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Effects of cardiovascular rehabilitation on some metabolic and cardiac function variables in patients treated with surgical or interventional procedures on the heart

Efectos de la rehabilitación cardiovascular sobre algunas variables metabólicas y de función cardíaca en pacientes tratados con procedimientos quirúrgicos o intervencionistas sobre el corazón

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ABSTRACT:
Introduction: Cardiovascular diseases are the leading cause of death and disability worldwide and although surgical and interventional procedures are often successful, post-procedure rehabilitation strategies ensure better long-term recovery. Objective: To demonstrate the effects of a cardiovascular rehabilitation strategy on left ventricular ejection fraction as well as on certain metabolic variables in patients treated with surgical or interventional procedures on the heart. Method: A pre-experimental study was conducted with 33 patients who had undergone surgical or interventional procedures on the heart. They were included in a cardiovascular rehabilitation strategy of 24 sessions based on physical exercise. Metabolic and cardiac function variables were measured to compare the differences of their values before and after the completion of rehabilitation. Results: The procedures patients had undergone were: angioplasties, coronary artery bypass graft surgery, valve replacement, pacemaker implantation, Bentall procedure and surgical atrial septal defect repair. Rehabilitation resulted in a significant improvement which was observed in the values of maximum oxygen consumption, ejection fraction, lipid profile and fasting blood glucose levels; however, the difference in the double product was not statistically significant. Conclusions: The cardiovascular rehabilitation strategy based on physical exercise improved fasting blood glucose levels, lipid profile, and left ventricular ejection fraction in patients who had undergone surgical or interventional procedures on the heart.
Keywords: Cardiac rehabilitation, Cardiovascular disease, Maximum myocardial oxygen consumption.
RESUMEN
Introducción: Las enfermedades cardiovasculares son la principal causa de muerte e incapacidad en todo el mundo y, aunque los procedimientos quirúrgicos e intervencionistas resulten exitosos, las estrategias de rehabilitación posteriores a estos garantizan una mejor recuperación a largo plazo. Objetivo: Demostrar los efectos de una estrategia de rehabilitación cardiovascular sobre la fracción de eyección del ventrículo izquierdo y sobre algunas va-

riables metabólicas en pacientes que hayan sido tratados con procedimientos quirúrgicos o intervencionistas sobre el corazón. Métodos: Se realizó un estudio preexperimental que incluyó 33 pacientes que habían recibido procedimientos intervencionistas o quirúrgicos sobre el corazón. Ellos fueron incluidos en una estrategia de rehabilitación cardiovascular de 24 sesiones basada en ejercicios físicos. Se obtuvieron variables metabólicas y de función cardíaca para comparar las diferencias entre sus valores antes y después de culminar la rehabilitación. Resultados: Los procedimientos que habían recibido los pacientes fueron: angioplastias coronarias, revascularización miocárdica quirúrgica, reemplazo valvular, implante de marcapasos, cirugía de Bentall y reparación quirúrgica de comunicación interauricular. Al aplicar la rehabilitación hubo una significativa mejoría en los valores del consumo máximo de oxígeno, la fracción de eyección, el perfil lipídico y la glucemia en ayunas; no así en el doble producto, variable cuya diferencia no tuvo relevancia estadística. Conclusiones: La estrategia de rehabilitación cardiovascular basada en ejercicios físicos mejoró los niveles de glucemia en ayunas, el perfil lipídico y la fracción de eyección del ventrículo izquierdo en pacientes que habían recibido procedimientos intervencionistas o quirúrgicos sobre el corazón**.**

Palabras clave: Rehabilitación cardíaca, Enfermedad cardiovascular, Consumo miocárdico máximo de oxígeno.

INTRODUCTION

Cardiovascular diseases are a group of disorders of the heart and blood vessels. Nowadays, one out of three persons dies due to an event related to cardiovascular diseases; likewise, an acute myocardial infarction takes place in the world every four seconds, and a stroke every five.[1]

Due to their high prevalence, cardiovascular diseases represent a public health problem worldwide and are considered the leading cause of death in the adult population in most countries. In addition, in developing countries, an increase in the incidence and mortality due to these diseases it is expected since economic and demographic changes that contribute to the increase on risk factors have occurred[2].

