastolického rozmeru, end-systolického rozmeru, end-systolický a end-diastolický objem ľavej komory.

Záver: Hybridný model cvičebnej rehabilitácie (kontrolované hodiny v kombinácii s domácim cvičením s využitím telerehabilitačných technológií) preukázal stredne pozitívny vplyv na morfofunkčný stav ľavej komory u pacientov s ICHS, klasifikovaných ako stredne a vysoko rizikové. Výsledky získané v intervenčných skupinách nemali štatisticky významný rozdiel v porovnaní s účinkami kontrolných skupín, ktoré využívali centrálny model kardiorehabilitácie.

Kľúčové slová: Ischemická choroba srdca. Cvičebná rehabilitácia. Fyzická terapia. Telekardiorehabilitácia.

INTRODUCTION

According to the World Health Organization (WHO) data, more than 17 million people die annually from cardiovascular diseases, including more than 7 million from coronary heart disease (CHD), with the most significant medical and social burden among cardiovascular diseases (Case et al., 2020, World Health Organization, 2021). Cardiac rehabilitation (CR) is a multidisciplinary intervention aimed at accelerating patients' physical and psychosocial recovery and reducing the risk of future cardiac events. For CHD patients, CR is an essential part of treatment that reduces or eliminates modified risk factors, restores normal functioning, improves the quality of life, reduces the risk of complications and death. Numerous studies have shown that CR can significantly reduce morbidity and mortality, and therefore it is highly recommended in clinical guidelines (Anderson et al., 2016; Frederix et al.,

2016). Exercise training, which is one of the critical components of multidisciplinary CR, positively affects the physical performance of patients with CHD, quality of life, and overall prognosis. According to various studies, exercise-based rehabilitation has reduced mortality by 27 – 31 % in patients with CHD (Chiaranda et al., 2014; Grazzi et al., 2014; Grazzi et al., 2016). However, despite these benefits, patient participation in exercise-based CR programs remains low. According to the latest data, less than half of patients with CHD participate in CR programs due to several socio-demographic factors (Kotseva et al., 2018). Such obstacles are often logistical factors (Bakhshayeh et al., 2021). The traditional approach to the organization of rehabilitation care for cardiac patients usually requires the patient to visit a medical or rehabilitation institution that is located far from his place of residence; classes are held only at certain times, often in a group method, and usually contain the same activities for all patients. All these factors can cause the patient to refuse to participate in the rehabilitation program (Nabutovsky et al., 2020). Contextual aspects are also essential, such as the country's economic indicators (Dereka, 2020), accessibility issues or mechanisms for referring patients to rehabilitation, which depend on the specifics of the health care system in a given country (Borg et al., 2019). Ukraine is one of the countries where CR is not available for most patients with CHD (Turk-Adawi et al., 2019). These challenges have contributed to the development of alternative CR models, with innovative approaches to improving patient participation in these programs and removing identified barriers (Pfaeffli et al., 2012).

Data on the effectiveness of the home-based cardiac rehabilitation program are not new (Anderson et al., 2016). Studies conducted in the 1980s documented the use of a home-based CR program in patients at low risk of ischemic cardiomyopathy (Ades et al., 2000). However, such programs only partially addressed the low involvement of CHD patients in CR programs, as high-risk patients remained excluded. The introduction of telemedicine technologies in the CR and the development of telecardiorehabilitation (TCR) have partially reduced the barriers described above. TCR involves organizing one or more services within the CR programs outside a medical institution or rehabilitation center, using devices for remote monitoring and remote communication with patients, preferably using modern communication technologies such as the Internet or video counseling (Frederix et al., 2015). Recent systematic reviews and meta-analyses show that TCR can be an effective alternative to traditional CR in achieving functional improvement and risk management without a significant difference in mortality or rehospitalization (Huang et al., 2015; Rawstorn et al., 2016; Veen et al., 2017). TCR can also be a highly effective complement to traditional center-based CR programs, as demonstrated in the Telerehab III study (Frederix et al., 2016). The European Society of Cardiology and the European Association of Preventive Cardiology recognize TCR as a valuable component of secondary cardiovascular prevention (Piepoli et al., 2016; Anderson et al., 2017; Frederix et al., 2019). At the same time, most research on the effectiveness of home-based CR and TCR programs still focuses on low-risk patients. This necessitates the study of the impact of TCR programs on the condition of patients in moderate and high-risk groups.

