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Cardiac rehabilitation in patients with ST-segment elevation acute myocardial infarction and percutaneous coronary intervention

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The authors declare no competing interests

Abbreviations
CR: cardiovascular rehabilitation
HR: Heart rate
LVEF: Left ventricular ejection fraction
PCI: Percutaneous coronary intervention

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ABSTRACT

Introduction: Cardiovascular rehabilitation is beneficial in multiple clinical situations. In patients who are treated through percutaneous coronary intervention it is necessary to continue deepening its study.

Objectives: To determine the effects of cardiovascular rehabilitation in patients with ST-segment elevation acute myocardial infarction who underwent percutaneous coronary intervention.

Method: Quasi-experimental study in 30 patients with ST-segment elevation acute myocardial infarction after being treated with coronary angioplasty, and who were attended at the Department of Cardiovascular Rehabilitation of the *Hospital Universitario Celestino Hernández Robau*, in the period from September 2016 to March 2018. Clinical and epidemiological data were collected, and ergometric and echocardiographic variables were analyzed before and after 12 weeks of developing a cardiovascular rehabilitation program.

Results: There was a positive effect on heart rate at rest (66±11 vs. 61±11 beats/minute; p=0.008), exercise time (8.3±2.5 vs. 10.2±2.0 minutes; p<0.0001) and maximum oxygen consumption (24.2±5.0 vs. 27.6±4.9 ml/kg/min; p<0.0001). There was improvement of the ejection fraction and reduction of the diameter of the left ventricle in diastole left ventricular end-diastolic diameter, but without significant statistical difference.

Conclusions: There was improvement in the ergometric and echocardiographic parameters after the cardiovascular rehabilitation program, which was more beneficial in patients with high blood pressure, smoking habit and percutaneous coronary intervention of two arteries.

Keywords: Cardiovascular rehabilitation, Percutaneous coronary intervention, Acute myocardial infarction, Ergometry

Rehabilitación cardiovascular en pacientes con infarto agudo de miocardio con elevación del segmento ST e intervencionismo coronario percutáneo

RESUMEN

Introducción: La rehabilitación cardiovascular es beneficiosa en múltiples situaciones clínicas. En pacientes que son tratados mediante intervencionismo coronario es necesario seguir profundizando su estudio.

Objetivo: Determinar los efectos de la rehabilitación cardiovascular en pacientes con infarto agudo de miocardio con elevación del segmento ST a quienes se les realizó intervencionismo coronario percutáneo.
Método: Estudio cuasi-experimental en 30 pacientes con infarto agudo de miocardio con elevación del ST después de ser tratados con angioplastia coronaria y que se atendieron en el Servicio de Rehabilitación Cardiovascular del Hospital Universitario Celestino Hernández Robau, en el período de septiembre de 2016 a marzo de 2018. Se recolectaron datos clínicos y epidemiológicos, y se analizaron variables ergométricas y ecocardiográficas al inicio y luego de 12 semanas de realizar un programa de rehabilitación cardiovascular.
Resultados: Existió un efecto positivo en la frecuencia cardíaca en reposo (66±11 vs. 61±11 latidos/minuto; p=0,008), el tiempo de ejercicio (8,3±2,5 vs. 10,2±2,0 minutos; p<0,0001) y del máximo consumo de oxígeno (24,2±5,0 vs. 27,6±4,9 ml/kg/min; p<0,0001). Existió mejoría de la fracción de eyección y reducción del diámetro del ventrículo izquierdo en diástole, pero sin diferencia estadística significativa.
Conclusiones: Existió mejoría en los parámetros ergométricos y ecocardiográficos luego del programa de rehabilitación cardiovascular, que fue más beneficioso en pacientes con hipertensión arterial, hábito de fumar e intervencionismo coronario percutáneo de dos arterias.
Palabras clave: Rehabilitación cardiovascular, Intervención coronaria percutáneo, Infarto agudo de miocardio, Ergometría

INTRODUCTION

Cardiovascular diseases are one of the leading causes of morbidity and mortality worldwide. Their most common form of presentation is the ischemic heart disease and within it, the acute myocardial infarction, which is often fatal[1-3].

Revascularization procedures, such as catheterization or surgery, are applied in an increasing proportion to patients who have suffered a cardiovascular event. This scenario provides thousands of cases that could benefit from cardiovascular rehabilitation (CR)[4-6] programs.

