

ORIGINAL ARTICLE

Superior Cardiovascular Effect of the Periodized Model for Prescribed Exercises as Compared to the Conventional one in Coronary Diseases

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Abstract

Background: Physical exercise improves the survival and quality of life of coronary patients, but the ideal way of prescribing these exercises is still controversial.

Objective: To create a new periodized model for the prescription of exercises for coronary patients and compare it with a conventional model.

Methods: 62 coronary patients under pharmacological treatment were randomized into two groups: conventional (NPG, n = 33) and periodized (PG, n = 29) training. The two groups were submitted to the same exercises during the 36 sessions making up the program, but prescribed in different ways. All patients underwent an evaluation consisting of: medical admission consultancy, cardiopulmonary endurance testing, 1 maximum repetition test (1MR) and body composition evaluation.

Results: The VO₂ peak improved in both groups, although more effectively in the PG (4% against 1.7%, p < 0.001). In addition, the functional capacity of this group improved by 13%, and there was a significant reduction in the percent body fat (2.1%, p < 0.005) and body weight (1.9 kg, p < 0.005). The muscle strength of both groups improved as diagnosed by the 1RM test for six different muscle groups (quadriceps, hamstrings, brachial biceps, brachial triceps, pectoral and large dorsal), and showed no significant difference between the groups, evidencing that the two models had the same efficiency.

Conclusions: The present study showed that periodization of the training of cardiac patients can improve their cardiorespiratory capacity and reduce the percent body fat more effectively than the conventional one. (Int J Cardiovasc Sci. 2018;31(4):393-404)

Keywords: Coronary Artery Disease / physiopathology; Exercise; Exercise Therapy; Exercise Movement Techniques; Percutaneous Coronary Intervention.

Introduction

According to the World Health Organization, cardiovascular disease is responsible for 33% of all deaths occurring in the world per year.¹ In Brazil, more than 900,000 deaths of individuals over the age of 30 years were registered in 2011.² Despite this, the number of patients over the age of 60 years who survive

a cardiovascular event and require secondary care is increasing every year.² Therefore, the regular practice of physical exercise and/or of cardiac rehabilitation has become fundamental for the reduction in mortality and comorbidities associated with cardiovascular disease.^{3,4} Exercise training in coronary artery disease (CAD) patients include improvements in cardiovascular and skeletal muscle functions, endurance, inflammation,

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DOI: 10.5935/2359-4802.20180036

Manuscript received July 25, 2017, reviewed November 27, 2017, accepted December 19, 2017.

quality of life, and cognitive functions, and relieved clinical symptoms (dyspnea, sleep disorders, stress and depressive symptoms).^{5,6}

Guidelines which involve physical exercise as a form of treatment for CAD respect a relationship of equilibrium between safety and effect of training,^{7,8} and recommend that resistance training (RT) be performed in combination with aerobic exercise training (AT).^{5,6} For RT, they provide recommendations concerning the maximum load limits during training, such as 50% of intensity in the one repetition maximum (1RM) test.⁷⁻⁹ For AT, the ventilatory threshold measured during maximum cardiopulmonary exercise test (CPT) is often used in CAD patients. For beginners with low physical function/greater cardiac risk, the guidelines recommend 40% to 50% of maximum oxygen consumption (VO_2 peak), and for CAD patients with higher fitness level or less cardiac risk, 50% to 75% of VO_2 peak.^{5,6} However, none of those documents describe the way in which the prescription of the exercises should be organized by time. The maximum load limits for training allow for the elaboration of an exercise session but not for a progressive training program. Such organization, which should involve the type of stimulus according to the training phase (continuous and/or with intervals), the form of load progression (volume and/or intensity),¹⁰ the frequency (session/week) and the evaluation and reevaluation dates, is known as periodization.¹¹

Periodization has been used in sport training since the 1990s,¹² and its inclusion in rehabilitation has been recently debated.¹³⁻¹⁵ The training can be described in more detail using periodization, emphasizing its basic principles as: specificity, overload and reversibility. Periodization is the process of manipulating training variables to prevent overtraining, maximize training adaptations, and attain overcompensation or a training effect.⁹ The classical approach to periodization is linear periodized training which appears in exercise guidelines for cardiac patients.⁸ This type consists of initial high-volume and low-intensity. For this reason, the clinical and physical results obtained from periodized physical training in cardiopulmonary and metabolic rehabilitation programs could be improved, improving the quality of life of the patients involved.