OBJECTIVE

To research the influence of exercise-based TCR on the morphofunctional condition of moderate and high-risk patients with coronary heart disease.

RESEARCH SAMPLE

The materials were obtained during the examination of 66 patients with CHD and based on the State Institution “National Research Centre for Radiation Medicine” of the National Academy of Medical Sciences of Ukraine. All participants who were engaged in the study signed an informed consent form. The study was conducted in compliance with the international principles of the Helsinki Declaration of the World Medical Association (World Medical Association, 2013) and following the Law of Ukraine “Fundamentals of Ukrainian legislation on health care” (Law of Ukraine, 1992) about ethical norms and rules of medical research with human participants. Furthermore, the study, part of which is this article, was approved by the Commission on Biomedical Ethics of the National University of Ukraine on Physical Education and Sport.

Inclusion criteria were followed: informed consent of the patient; chronic coronary heart disease whose clinical manifestation was stable angina pectoris, confirmed by objective diagnostic methods; no contraindications to participation in the exercise

program; patients belonging to moderate or high-risk groups, the presence of a smartphone, the ability to use digital technologies.

Exclusion criteria were followed: age over 70 years; female sex; unstable angina, unstable clinical status, chronic heart failure of II-IV functional classes according to New York Heart Association Functional Classification; percutaneous angioplasty in the last 2 weeks, coronary artery bypass grafting in the previous 3 months, acute cerebrovascular accident over the previous 6 months before inclusion in the study; acute myocardial infarction over the previous 6 months before inclusion in the survey; symptomatic and/or exercise-induced cardiac arrhythmia or conduction disturbances, acute myocarditis and/or pericarditis, valvular or congenital heart disease requiring surgical treatment; type 1 diabetes mellitus or decompensated type 2 diabetes mellitus; body mass index > 35 $kg \cdot m^{-2}$; uncontrolled hypertension, anemia, severe respiratory disease, physical defects associated with severe musculoskeletal or neurological problems, recent embolism, thrombophlebitis, acute or chronic inflammatory disease, acute or chronic decompensated non-cardiac disease in the active stage, malignant neoplasms, aortic aneurysm, severe mental disorders, anamnestic data on alcoholism and drug addiction; refusal of the patient to participate.

The average age of patients was 56.1; 8.2 years ($\bar{x}$; S). The average duration of CHD in patients was 5.2; 1 years ($\bar{x}$; S), the average age of CHD was 50.9; 7.9 years ($\bar{x}$; S).

Four groups of patients were formed during research:

- Intervention group №1 (n = 22) and control group №2 (n = 22) – patients, according to the clinical and functional examination, were classified as a moderate risk;
- Intervention group № 3 (n = 21) and control group №4 (n = 21) – patients who were classified as high risk.

A combined (hybrid) organizational model was used in the intervention groups through exercise-based rehabilitation. The physical therapy program for the intervention groups included an average of 36 – 40 classes three times a week. The first 8 – 10 classes were controlled. They were conducted based on the rehabilitation department of the clinic. The following classes were passed by patients independently at home with the use of telerehabilitation technologies. To implement the program at home, a web page with personalized access was created. The patient received all the information about the training program, individualized advice, and reports to the physical therapist on implementing appointments. In addition, patients' communication with the physical therapist is carried out regularly, once a week, in the format of instant text messages, by e-mail, video calls, or telephone conversations, according to the patient's preferences.

For control groups, physical therapy programs were fully implemented based on the rehabilitation department. The number of physical therapy sessions in the intervention groups and control groups did not differ. On average, 35.9; 3.3 ($\bar{x}$; S) physical therapy classes were conducted with patients in the intervention group №1, in the control group №2, the same indicator was 36.4; 3.0 classes, in the intervention group №3 performed 34.9; 3.1 ($\bar{x}$; S), in the control group №4 performed 34.3; 3.1 ($\bar{x}$; S) classes. Physical therapy programs for patients of intervention groups and control groups were built according to the European Society of Cardiology recommendations (Knuuti et al., 2020). The basis of training programs was aerobic exercise 50 – 70 % of the intensity of the maximum individual capacity of patients, determined by exercise testing. Surveys of all participants were performed at the beginning of the study and after three months.