The CR of ischemic heart disease has adapted to the patient's circumstances with different revascularization techniques, which have evolved rapidly in recent decades. Among them, the most used is the placement of stents. Its use has significantly changed hospital stays, a circumstance which affects the first phase of the CR. Early incorporation into the usual life of the patient, to which an angioplasty with stent has been performed, due to absence of the technique's impediments, has allowed the early inclusion of these patients in phase II of the CR[7].

The benefits of the CR in patients who have undergone percutaneous coronary intervention (PCI) with placement of stents have been widely studied and include: decrease of mortality from adverse cardiovascular events, better functional capacity, ventricular function, ventricular remodeling, endothelial function and increased collateral circulation[8-10]. However, in our country, there are no studies which expose the changes that, on different ergometric and echocardiographic variables, show the development of a CR program in such patients during the acute phase of the myocardial infarction.

Based on these elements, the present research was intended to determine the changes that take place in ergometric and echocardiographic variables after completing the physical training protocol as part of a CR program, in patients with PCI due to ST-segment elevation acute myocardial infarction, and to relate changes in the ergometric parameters according to the presence of cardiovascular risk factors and number of coronary arteries treated during the PCI.

METHOD

Type of study and population

A quasi-experimental study was conducted in a study population defined according to all patients with ST-segment elevation acute myocardial infarction who underwent coronary angioplasty with implantation of stent, and that joined the CR program assigned to the Department of Cardiology of the *Hospital Universitario Celestino Hernández Robau* in the city of Santa Clara, Cuba, in the period from September 2016 to March 2018.

Sample and inclusion criteria

There were selected 30 patients in the study population who met the inclusion and exclusion criteria defined for the research; specifically, those with ST-segment elevation acute myocardial infarction who underwent PCI and met the inclusion criteria in the CR program.

Exclusion criteria

There were excluded those patients who quit the program before carrying out the final ergometry, the ones that did not fulfilled, at the least, 75% of the scheduled exercise sessions and those that, despite being incorporated into the program, presented contraindications while performing physical exercise. Moreover, patients who did not agree to participate in the study.

Procedures

For the collection of the information, a questionnaire was prepared, which covered the variables of interest, through the review of the individual medical records of the patients, located in the CR department of the *Hospital Universitario Celestino Hernández Robau* (Santa Clara, Cuba).

In order to assess the effects of the CR program, the information provided by the ergometric test was analyzed, according to the RAMPA protocol performed at the beginning of the program and after ending phase II. All ergometric tests were performed on endless tape (Ergocid-AT Plus, ICID, Cuba). At the end of the 12 weeks of the physical training sessions planned, changes in ergometric variables (maximum heart rate, double product and exercise time) were analyzed and their relationship with clinical variables and the number of epicardial coronary arteries treated with implantation of stents during the PCI.

Through transthoracic echocardiography (ALOKA SSD 5000 Alpha 10, Japan) were determined the diastolic diameter (bimodal mode in view of the parasternal long axis) and the left ventricle ejection fraction (LVEF, Simpson's method) at the beginning and at the end of the CR program.

Physical training protocol

After a successful risk stratification that included clinical, electrical, hemodynamic and echocardiographic elements, patients were incorporated into the fitness program. The exercise sessions were conducted in the area of CR of the hospital where the research was conducted and they were supervised by a cardiologist. The program lasted 12 weeks and had three sessions of exercise a week at an intensity of 60 to 70% of the heart rate reached in the basal ergometry. During the remaining days, walks of about 30 minutes were carried out at home.

The physical exercise session began with an initial phase of 15 minutes of stretching and calisthenics. Later, 20 minutes of aerobic exercises, and last, 15 minutes of cooling and relaxation exercises.

The treatment was complemented with psychological intervention, educational talks about the disease, risk factor control and leisure time activities. Each patient underwent periodic reviews conducted by the cardiologist, who monitored the evolution of the disease and the effect of training on it.