Nowadays, in Latin America and the Caribbean, the 31 % of the total death are due to diseases of cardiovascular origin. In this sense, it is estimated that approximately 20.7 million of death in this region will take place due to these diseases in the next ten years.[3] In Mexico, particularly, heart diseases have been the leading cause of death for more than 20 years.[4]

Cardiovascular rehabilitation is an important pillar in the treatment of patients who had suffered an acute myocardial infarction since it provides better physical, psychological and social conditions. This one is carried out so the patient can have as much functional independence as his or her condition allows and a signifycant reduction (up to 30 %) in mortality after a cardiac event is achieved.[4,5]

The main objective of cardiovascular rehabilitation is to improve patients' quality of life, which requires a joint and coordinated effort from various healthcare specialties. Rehabilitation strategies are planned through physical training sessions, psychological support as well as an emphasis on controlling risk factors present in patients with heart problems or disorders.[6]

A significant reduction in mortality has been demonstrated in patients with cardiovascular diseases enrolled in cardiac rehabilitation programs.

The six-minute walk test is very useful to determine the exercise tolerance level in patients with a heart disease entering a cardiovascular rehabilitation program. This test consists of determining the maximum distance a person can walk at their maximum capacity, without running, on a flat surface for six minutes. During the test, oxygen saturation is also measured by pulse oximetry.[7,8]

The six-minute walk test is considered a simple alternative for evaluating the clinical effects that occur during therapeutic phases and allows to show the changes in patients' clinical status[9].

This research aims to: Demonstrate the effects of a cardiovascular rehabilitation strategy based on physical exercise on left ventricular ejection fraction and on some metabolic variables in patients treated with surgical or interventional procedures on the heart.

METHOD

A pre-experimental, prospective longitudinal

study was conducted, which included 33 subjects who consented to participate in the research. All participants had undergone some type of interventional or surgical procedure on the heart. They attended a cardiovascular rehabilitation program based on physical exercise at a leading clinic in Colombia, with the aim of demonstrating its benefits.

Participants were required to sign an informed consent form, which had been previously approved by the ethics committee of the institution where the study was conducted.

The study exclusion criteria included patients who presented with severe lower libs pain, unstable angina, heart rate greater than 120 beats per minute, systolic blood pressure greater than or equal to 180 mmHg, diastolic blood pressure greater than or equal to 100 mmHg, and resting oxygen saturation less than or equal to 89%. Patients who presented hemodynamic instability or who expressed a desire to withdraw were also excluded from the study. Based on these criteria, a total of 17 patients withdrew from an initial population of 50 subjects.

Sociodemographic, anthropometric, and physiological data were obtained from the patients. Exercise tolerance was assessed using the six-minute walk test, which was performed by cardiac rehabilitation specialists before and after the 24 exercise sessions. Oxygen consumption was expressed in METs (metabolic equivalents), expected distance was calculated using the Enright and Sherrill formula[10]

For women:

$$(2{,}11 * size\ in\ cm) - (2{,}29 * weight\ in\ kg) - (5{,}78 * age) + 667$$

For man:

$$(7{,}57 * size\ in\ cm\ ) - (5{,}02 * age) - (1{,}76 * weight\ in\ kg) - 309$$

The protocol used for the six-minute walk test is that recommended by the American Thoracic Society guidelines.[10,11] Perceived exertion was measured using the modified Borg scale.[9] Variables such as heart rate, respiratory parameters as well as systolic and diastolic blood pressure were obtained during the exercise program, while oxygen saturation was measured using a portable pulse oximeter (Nellcor Puritan Bennett). Indirectly, the double product (calculated as the product of systolic blood pressure and heart rate) was estimated as an indicator of myocardial oxygen consumption.[12]

The exercise-based rehabilitation program consisted of 24 sessions of 60 minutes each, distributed over two months, three times per week. The first ten minutes at the beginning and end of each session were used for warm-up and cool-down, respectively; while the main part of the training lasted 40 minutes. The warm-up consisted of general movements of the different muscle groups. The cool-down included coordination exercises, stretching, proprioception exercises, and breathing exercises.