METHODOLOGY

Social and demographic, and clinical data of patients were obtained during the survey and through the analysis of medical records. Echocardiography was used to assess the structural and functional condition of the cardiovascular system. The studies were performed in the mode of one-dimensional (M) and two-dimensional scanning (B). In the M-mode, we investigated the following: the septal thickness (ST) was measured with an accuracy of 0.5 mm; left ventricular posterior wall thickness (LVPWT) to the nearest 0.5 mm, end-systolic dimension (ESD), and end-diastolic dimension (EDD) to the nearest 1 mm. The B-mode was defined according to the modified Simpson's formula the end-systolic (ESV) and end-diastolic volumes (EDV) of a left ventricle with an accuracy of 1 ml.

Left ventricular myocardial mass (LVMM) was calculated by the formula R. Devereux (Sandrikov, 2000). LVMM index (iMMLV) was calculated as the ratio of LVMM to body surface area ($g \cdot m^{-2}$). Accuracy of calculations was up to 1 $g \cdot м^{-2}$. Stroke volume (SV) was calculated as the difference between EDD and left ventricular ESD. Left ventricular ejection fraction (EF) was defined as a percentage SV to EDD. EF was determined to the nearest 1 %.

Statistical analysis. The analysis of the correspondence of the type of distribution of quantitative indicators of the law of normal distribution was tested by the Shapiro-Wilk test (W). For the quantitative indicators that had a normal distribution, the mean was determined ($\bar{x}$) and standard deviation (S). For the metrics with a distribution that did not fit the normal, we decided the median (Me) and the upper and lower quartiles (25 %; 75 %). The significance of the difference for the independent groups was evaluated using the Mann-Whitney U-test and for the dependent groups using the Wilcoxon test. The importance of the difference for the qualitative indicators was assessed using Fisher's exact test. Statistical analysis of the received results was conducted using the program Statistic 10.0 (StatSoft, USA).

RESULTS

Table 1 shows the essential demographic and clinical characteristics of study participants. As can be seen from the presented data, at the initial stage of the study, there was no significant difference between the groups in the main factors that may affect the effectiveness of rehabilitation measures.

Analysis of clinical indicators revealed a positive effect of exercise programs on patients' weekly frequency of anginal attacks. The data are presented in table 2.

No angina pectoris or any complications during physical therapy sessions were observed in patients of the intervention and control groups during the study.

Echocardiographic study showed a statistically significant decrease in the left ventricular end-systolic dimension, end-diastolic and end-systolic volumes, left ventricular myocardial mass index, and an increase in ejection fraction in patients at moderate risk after the intervention. That is, most of the studied indicators of the structural and functional state of the myocardium in patients showed positive changes ($p < 0.05$). While comparing the data of the intervention group and the control group, no statistically significant difference was found (Table 3).

Table 1 Social, demographic, and clinical characteristics of the patients at the beginning of the study

Researched indicator	Intervention group №1 (n=22)	Control group №2 (n=22)	Intervention group №3 (n=21)	Control group №4 (n=21)
Age, years ($\bar{x}$; S)	54.3; 6.2	53.8; 5.8	57.4; 7.9	58.9; 8.5
Number of smokers, n (%)	10 (45.5)	9 (40.1)	8 (38.1)	7 (33.3)
Number of people with high blood pressure, n (%)	10 (50)	9 (45)	8 (36.4)	9 (42.9)
Number of obese people, n (%)	8 (36.4)	9 (40.9)	9 (42.9)	7 (33.3)
Number of people with type 2 diabetes, n (%)	0 (0)	1 (4.5)	1 (4.8)	0 (0)