Therefore, the objective of this study was to create a periodization model for the prescription of exercises aimed at patients with CAD in phase II of the cardiac rehabilitation program, and compare the results with those of patients submitted to a non-periodized program.

Method

Subjects

After approval of the project by the Ethics in Research of the Parana Pontific Catholic University (434/2010), 534 patients referred to the rehabilitation service of the Hospital Cardiológico Costantini (HCC) were evaluated.

The inclusion criterion was: men undergoing a percutaneous coronary intervention (angioplasty) or post-acute myocardial infarction with a left ventricular ejection fraction $\geq 50\%$ (evaluated by transthoracic echocardiography) and stratified as of low or moderate risk for the practice of exercise according to the American Association of Cardiopulmonary Rehabilitation and Prevention.¹⁶ The exclusion criteria were: musculoskeletal injuries induced by exercise, failure to complete the 36 sessions and/or cardiovascular complications that lead to stop the exercise program. Patients stratified as at low or moderated risk according to the American College of Sports Medicine (ACSM)¹⁰ were submitted to a medical admission consultancy (MAC).

After evaluation, 62 patients who met the inclusion criterion were selected.

Outcomes of the measures

Cardiopulmonary exercise test

Cardiopulmonary exercise test was carried out by a doctor from the HCC using a gas analyzer (Cortex, model Metalyzer3B), an electric treadmill (Inbramed, model Inbrasport Super ATL) and a computer program (Ergo PC Elite). The CPT chosen was an individualized ramp protocol for each patient, measuring blood pressure every 3 minutes with an analogical sphygmomanometer (Missouri) and a stethoscope (BD). In addition, the electrocardiographic tracing was monitored using electrodes (3M) throughout the entire endurance phase and recovery period. The volumes and gases (O_2 and CO_2) were calibrated before the tests. The V-slope method was used to determine the first ventilatory threshold (VT1). The second ventilatory threshold (VT2) was determined by respiratory point compensation, that is, transition between aerobic and anaerobic system in CPT. At this moment, the production of CO_2 loses linearity, exponentially increases and exceeds oxygen consumption (VO_2). This point was considered the VT2. Maximum oxygen consumption was established from the mean measured during the last 30 seconds of exercise.

One repetition maximum test

The 1RM test was carried out by one of the instructors from the HCC rehabilitation service. It was defined as the heaviest weight that can be moved in an exercise with no more than one repetition. Before starting the test, all subjects performed a 5-minute general warm-up of cycling and, after that, they carried out 10 repetitions with no additional load to adjust the speed and angle of movement. First, the instructor explained how to carry out each movement. The 1RM test was done encompassing the large muscle groups (quadriceps, hamstrings, pectoral, biceps, triceps and large dorsal), and the weight was increased by 5 kg at every repetition, with 3-5 minutes of rest between lifts after three to four subsequent attempts. The test was interrupted when the patient was unable to complete the one repetition with the proposed load, and, in this case, the previous load was considered the ideal one. The MEGAMOVEMENT station was used for the test in the following positions: extensor chair, leg curl, hip adduction and abduction, bench press, biceps and triceps curl, and high pulley rear.