During the 40-minute main part of the session, aerobic exercises were performed on the cycle ergometer and on the treadmill, in addition to strength exercises for upper libs with multistregth equipment, resistance bands and dumbbells and for lower limbs with resistance bands, multistrength equipment and exercises for activating the soleus muscle.

Aerobic exercise was performed between the 50 and the 70 % of the peak heart rate (PHR) obtained during the exercise test according to the Naughton protocol.[13]

It should be said that the design and development of the research were carried out under the ethical considerations of the Declaration of Helsinki[14] and the resolution N°.008430 of the Colombian Ministry of Health as well as under the approval of the directors and the ethics and research committee of the institution where the study was conducted.

Statistic analysis:

The analysis was performed with the statistical software SPSS version 15.0. Using Shapiro-Wilk could be proven that data do not meet the normal range. Continuous variables were presented as median and interquartile rage and the categorical ones as absolute and relative frequencies. For comparisons before and after the intervention the Wilcoxon test for paired samples was used, for the correlations among independent groups the Mann-Whitney U-test was employed and the Fisher´s exact test for categorical variables. $p < 0.05$ was considered as statistically significant value.

RESULTS

Table 1 shows a characterization of the sample selected**.** The 58 % were males and the rets 42 %, females. Sociodemographic characteristics studied were related to sex and none of them showed statistically significant differences. Mean age was placed on 64 years old and its interquartile range between 52 and 72 years old. Regarding schooling level, high school graduated predominated in a 48 %. Body mass index of the sample had a median of 24.5 with an interquartile range between 22.1 and 27.3. According to this index there was a predominance of normal weight of the 39.4 % of the sample.

The interventional or surgical procedures on the heart the patients had undergone were: percutaneous coronary angioplasty in 42.4% of cases, coronary artery bypass graft surgery in 36.4%, valve replacement in 9.1%, implanta-

tion of a permanent pacemaker in 6.1%, surgery using the Bentall procedure in 3%, and surgical atrial septal defect repair, also in 3%.
Figure 1 shows the identified risk factors. These included age, which differed between the sexes, sedentary lifestyle, history of acute myocardial infarction, high blood pressure, tobacco smoking, diabetes *mellitus*, abdominal circumference with values indicative of metabolic risk and dyslipidemia. Obesity and overweight were more prevalent in women.

Tabla 1. Sample characterization

Variable	Total (n=33)	Men (n=19)	Women (n=14)	*P value**
Age (years)	64 [56 – 72]	61 [54 – 69]	67 [59 – 75]	0,183
Academic level				0,049
Elemental	5 (15,2 %)	5 (26,3 %)	0 (0 %)	
High school	16 (48,5 %)	7 (36,8 %)	9 (64,3 %)	
Universitary	12 (36,4 %)	7 (36,8 %)	5 (35,7 %)	
BMI (kg/m²)	24,5 [22,1 – 27,3]	23,9 [21,8 – 26,1]	25,8 [23,5 – 28,9]	0,142
Abdominal circumference (cm)	89 [84 – 95]	90 [85 – 95]	88 [83 – 94]	0,598
BMI Category				0,110
Low weight	2 (6,1 %)	0 (0 %)	2 (14,3 %)	
Normal	13 (39,4 %)	9 (47,4 %)	4 (28,6 %)	
Overweight	12 (36,4 %)	8 (42,1 %)	4 (28,6 %)	
Obesity	6 (18,2 %)	2 (10,5 %)	4 (28,6 %)	
Interventional or surgical procedure on the heart				0,874
Percutaneous coronary angioplasty	42,4% (14)	8 (42,1 %)	6 (42,9 %)	
Coronary artery bypass graft surgery	12 (36,4 %)	7 (36,8 %)	5 (35,7 %)	
Valve replacement	3 (9,1 %)	2 (10,5 %)	1 (7,1 %)	
Pacemakers implantation	2 (6,1 %)	1 (5,3 %)	1 (7,1 %)	
Bentall procedure	1 (3,0 %)	1 (5,3 %)	0 (0 %)	
Surgical repair of an ASD	1 (3,0 %)	-	1 (7,1 %)	