Variables evaluated before and after the rehabilitation program

- Heart rate (HR) at rest (beats/minute): Number of heart beats in a minute after 10 minutes at rest and 30 minutes without smoking or drinking coffee.
- Maximum HR (beats/minute): Maximum rate reached during the exercise phase of the ergometric test.
- Exercise time (minutes): Time elapsed during the exercise phase of the ergometric test.
- Double product: It is obtained by multiplying the maximum systolic blood pressure by the maximum HR during the exercise phase of the ergometric test. It is expressed in an integer, without unit of measure.
- Maximum oxygen consumption (ml/kg/min): It is an indicator of the aerobic physical capacity of the patient, obtained during the maximum peak of the exercise phase of the ergometric test.
- Energy charge (MET): It is the result of aerobic work together with the anaerobic; it is estimated by dividing the maximum oxygen consumption between 3.5.
- Diameter of the left ventricle in diastole (millimeters): Measurement of the left ventricle in telediastole obtained in the parasternal long axis in bimodal mode.
- LVEF (%): Fraction of percentage of blood volume propelled by the left ventricle during systole, with respect to the telediastolic volume. It was obtained through the Simpson's method.

Statistical analysis

The data collected were entered into a file and processed using the statistical software package SPSS, version 21.0 for Windows. These data were summa-

rized in tables and statistical graphs.
The qualitative variables were expressed in absolute and relative frequencies, and the quantitative variables with the mean and standard deviation. For evaluating the differences between the quantitative variables, before and after the rehabilitation program, the Wilcoxon test was used. For the interpretation of the statistical significance of the used statisticians, the value of *p* was evaluated as follows: If $p \leq 0.01$ indicates a very significant result of the statistician, if $p < 0.05$ indicates a significant result and if $p > 0.05$ indicates a non-significant result.

Ethics

This research was approved by the Ethics Committee of the *Hospital Universitario Celestino Hernández Robau* and the physical training protocol, approved by the local Scientific Committee. All patients signed the informed consent.

RESULTS

In **table 1** are displayed the epidemiological characteristics of the studied sample. The male sex predominated, with 73.3% of the total. The mean age was significantly higher in men over women (58.6±6.7 *vs.* 52.0±6.2 years; p= 0.021).

In **figure 1** is displayed the clinical context in which the PCI was performed. In 43.3% of patients it was following a failed thrombolysis (rescue PCI); in an elective form, in 36.7%, and only 2 patients (6.7%) underwent primary PCI.

In **table 2** is shown the behavior of the main ergometric variables before starting the CR program and after 12 weeks of complementing the protocol of physical training. As it can be observed, there was a very significant reduction in the HR at rest (66±11 *vs.* 61±11 beats/min; p= 0.008), with a significant increase in exercise time (8.3±2.5 *vs.* 10.2± 2.0 minutes; p<0.0001) and the maximum oxygen consumption (24.2±5.0 *vs.* 27.6±4.9 ml/kg/min; p<0.0001).

In **Figure 2** is shown the behavior of the LVEF and the diameter of the left ventricle in telediastole before and after the exercise program. It is observed that after 12 weeks of physical training there was an increase in the LVEF of 56.6±8.3% at the start *vs.* 58.5±5.4% at the end of the program, although the difference was not statistically significant (p=0.062).

In **table 3** are displayed the changes in the ergometric parameters before and after the exercise program according to the presence of risk factors. It can be observed that patients with high blood pressure and smoking had the biggest benefits by improving significantly, the first, in the three parameters evaluated (HR at rest [66±12 *vs.* 61±12; p=0.03], exercise time [8.4±2.8 *vs.* 10.4±2.2; p<0.0001] and maximum oxygen consumption [24.5±5.7 *vs.* 28.0± 5.0; p<0.0001]), and the second ones in the HR at rest

Table 1. Epidemiological characteristics of the sample studied.

Variables	Sex		Total
	Male	Female	
Patients [n (%)]	22 (73.3%)	8 (26.7%)	30 (100%)
Age (X ± SD]	58.6 ± 6.7*	52.0 ± 6.2	56.9 ± 7.1
Risk factors [n (%)]			
High blood pressure	16 (72.7%)	6 (75.0%)	22 (73.3%)
Smoking habit	10 (45.5%)	3 (37.5%)	13 (43.3%)
Diabetes mellitus	6 (27.3%)	2 (25.0%)	8 (26.7%)
Dyslipidemia	5 (22.7%)	1 (12.5%)	6 (20.0%)
None	3 (13.6%)	1 (12.5%)	4 (13.3%)

* p=0.021

Table 2. Ergometric parameters before and after the physical training program.