Table 2 Dynamics of anginal attacks in patients of moderate and high-risk groups

Researched indicator	Groups	The value of indicators	
		Before intervention	Three months later
		Me (25 %; 75 %)	Me (25 %; 75 %)
Weekly number of angina attacks	Moderate risk patients		
	Intervention group №1	14.5 (12; 15)	7 (5; 9)*
	Control group №2	13 (12; 14)	7 (5; 10.5)*
	High-risk patients		
	Intervention group №3	24 (20; 25)	11 (9; 13)*
	Control group №4	23 (20; 25)	12 (9; 13.5)*

Note: * – differences are statistically significant with indicators before intervention at $p < 0.01$

Table 3 Dynamics of the structural and functional condition of the myocardium in patients of moderate risk according to echocardiographic studies

Researched indicator	Groups	The value of indicators	
		Before intervention	Three months later
		Me (25 %; 75 %)	Me (25 %; 75 %)
Left ventricular end-diastolic dimension, mm	Intervention group №1	49.5 (47; 53)	49.0 (47; 54)
	Control group №2	49.0 (46; 53)	49.0 (53; 49,4)
Left ventricular end-systolic dimension, mm	Intervention group №1	35.0 (33; 40)	34.5 (31; 37)*
	Control group №2	34.0 (32; 36)	31.7 (35; 32.8)*
Left ventricular end-diastolic volume, ml	Intervention group №1	110.5 (105; 138)	104.5 (99; 132)*
	Control group №2	113.5 (96; 135)	108.5 (103; 108.2)*
Left ventricular end-systolic volume, ml	Intervention group №1	42.0 (38; 55)	40.8 (34; 56)*
	Control group №2	43.5 (36; 50)	40.5 (36; 48)*
Septal thickness, mm	Intervention group №1	12.0 (11; 12,9)	11.8 (10.7; 12.6)
	Control group №2	11.6 (10.5; 12)	11.6 (10.3; 12)
Left ventricular myocardial mass index, $g \cdot m^{-2}$	Intervention group №1	140.0 (121; 148)	133.0 (114; 141)*
	Control group №2	130.0 (125; 135)	123.5 (120; 130)*
Left ventricular posterior wall thickness, mm	Intervention group №1	11.0 (9; 12,5)	10.8 (8.5; 12)
	Control group №2	11.0 (10; 12)	11.0 (9.6; 12)
Ejection fraction, %	Intervention group №1	59.5 (56; 63)	61.5 (58; 65)*
	Control group №2	62.0 (60; 65)	63.0 (58; 66)*

Notes: * – differences are statistically significant with indicators before intervention at $p<0.05$

Table 4 Dynamics of the structural and functional condition of the myocardium in patients of high risk according to echocardiographic studies

Researched indicator	Groups	The value of indicators	
		Before intervention	3 months later
		Me (25 %; 75 %)	Me (25 %; 7 5%)
Left ventricular end-diastolic dimension, mm	Intervention group №3	49.0 (47; 54)	48.0 (46; 53)*
	Control group №4	53.0 (47; 56)	52.4 (47; 55.7)*
Left ventricular end-systolic dimension, mm	Intervention group №3	36.0 (32; 38)	35.0 (32; 38)*
	Control group №4	36.0 (32; 40)	35.8 (31.5; 40)*
Left ventricular end-diastolic volume, ml	Intervention group №3	120.0 (93; 145)	114.0 (89; 139)*
	Control group №4	138.5 (110; 172)	133.5 (110; 167)*
Left ventricular end-systolic volume, ml	Intervention group №3	40.0 (35; 61)	37.0 (32; 58)*
	Control group №4	37.0 (29,5; 57)	36.0 (26,5; 55)*
Septal thickness, mm	Intervention group №3	11.5 (11.5; 12.5)	11.2 (11; 12)
	Control group №4	11.9 (11; 12)	12.0 (11; 12)
Left ventricular myocardial mass index, $g \cdot m^{-2}$	Intervention group №3	136.0 (120; 155)	130.0 (115; 148.6)*
	Control group №4	142.5 (130; 151)	136.5 (124; 145)*
Left ventricular posterior wall thickness, mm	Intervention group №3	11.0 (10.5; 12)	11.0 (10; 11.6)
	Control group №4	11.0 (10; 11.7)	11.0 (9.8; 12)
Ejection fraction, %	Intervention group №3	55.0 (52; 59)	56.0 (53; 58)*
	Control group №4	55.0 (49; 59)	55.0 (48; 59)*

Notes: * – differences are statistically significant with indicators before intervention at $p<0.05$.