*** Mann-Whitney U-test for continuous variables and Fisher´s exact test for categorical variables**
BMI: body mass index; ASD: atrial septal defect

At the end of the rehabilitation strategy, the values of a group of variables obtained before and after its implementation were compared. This result is shown in **table 2**. All the variables compared showed a statistically significant improvement, except for the double product, although with better figures after the exercises, but with a non-significant p-value. Left ventricular ejection fraction, fasting blood glucose and cholesterol showed the greatest difference between the two time points.
After the six-minute walk test, oxygen consumption and distance covered improved significantly, as did some components of the lipid profile.

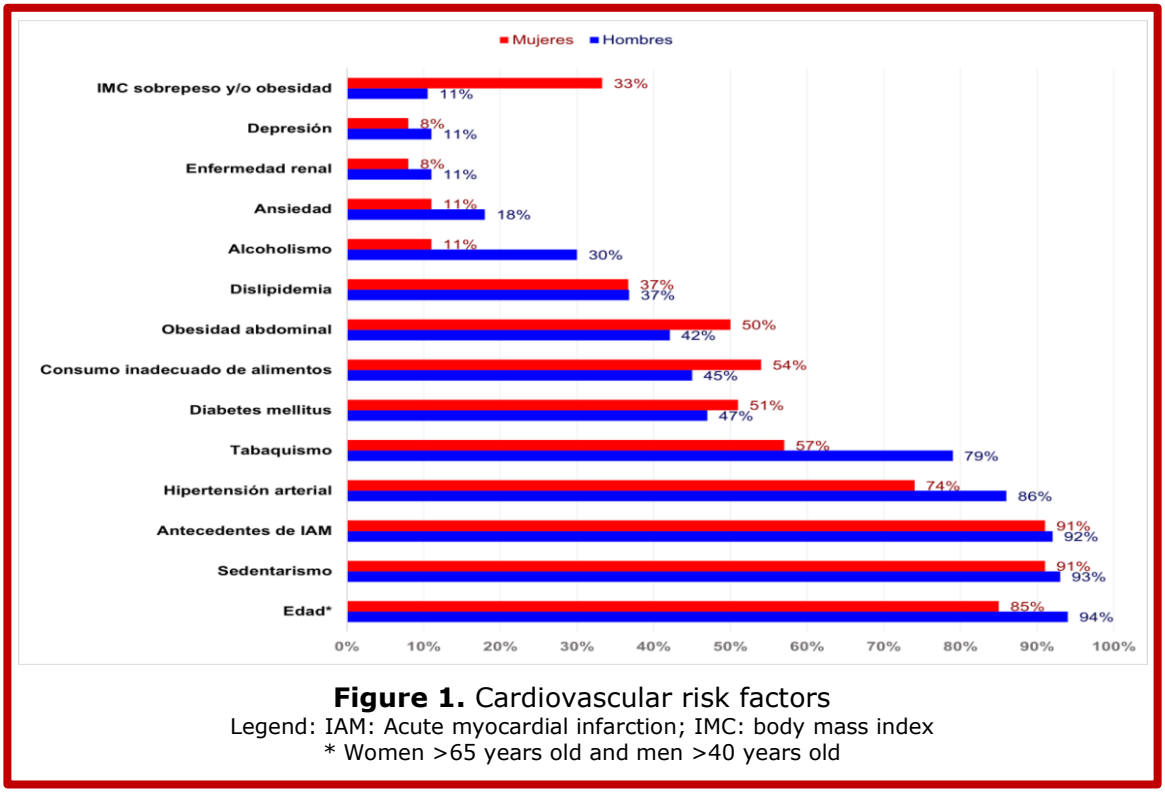

Figure 1. Cardiovascular risk factors
Legend: IAM: Acute myocardial infarction; IMC: body mass index
* Women >65 years old and men >40 years old