Ergometric variables	Pre CR	Post CR	p
HR at rest (bpm)	66 ± 11	61 ± 11	**0.008**
Maximum HR (bpm)	131 ± 21	129 ± 23	0.764
Exercise time (min)	8.3 ± 2.5	10.2 ± 2.0	**<0.0001**
Double product	20215 ± 3878	20577 ± 3799	0.465
Energy charge (MET)	6.9 ± 1.5	7.9 ± 1.4	**0.001**
MVO_2 (mL/kg/min)	24.2 ± 5.0	27.6 ± 4.9	**<0.0001**

bpm, beats per minute; HR, heart rate; MET, metabolic equivalents; min, minutes; MVO2: maximum oxygen consumption.

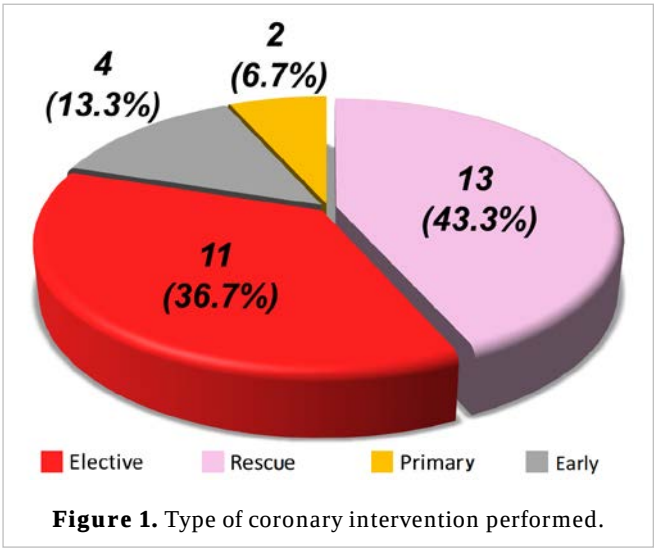

Figure 1. Type of coronary intervention performed.

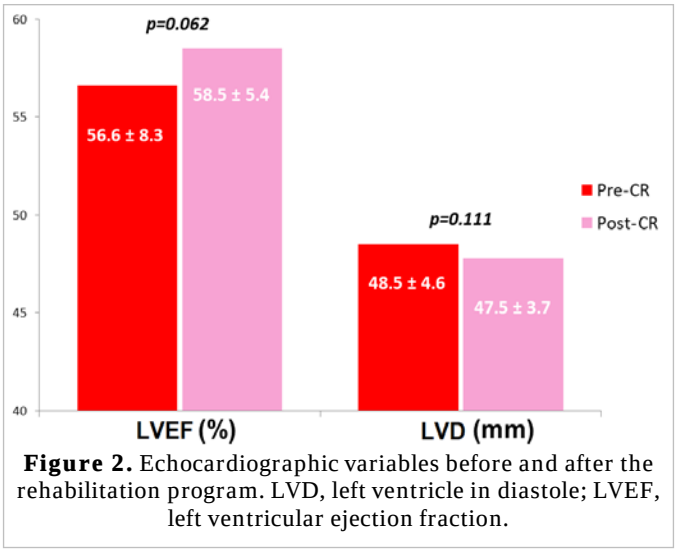

Figure 2. Echocardiographic variables before and after the rehabilitation program. LVD, left ventricle in diastole; LVEF, left ventricular ejection fraction.

(68±11 *vs.* 60±14; p=0.03) and the exercise time (7.9± 1.7 *vs.* 9.7±1.1; p=0.03).

In **table 4** is observed the value of these ergometric variables, evaluated before and after the exercise program, depending on how many coronary arteries were treated during PCI. The biggest changes were observed in the patients with one or two treated arteries. From the two patients with three treated arteries, one of them presented a high oxygen consumption since the beginning of the program, which was maintained after the rehabilitation program (32 ml/kg/min before and after) and the other patient did not present cardiovascular risk factors, and only showed a slight increase of the maximum oxygen consumption (22.4 *vs.* 24.4 ml/kg/min; p>0.05).

DISCUSSION

The present research is the first in our province in terms of evaluating changes in several ergometric and hemodynamic parameters before and after an exercise program in patients undergoing PCI due to ST-segment elevation acute myocardial infarction.

There are several factors that explain the greater

Table 3. Ergometric parameters before and after the physical training program according to the evidenced risk factors.