Body composition evaluation

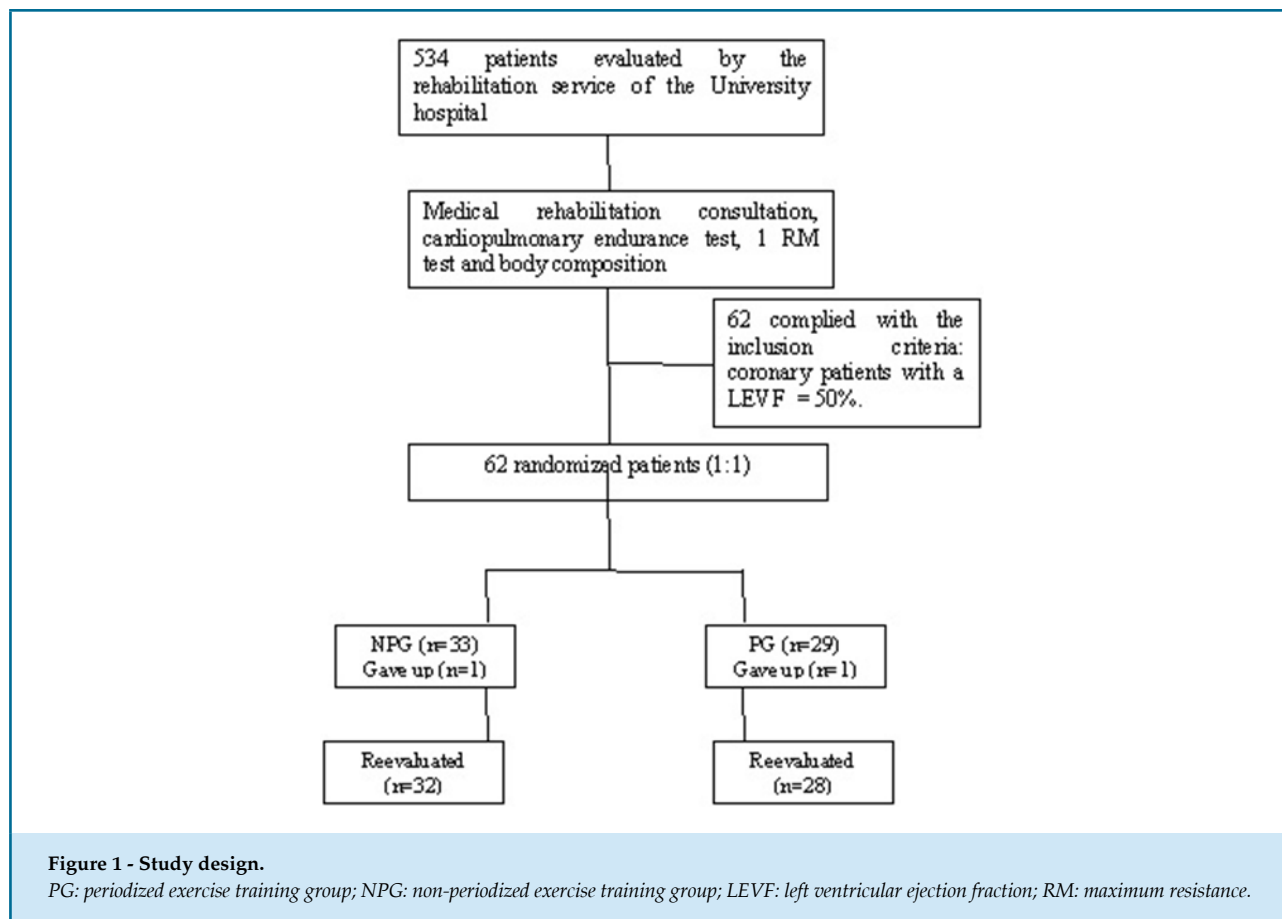
The body composition (Bc) was evaluated by a rehabilitation instructor. The Faulkner protocol was composed of six circumference measures (calf, thigh, arm, forearm, hip, and abdomen) and four skinfold measures (abdomen, suprailiac, subscapular and triceps).¹⁵

A tape measure (Wiso model R88) was used combined with an adipometer (Cescorf). Fat percentages, ideal body mass, lean and fat masses were calculated using the Faulkner equation.¹⁷

The volunteers were reevaluated after 36 sessions (MAC + CPT + 1MR + Bc).

Experimental design

This study was a randomized controlled trial, in which 62 male patients were included and randomly assigned to two groups: a non-periodized training group (NPG, n = 33) and a periodized exercise training group (PG, n = 29). Blinded scaled envelopes were prepared with papers named PG and NPG and kept secure by an independent person (Figure 1).



Training protocols

All subjects of both groups carried out AT and RT for 12 weeks, 3 sessions per week (36 sessions) on non-consecutive days.

The AT was carried out on a treadmill (Movement models RT250, LX160 and LX150), while, in the RT, ankle weights, dumbbells, and a muscle toning machine (MEGAMOVEMENT II station) were used.

Resistance protocol

The RT was made in upper and lower limbs, being two sessions for lower limbs and one session for upper limbs. Hence, 24 sessions of AT were carried out on a treadmill and with lower resistance exercise (LRE), whereas, in the other 12 sessions, the treadmill and upper resistance exercise (URE) were used. Thus, every two consecutive sessions of treadmill + LRE were followed by one of treadmill + URE.

The exercise selection for RT was similar in the two groups and included: leg extension, leg curl, hip flexion, knee flexion, hip abduction and adduction, ankles planti-flexion and hip flexion associated with knee flexion, elbow flexion and extension, shoulder abduction, scapular adduction, shoulders anterior flexion, pendulum exercise for the decoaptation of the shoulder joint, bench press, lat pulldown, biceps and triceps curl and pulley. The two groups carried out three sets of 15 repetitions of each exercise and the intensity of the RT varied from 30% to 50% of the loads obtained in the 1RM test. The difference between the two groups was that, in the PG, the intensity was increased progressively in each microcycle (four weeks) and, in the NPG, the intensity was increased according to patient's resilience (Table 1). According to the ACSM,¹⁰ the rest intervals between sets were of 1 to 2 minutes.