Among patients in the high-risk group after three months in the intervention group №3 and in the control group №4, there were statistically significant changes in all indicators except the septal thickness and posterior wall thickness (Table 4). Furthermore, no statistically significant difference was found during the comparison of the intervention group and the control group.

DISCUSSION

CR with telemedicine technologies, or telecardiorehabilitation, is a promising model of providing rehabilitation services developing rapidly in recent years (Huang et al., 2015; Rawstorn et al., 2016; Veen et al., 2017). Compared to interdisciplinary intervention programs, which are often hampered by economic, geographical, and bureaucratic barriers,

non-invasive remote monitoring can be a solution to continue a rehabilitation program at home and promote long-term care (Anderson et al., 2017; Bakhshayeh et al., 2021). The results of randomized controlled trials of the recent years (Cartwright et al., 2013; Kraal et al., 2014; Bravo-Escobar et al., 2017) indicate the cost-effectiveness of TCR programs, their beneficial effects on quality of life and correction of risk factors, comparable to the impact of center-based CR programs. However, most data on the effectiveness of TCR programs are based on studies involving low-risk patients. This necessitates the analysis of the impact of TCR programs on the condition of patients in moderate and high-risk groups.

In the modern literature, much research is devoted to studying left ventricular myocardial dysfunction in CHD and its importance as a prognostic factor (Belenkov, 2002; Milani et al., 2006). At the same time, insufficient attention has been paid to the study of the impact of exercise-based TCR programs on the structural and functional condition of the heart in patients with a high risk. The number of studies on this topic is limited, and their results are contradictory. Remarkably, several previous studies have not found a positive effect of exercise-based rehabilitation on the contractility of the left ventricular myocardium (Smart et al., 2007; Smart et al., 2012). However, other studies have shown a significant improvement in the ejection fraction under the influence of exercise in patients with CHD with chronic heart failure (Karapolat et al., 2009; Lomakina, 2015).

In this study, it was found that the hybrid model of exercise-based rehabilitation (controlled classes based on the rehabilitation department and replaced by independent classes at home using telerehabilitation technologies) showed a positive effect on the morphofunctional state of the heart compared with the impact of center-based CR program. After three months of training, patients in the intervention groups showed a statistically significant improvement in myocardial contractility, as evidenced by an increase in the ejection fraction, and a decrease in end-diastolic dimension, end-systolic dimension, end-systolic and end-diastolic left ventricular volumes. No statistically significant difference was found between the indicators of the intervention groups and the control groups.

Thus, the results of this study indicate a possible positive effect of exercise-based rehabilitation on the structural and functional state of the heart, regardless of the chosen model of cardiorehabilitation. Also, it should be noted that some studies have shown that the effect of exercise-based rehabilitation on the geometry of the heart increases with the duration of training (Prom, 2004; Lomakina, 2015). Thus, in the work of L.O. Lomakina (2015) in patients with CHD with hypertension and chronic heart failure, the most significant positive changes in the structural and functional state of the cardiovascular system under the influence of the physical therapy program were observed after 12 months. The obtained results indicate the expediency of further study of the effectiveness of TCR programs for patients with CHD of moderate and high-risk groups.

The results obtained in this study should be interpreted with the following limitations: small samples of study participants, only males participated in the study, a short duration of observation, the study is not blinded.

CONCLUSIONS

The hybrid model of exercise-based rehabilitation (controlled classes based on rehabilitation departmentin combination with home-based exercise using telerehabilitation technologies) showed a moderately positive effect on the structural and functional condition of the left ventricle of patients with CHD, classified as moderate and high risk. The results obtained in the intervention groups did not have a statistically significant difference from the results of the control groups, which used a center-based model of CR. During the study, patients did not observe any angina pectoris or any complications during physical therapy sessions, which indicates the safety of this organizational model of CR.

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