Variables	Risk factors									
	HBP	p	DM	p	Dyslipidemia	p	Smoking	p	None	p
Heart rate at rest (bpm)										
Pre CR	66 ± 12	**0.03**	66 ± 13	0.24	60 ± 11	0.78	68 ± 11	**0.03**	64 ± 9	0.59
Post CR	61 ± 12		61 ± 12		59 ± 3		60 ± 14		61 ± 3	
Exercise time (minutes)										
Pre CR	8.4 ± 2.8	**0.00***	9.5 ± 3.6	0.16	8.6 ± 2.2	0.07	7.9 ± 1.7	**0.03**	8.0 ± 2.1	0.06
Post CR	10.4 ± 2.2		10.7 ± 2.6		10.5 ± 1.1		9.7 ± 1.1		9.5 ± 1.3	
Maximum consumption of O_2 (ml/kg/min)										
Pre CR	24.5 ± 5.7	**0.00***	26.7 ± 7.5	0.12	26.4 ± 7.4	**0.04**	24.3 ± 5.3	0.08	22.9 ± 0.9	0.06
Post CR	28.0 ± 5.0		29.3 ± 7.1		31.9 ± 6.8		27.1 ± 4.7		24.3 ± 0.7	

*p<0.0001. Values are expressed in mean ± standard deviation.
bpm, beats per minute; DM, diabetes mellitus; HBP, high blood pressure; CR, cardiac rehabilitation.

Table 4. Ergometric parameters before and after the physical training program according to the amount of coronary arteries treated.

Variables	Number of vessels treated					
	One (n=21)	p	Two (n=7)	p	Three (n=2)	p
Heart rate at rest (bpm)						
Pre CR	65 ± 11	0.06	74 ± 7	**0.02**	53 ± 12	0.65
Post CR	60 ± 11		64 ±12		57 ± 1	
Exercise time (minutes)						
Pre CR	8.4 ± 2.8	**0.00***	7.3 ±1.2	**0.02**	10.3 ± 1.6	0.65
Post CR	10.3 ± 2.3		9.8 ±1.0		10.1 ± 0.1	
Maximum consumption of O_2 (ml/kg/min)						
Pre CR	24.3 ± 5.3	**0.00***	23.0 ±4.0	**0.02**	27.2 ± 6.8	0.32
Post CR	27.4 ± 5.5		28.0 ±3.3		28.3 ± 5.3	

*p<0.0001. Values are expressed in mean ± standard deviation.
bpm, beats per minute; CR, cardiac rehabilitation.

proportion of men compared to women. Steadily, males are the most affected in the context of acute coronary syndromes and certain age groups, for the most widely demonstrated biological propensity[11]; in addition, specifically regarding reperfusion methods, there is a tendency towards a lower use of PCI in women.

In a study in patients who were treated with primary angioplasty, Hurtado-Martínez *et al*[11] reported only 22% of female patients treated. Among the reasons, there is a greater debut age of women, a longer time of evolution of symptoms when arriving at the hemodynamics room, as well as an increased hospital mortality. Similarly happened with the study of Goel *et al*[12], where they evaluated the impact of the CR in 2395 patients who were treated with coronary angioplasty; 40% of patients participated in the CR program and 70% of them were men.

In relation to risk factors, high blood pressure was the most prevalent in our study, followed by smoking, and only four patients did not present any risk factor. As it is known, patients who present any manifestation of cardiovascular disease have a higher risk profile, and of these, modifiable factors such as smoking and dyslipidemia are an ideal target for action in the context of CR. Others such as high blood pressure and diabetes mellitus require greater monitoring and the rehabilitation scenario is adequate because monitoring and adjustments are routinely established for program's participants.

Our results coincide with those found in the study of Goel *et al*[12], who reported high blood pressure (62%), smoking (43%) and diabetes mellitus (17%) as the most prevalent risk factors in their patients incorporated to CR[12].

Although the differences were not statistically significant, after 12 weeks of physical training, there was an increase of the LVEF and a reduction of the left ventricle telediastolic diameter. This improvement should be considered relevant, taking into account that both variables were not in a pathological range, because, as already mentioned, the angioplasty avoids further ventricular remodeling. In addition, the low variation of the LVEF and the diameter of the left ventricle in diastole could be due, in part, to the short period of time between one determination and another; in other studies, where the time between the completion of the echocardiogram at the start of the CR program and the follow-up was higher (6 months), there was definitely a significant increase of the LVEF (52.3±16 % *vs.* 57.3±15 %; p= 0.02) and a reduction in the final systolic volume of the left ventricle[13]; as well as improvement in the myocardial oxygen consumption (26%, p<0.001) and the quality of life (26.8%, p=0.001), which was observed only in patients of the training group program.