Aerobic protocol

The intensity of the AT on the electric treadmill for the two groups was defined from the result obtained in the CPT. The heart rate (HR) corresponding to the VT1 was defined as the lower limit training (HRVT1), whereas the HR corresponding to the VT2 was defined as the upper limit training (HRVT2). The interval between HRVT1 and HRVT2 corresponded to the ideal training intensity for each patient, known as the target zone (TZ).³

The two groups began the AT program with 25 minutes of activity divided into 5 minutes of warm-up,

Table 1 - Resistance and aerobic training programs for NPG and PG

Training periods	Sets	Repetitions	Load (%1RM)
Resistance training			
NPG			
Weeks 1 - 12	3	15	30-50%
GP			
Weeks 1 - 4	3	15	30%
Weeks 5 - 8	3	15	40%
Weeks 9 - 12	3	15	50%
Endurance training		Intensity	
NPG			
Weeks 1 - 12	HRVT1 to HRVT2		
GP			
Weeks 1 - 6	HRVT1		
Weeks 7 - 12	Interval training (2 min HVT1+AHR, 1 min HRVT2)		

PG: periodized exercise training group; NPG: non-periodized exercise training group; HRVT1: heart rate ventilatory threshold 1; HRVT2: heart rate ventilatory threshold 2; AHR: average heart rate.

15 minutes of training in the TZ and the 5 final minutes of cool down. After every three sessions, 5 extra minutes of training within the TZ were added. From the 10th to the 36th session, the total work time was of 40 minutes, 30 of which were within the TZ. The 5 minutes of warm up and cool down each were maintained throughout the 36 sessions.

The NPG trained along the 36 sessions within the TZ range proposed prescribed by HR (corresponding to the VT1 and VT2 of the CPT) without a predict load progression. The patient chose the training intensity, provided it was within the TZ (Figure 2A).

The AT of PG was divided in two microcycles of 18 sessions. First the average of HR (AHR) was determined between HRVT1 and HRVT2, obtained from the formula: $AHR = (HRVT2 - HRVT1) / 2$. The training intensity until the 18th session was determined by HRVT1 + AHR. This was designated as target zone 1 (TZ1). The second target zone (TZ2) was determined by the interval between HRVT1 + AHR and HRVT2. For instance, if the patient displayed HR in VT1 of 100 bpm and 130 bpm in VT2,

the TZ1 was the interval between 100 and 115 bpm, and the TZ2 between 115 to 130 bpm. After the 18th session, the interval training commenced, corresponding to 2 minutes of intensity in AHR and 1 minute in HRVT2.

Thus, the difference between the models of the AT proposed was based on the progression of load, that is, pre-determined in PG (18th session), regulated by the increase of HR of training and change within the TZ (TZ1 for TZ2), whereas in NPG, the intensity was regulated only by patient, always between TZ1 and TZ2 (Table 1). The patients of NPG and PG trained with a conventional HR monitor (Oregon model HR102). Additionally, the instructors check regularly the HR with finger oximeters (Nonin). It is important to emphasize that coronary patients at low risk for the practice of exercises were reminded to train between the ventilatory thresholds, following the recommendation of the Brazilian Society of Cardiology.³

Throughout the 36 training sessions of the NPG, the safety criteria for training and the intensity limits were respected, the loads for RT varied from 30% to 50% of the 1RM test, and the TZ limits for AT were also respected. Moreover, the volume of training was maintained, carrying out three sets of 15 repetitions for each localized exercise and a maximum time of 40 minutes of AT after the 10th session. These limits were presented to the patients, who defined their ideal training loads themselves according to their comfort zone and received orientation from the instructor regarding the implementation of the movements.

In the PG the prescription of their exercises was periodized. This group performed the same volume of training with the same intensity intervals prescribed for the NPG, but with the prescription organized by time. Thus, three training macrocycles were created, the first known as adaptation (MAD), the second as fundamental (MFU) and the third as specific (MSP). Each macrocycle, which presented a different objective, was composed of 12 microcycles and each microcycle was defined as a group of three classes or training sessions. The objective of MAD was to improve neuromuscular coordination and cardiopulmonary adaptation. The objective of MFU was to improve the ventilatory threshold and muscle fiber recruitment. And the objective of MSP was to improve VO₂ peak (Figure 2) and resistance strength.