Table 2. Comparison of variables before and after the rehabilitation strategy based on physical exercise

Variable	Before	After	*P value**
Ejection Fraction (%)	43 [38 – 48]	49 [44 – 53]	<0,001
Six-minute walk			
VO_2 (mL·kg⁻¹·min⁻¹)	9,6 [8,3 – 11,0]	11,1 [9,8 – 12,3]	0,002
Meters covered	245 [185 – 305]	303 [245 – 361]	0,002
Doubled product	9,946 [8,634 – 11,258]	9,435 [8,254 – 10,616]	0,400
Lipid profile (mg/dL)			
Cholesterol	241 [232 – 250]	217 [213 – 221]	<0,001
HDL	44 [38 – 50]	32 [29 – 35]	0,001
LDL	138 [130 – 146]	132 [128 – 136]	0,002
Triglycerides	158 [150 – 166]	140 [133 – 147]	0,002
Fasting blood glucose	151 [145 – 157]	126 [124 – 128]	<0,001

*** Mann-Whitney U test for continuous variables and Fisher´s exact test for categorical variables**
VO_2: oxygen consumption; HDL: high-density lipoproteins; LDL: low-density lipoprotein

DISCUSSION

Physical exercise in cardiac rehabilitation is essential as a preventive method. A training program such as that presented in this research generates positive effects on physical, mental, and psychosocial health as well as on morbidity and mortality from heart diseases.

With this intervention, the lipid profile and oxygen consumption were improved in the rehabili-

tated patients. Similar results were obtained by Roselló M. *et al.*,[15] who also studied the effects on body mass index and waist-to-hip ratio. Other authors report benefits on blood glucose and lipids that are equivalent to those described here.[16, 17, 18, 19, 20]

Rehabilitation strategies such as the one carried out in this research help control body weight by improving the lipid profile, and when combined with dietary changes, they provide benefits to patients with heart conditions. The reduction of plasma triglycerides and the increase in the level of plasma high-density lipoproteins are attributed to physical exercise[21].

In a cardiovascular rehabilitation protocol carried out by Ávila J. *et al.*,[22] the aforementioned parameters behaved similarly in their patients, although their study also included differences in diastolic blood pressure before and after training. In the current research, variables related to blood pressure were not considered, which would be very useful to be taken into account in future studies. For this study, only the value of the double product was used.

On the other hand, it should be noted that regular physical exercise is the only non-pharmacological measure capable of raising plasma high-density lipoproteins levels and reducing triglycerides.[23] The beneficial effects of physical exercise on hyperglycemia are also well known, as it acts on two fundamental levels: firstly, it promotes glucose uptake by the muscles; secondly, it reduces muscle resistance to insulin action. Thus, exercise is an important component in the treatment of diabetes *mellitus*, and consequently, health promoters include it among their actions to improve the patients' quality of life affected by this disease.[24]

In the current study, blood glucose levels were reduced in the sample. A quasi-experimental study conducted by Expósito-Tirado J.A. *et al*.[25] on the effectiveness of cardiac rehabilitation in diabetic patients shows an improvement in glycosylated hemoglobin levels as a criterion for the disease control.

Similarly, the results shown by Andrade J *et al*.[19] indicate a reduction in the mean values of biochemical variables, most notably in blood glucose and glycosylated hemoglobin.

Another reviewed report concludes that different variables, such as blood glucose, total cholesterol, high-density lipoproteins, low-density lipoproteins, and triglycerides; showed improvement in a manner very similar to that of the current study.[26]

CONCLUSIONS

The rehabilitation strategy based on physical exercise implemented in this research yielded positive effects, including recovery of left ventricular ejection fraction and improvement in metabolic variables such as lipid profile and blood glucose levels. This strategy also resulted in improved oxygen consumption and exercise capacity in a group of patients who had undergone surgical or interventional procedures on the heart.

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