Although the angiographic restenosis rate in this research[13] did not vary with training (29% *vs.* 33%, p>0.05) and there were not significant differences after angioplasty or stent implantation, the residual stenosis was lower in the trained patients (-29.7%; p=0.045); in those with angiographic restenosis, the thallium improved only in the training group (19%;

p<0.001). During follow-up (33±7 months), trained patients had one minor rate of cardiovascular events (11.9 *vs.* 32.2%; RR: 0.71 [CI 95%: 0.60 - 0.91]; p=0.008) and rehospitalization over monitoring (18.6 *vs.* 46%; RR: 0.69 [CI 95%: 0.55- 0 .93]; p <0.001).

When evaluating the behavior of the main ergometric variables, we found a very significant reduction in the HR at rest, with a very significant increase in exercise time and maximum oxygen consumption. An interesting study by Uematsu *et al*[14] in 29 patients with acute myocardial infarction who underwent single-photon emission computed tomography before and after six months of a CR program, it was observed that in those with improvement in myocardial perfusion parameters, a reduction in the HR at rest was found simultaneously at the end of the CR program.

The energy charge is a parameter that is obtained by dividing the maximum oxygen consumption by 3.5; reason why its behavior is in line with this last parameter and does not provide more information to analyze them separately.

The maximum HR achieved in the ergometric test and the double product were not significantly modified after the program. One possible explanation is that the theoretical maximum rate that the patient must reach (220 – age of the patient)[15] remains constant, and by achieving greater exercise time is one of the ending criteria for the ergometric test when achieving a maximum or submaximum HR without presenting symptoms or electrical changes. Also, the effect of medications such as beta-blockers can influence this behavior.

Concerning the double product, no significant differences were observed after the exercise protocol. This result is mainly due to the fact that the patients experienced significant increases in systolic blood pressure during the exercise, despite presenting increased exercise time and maximal oxygen consumption. This is a positive result because a better overall performance is achieved during physical exercise without increasing myocardial oxygen consumption, afterload, or the work of the heart muscle in a clinically important way.

Regarding the relationship between the ergometric parameters and the risk factors, hypertensive patients and smokers had the greatest benefits. This may reflect not only the benefits of physical exercise directly, but the entire multidisciplinary intervention that takes place during the CR, where intervention in risk factors, dietary and behavioral habits form an integral part of this program[16,17]. At the other extreme, patients with diabetes mellitus and those who did not have risk factors were those who did not show significant changes in the variables under analysis. In the case of the former, it is a subgroup of very high risk patients, with greater comorbidities in which it is likely to obtain fewer benefits. In the case of patients without risk factors, on the contrary, they start from a lower risk profile and the effect of controlling risk factors on the cardiovascular system is not evident.

In the bibliography consulted we did not find an analysis of the variation of the ergometric parameters according to the presence of risk factors, however, it is necessary to identify which are the patients that may have lower benefits, which would allow for a deeper and more personalized work.

Regarding the amount of coronary arteries affected, the greatest changes were found in those patients with one or two arteries treated during the PCI. In patients in whom two arteries were treated, changes of greater magnitude in the ergometric parameters were observed in comparison with the patients who had just a single artery treated. It is likely that, in these patients, when a more complete revascularization was achieved, they presented a better recovery of left ventricular function. These results coincide with Zhao *et al*[18], who reported the absence of benefits after CR in patients with multivessel disease and incomplete revascularization; but contrast with Mori Junco *et al*[19], who demonstrated through the Cox regression, adjusted for age, sex, presence of diabetes mellitus and number of affected coronary vessels, that there were no significant differences in the risk of new cardiovascular events in patients with partial or complete revascularization after an CR program.

As is can be observed, the CR is a very useful intervention in the PCI scenario. It is beneficial not only for the improvement of the patient's cardiopulmonary function but, as it is a multidisciplinary process, the control of risk factors such as smoking, lipid levels and the optimization of chronic diseases such as diabetes mellitus, positively influence the patient who undergoes coronary stent implantation[20,21].

CONCLUSIONS

There was improvement in the ergometric parameters (heart rate at rest, exercise time and maximum oxygen consumption) and in the echocardiographic

parameters (left ventricle ejection fraction and telediastolic diameter) studied after a program of cardiac rehabilitation in patients who underwent percutaneous coronary intervention or after an ST-segment elevation acute myocardial infarction. A greatest benefit was found in patients with high blood pressure, smoking and those with two coronary arteries treated.

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