Data analysis

The results obtained in this study were expressed as means, medians, minimum and maximum and standard

deviations (quantitative variables) or frequencies and percentages (qualitative variables). The data were tested through normal distribution using the Kolmogorov-Smirnov test. The groups were compared regarding the quantitative variables using Student t test for dependent samples or Mann-Whitney nonparametric test. Regarding the qualitative variables, the comparisons were made considering Fisher exact test or chi-square test. Student t test was used to compare the moments of evaluation in the case of paired samples or nonparametric Wilcoxon test. In order to compare the groups and the evaluation moments (initial x final), a variance analysis model with a repeated measurements factor (split-plot) was considered. All variables which presented significant interaction between group and evaluation moment were analyzed by comparing the groups at each moment, and the evaluation moments within each group, where values for $p < 0.05$ indicated statistical significance. The data were analyzed using the Statistica V 8.0 program.

Results

Baseline characteristics

One NPG patient and another from the PG did not complete the 36 exercise sessions. As a consequence, a total of 60 patients (NPG $n = 32$ and PG $n = 28$) were reevaluated.

Table 2 provides the baseline characteristics of the 60 patients who met the inclusion criteria. All variables evaluated had a normal distribution (Kolmogorov-Smirnov test, $p > 0.05$) (Table 2).

Adverse events during treatment period

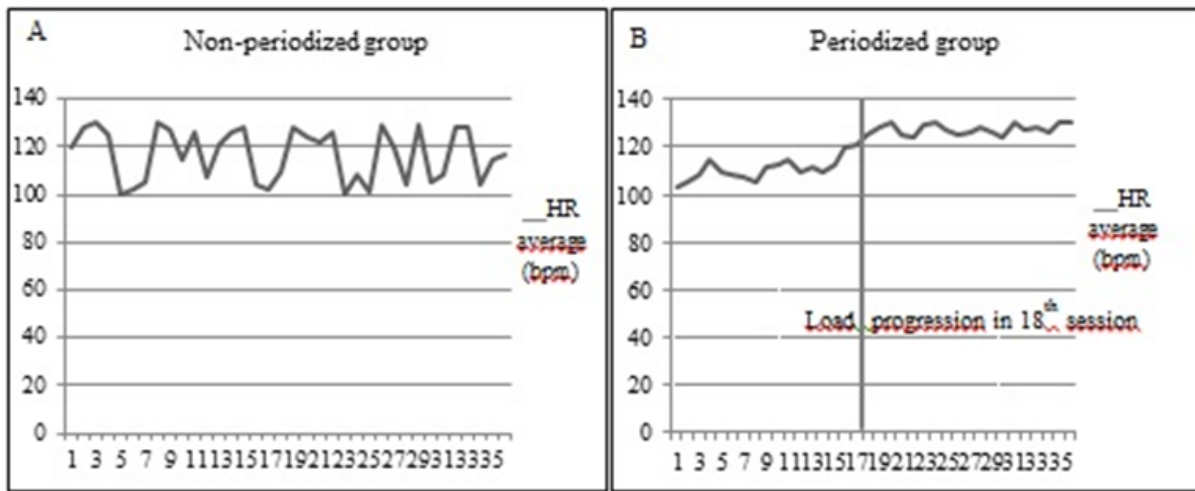
No significant adverse events were registered during the training period.

Body composition parameters

No significant differences were observed between groups. However, there was a significant difference within the groups in all variables in PG and only in %fat above ideal in NPG (Table 3).

Cardiopulmonary testing

There was no significant difference between baseline values for all cardiopulmonary variables between the two groups. However, significant post-training changes were observed in functional capacity (FCR) reached, VO₂ peak and VO₂ for the VT1 and VT2, with superior training



SESSIONS		1 st -12 th				13 th -24 th				25 th -36 th			
MACROCYCLES		ADAPTATION				FUNDAMENTAL				SPECIFIC			
TRAINING OBJECTIVES		NEUROMUSCULAR COORDINATION				IMPROVEMENT IN ANAEROBIC THRESHOLD				IMPROVEMENT IN VO ₂ PEAK			
MICROCYCLES		1	2	3	4	5	6	7	8	9	10	11	12
LOAD PROGRESSION													
AEROBIC TRAINING		HRVT1				2 min HRVT1- 1 min HRVT2							
Time (min)	50												
	40												
	30												
	20												
RESISTANCE TRAINING		LOAD PROGRESSION											
% 1 RM test	60												
	50												
	40												
	30												

Figure 2 - Periodized exercise prescription model. A, B- Heart rate variation in aerobic training. C- Exercise prescription model. RM: maximal resistance; HRVT1: heart rate ventilatory 1; HRVT2: heart rate ventilatory 2.

effect for PG. In addition, there was a significant difference within groups in FCR, VO₂ peak, VO₂VT1, VO₂VT2, VT2 speed in both groups compared pre- and post-training. A significant difference was noted in maximum speed reached in PG and VT1 and VT2 inclination in NPG in the comparison between groups (Table 4).

Skeletal muscle function

The evaluation of the muscle strength parameters within groups, compared pre- and post-training, showed a significant improvement. In a comparison made between the groups, no significant difference could be found (Table 5).

Table 2 - Baseline characteristics of the study population

Sample characteristic	PG	NPG
n (men)	28 (100%)	32 (100%)
Age \pm SD, years	55.89 \pm 8.2	62.4 \pm 11.8
Left ventricular ejection fraction, ** %	65.57 \pm 5.5	66.09 \pm 5.7
Body mass index	28.2 \pm 3.5	28.9 \pm 4.4
Abdominal circumference	100.7 \pm 9.0	101.0 \pm 10.6
Positive family history / cardiovascular disease	20 (71.5%)	24 (80%)
Dyslipidemia	27 (96.7%)	32 (100%)
Obesity	12 (42.8%)	22 (68.75%)
Sedentary life style	22 (78.5%)	25 (78.1%)
Stress	25 (89.2.8%)	22 (68.75%)
Smoking habit	4 (14.2%)	8 (25%)
Diabetes mellitus	5 (17.8%)	3 (9.3%)
High blood pressure	12 (42.8%)	15 (46.8%)
Stratification of risk for exercises		
Low risk	21 (75%)	25 (78.1%)
Moderate risk	8 (21.6%)	3 (8.1%)
Anatomic location of injuries		
Right coronary	5 (14.2%)	
Posterior descending	0	
Left main coronary	2 (7.1%)	
Anterior descending	18 (64.2%)	
Diagonal	5 (17.8%)	
Circumflex	6 (21.4%)	
Marginal	0	
Arteries with stent implants		
Right coronary		
1 stent	4 (14.2%)	
2 stents	1 (3.5%)	
3 stents	0	
Posterior descending		
1 stent	1 (3.5%)	
Left main coronary		
1 stent	2 (7.1%)	

Anterior descending	
1 stent	16 (57.1%)
Diagonal	
1 stent	1 (2.7%)
Circumflex	
1 stent	6 (21.4%)
2 stents	6 (21.4%)
Marginal	
1 stent	0
Incomplete revascularization of myocardium	1 (3.5%)
Prior surgery for revascularization of myocardium	2 (7.1%)
Prior angioplasties	5 (14.2%)
Medications, [†] %	
Antiplatelet agents	28 (100%)
Anticoagulant	28 (100%)
Antihypertensive	13 (46.4%)
Beta-blockers	26 (92.8%)

PG: periodized exercise training group. NPG: non-periodized exercise training group; ** Obtained by transthoracic echocardiography; † Standard dose of medication.

Discussion

This study ascertained the following outcomes: superior improvement of body fat, fat above ideal and body mass, VO₂ peak and VO₂ at VT1-2 in the PG; muscle strength improvement in both groups. Periodization training is suggested in most recent guidelines.⁵⁻⁸ However, the superiority of periodized training (RT and AT) has been poorly studied in CAD patients.

The main finding of this study was that the periodized exercise prescription program was superior to the conventional one with respect to the increase in VO₂ peak for coronary patients taking part in a rehabilitation program. VO₂ peak is closely associated with morbidity and mortality in cardiac patients.¹⁸ This information is very important since periodization is still not in the rehabilitation programs of CAD patients.¹⁹ In addition, VO₂ peak is recognized as being the best indicator of survival for this population.²⁰⁻²² Therefore, the inclusion

Table 3 - Body composition parameters

Group	PG (n = 28)		p	NPG (n = 32)		p
	Pre	Post		Pre	Post	
Body fat (%)	24.0 ± 3.5	21.9 ± 3.6	0.03*	23.9 ± 4.4	22.9 ± 4.1	0.34
Fat above ideal (%)	6.7 ± 3.2	4.8 ± 2.9	0.02*	5.6 ± 5.7	4.5 ± 5	0.42
Body mass (kg)	85.9 ± 11.7	77.4 ± 9.7	0.02*	83.9 ± 15.1	83.2 ± 14.9	0.84

PG: periodized exercise training group; NPG: non-periodized exercise training group. *p < 0.05 (Student t test) within-group differences.

Table 4 - Cardiopulmonary testing

Group	PG (n = 28)		p	NPG (n = 32)		p
	Pre	Post		Pre	Post	
FCR (% of predicted value)	88.7 ± 12.4	101.9 ± 13.8 [†]	0.00*	80.2 ± 15.3	86.5 ± 12.2 [†]	0.00*
VO ₂ peak (mL/kg/min ⁻¹)	27.2 ± 6.3	31.5 ± 7.3 [†]	0.00*	22.9 ± 5.7	24 ± 6 [†]	0.00*
VO ₂ VT2	23.64 ± 4.8	27.7 ± 3 [†]	0.00*	19.9 ± 5.4	21.6 ± 5.4 [†]	0.04*
VO ₂ VT1	17.0 ± 2.3	20.7 ± 2.3 [†]	0.00*	15.8 ± 3.5	16.4 ± 3.4 [†]	0.23
HR maximum reached	159.7 ± 22	162.6 ± 18.5	0.30	138.3 ± 18.3	136.1 ± 18.6	0.33
HR VT2	169.9 ± 21	141.9 ± 20.5	0.39	119.2 ± 16.2	118.8 ± 15.8	0.86
HR VT1	110 ± 14.5	114.3 ± 15.7	0.10	100 ± 15.6	96.1 ± 20.6	0.29
Maximum speed reached (km/h)	8.2 ± 2.4	8.8 ± 2.4	0.05*	6.8 ± 1.9	7.2 ± 1.9	0.19
Speed VT2 (km/h)	7.1 ± 1.8	7.9 ± 1.8	0.05*	5.7 ± 1.5	6.3 ± 1.3	0.02*
Speed VT1 (km/h)	5.4 ± 1.4	6 ± 1.9	0.06	4.5 ± 1.3	4.8 ± 1	0.12
% max inclination (degrees)	13 ± 6.1	14.3 ± 6.1	0.12	12.3 ± 4.4	13.8 ± 4.3	0.12
% inclination VT2 (degrees)	12 ± 5.4	12.5 ± 6.6	0.45	10.3 ± 4	12.2 ± 3.3	0.01*
% inclination VT1 (degrees)	8.4 ± 4.2	9.6 ± 5.2	0.14	7.4 ± 3.2	8.7 ± 3	0.05*

PG: periodized exercise training group; NPG: non-periodized exercise training group; FCR: functional capacity reached; HR: heart rate; * Intra-group difference (Student t test for dependent samples, p ≤ 0.05); † Difference between groups (Student t test, p < 0.05).

of periodization as a fundamental basis for exercise prescription in cardiac rehabilitation programs could improve the results in VO₂ peak.

Cardiopulmonary testing

The two training groups showed improvements in VO₂ peak and in the VO₂ of the VT2, but only the PG showed a significant increase in the VO₂ of the VT1.

VO₂ peak is an independent predictor of mortality and morbidity in CAD patients.⁶ In the comparison between groups, the PG showed a significant effect compared to the NPG. Also, both groups improved their functional capacity (% of the predicted value), with most significant differences in favor of PG, which were attributed to the better structuring of the load progression in this group. The classical approach to periodization is the linear periodized training that appears in exercise training

Table 5 - Intra & intergroup comparison of muscle strength

Group	PG		P	NPG		P
	Pre	Post		Pre	Post	
Extensor chair (kg)	13.5 ± 5.5	24.0 ± 8.3	0.00*	10.4 ± 5	20.6 ± 8.4	0.00*
Leg curl (kg)	7.9 ± 3.3	14.1 ± 4.3	0.00*	6.5 ± 3	11 ± 6.5	0.00*
Bench press	12.6 ± 4.5	21.2 ± 6.5	0.00*	9.7 ± 5	18.2 ± 6.9	0.00*
Triceps	8.9 ± 3.6	15.5 ± 4.4	0.00*	7.2 ± 3.5	12.3 ± 3.5	0.00*
Biceps	8.4 ± 2.5	13.3 ± 3.4	0.00*	7.2 ± 3.1	11.4 ± 3.6	0.00*
High pulley rear	15.5 ± 5.7	28.5 ± 7.9	0.00*	11.8 ± 7.2	23.9 ± 11.4	0.00*

* Intra-group difference (Student *t* test for dependent samples, $p < 0.05$)

guidelines for cardiac patients,^{6,8} but has never been compared to non-periodized training in this population. Linear periodized training has superior cardiac and musculoskeletal function as compared to non-periodized training for athletes and healthy subjects^{10,23} and with respect to cardiometabolic risk in obese adolescents.²⁴ Ribeiro et al.²⁵ have described that, for beginners, walking programs remain the most prescribed modality for CAD patients because they are safe, controlled, and can be performed anywhere.

The intensity of the AT of the NPG was moderate, between VT1 and VT2, that is, between the minimum and maximum stable phases of lactate production.¹⁹ Therefore, they trained during almost the whole period (36 sessions) predominantly using the aerobic system as their energy source, without generating acidosis, and metabolic recovery was not necessary during the session, allowing for the maintenance of continuous training. Jolliffe et al.¹ have carried out a meta-analysis involving 8,440 patients with 32 randomized and controlled studies. They concluded that AT was safe, improved the aerobic capacity and reduced mortality, confirming the findings of the present study for PG.

The volunteers in the PG trained in the same interval of intensity as the NPG (between the HRVT1 and HRVT2). A training TZ was created for both groups corresponding to the HR interval for VT1 and VT2, but a load progression was organized for the PG. The intensity of AT was limited to the AHR up to the 18th session and this interval training was defined as the ideal to improve aerobic performance.²² The improvement of the VO₂ of the VT2 in the PG was attributed to this specificity of

the training, which did not occur in NPG. As from the 19th session (half of the fundamental macrocycle), the volunteers started training above the AHR up to the HR corresponding to the VT2. Due to the increased intensity of training, interval training started in PG. From the 5th minute of walking on the treadmill, the patient trained 2 minutes close to the HRVT1 followed by 1 minute close to the HRVT2, and maintained this alternating scheme until completing 30 minutes of workout. Due to its specificity, this training intensity promoted a greater increase in the VO₂ of the VT2, a fact confirmed by the findings of the present study. It is important to highlight that this AT with intervals, limited by the maximum stable lactate phase, has already been proven. Cornish et al.²⁶ have published a meta-analysis involving 213 patients with seven randomized studies, which demonstrated the need for more studies in order to determine the risks and benefits of interval training above the VT2. In addition, the authors have noted different prescription methodologies, with the patients starting the exercise program with sets of high intensity training with intervals in the majority of cases.²⁷ We believe that periodization allows for a greater chance of standardizing the prescriptions.

Body composition

The volunteers in the PG showed reductions in their fat mass, weight of fat above the ideal value and in their body weight. Increments in body mass and body fat are associated with several chronic diseases, such as diabetes and cardiovascular disease.²⁸

Studies have shown that moderate AT promotes an improvement in body composition.^{29,30} This was important because obesity is considered to be an important modifiable cardiovascular risk factor.³¹ A simple improvement in food habits is not sufficient for a rapid and appropriate decrease in fat mass. Therefore, the physical exercise association was fundamental for body weight decrease and long-term maintenance of these changes.³¹ Studies^{28,32,33} have recognized aerobic exercise as the most suitable form of training by providing positive effects on glucose and lipids and decrease on body fat and the strength exercises. Inoue et al.²⁴ have shown that the association of strength and AT was more effective than only AT to improve lipid profile and insulin resistance sensitivity on obese adolescents.

The improvement in aerobic capacity or exercise tolerance results in a greater consumption of calories to maintain the activity and, consequently, burning more fat.²⁴ Lira et al.³⁴ have studied the effects of intensity and type of exercise on lipoprotein profiles and highlighted the higher energy expenditure achieved by associating volume and intensity. This fact justifies the finding that the PG, with its greater cardiopulmonary evolution and tolerance to exercise, presented greater body fat decrease. This is because improving the aerobic capacity increases the caloric expenditure per session, since the patient is walking more within a same time interval.

Skeletal muscle function

Both training groups presented a significant improvement in strength after the training period. In this case, the PG showed no advantage.

During MAD the patients worked with loads equivalent to 30% of the maximum determined in the 1RM test, in the MFU, with 40%, and in the MSP, with 50%. This organized progression of the load was not more effective than the random progression used for the NPG. This could be attributed to the fact that these low training loads did not recruit different energy sources and/or types of muscle fibers. In addition, in the first 12 weeks of training, the increase in strength occurs due to neural adaptation and not to hypertrophy, which is independent of the load.^{8,11} The increase in strength noted in both groups could have contributed to the improvement in the VO_2 peak, in the walking speed and in the inclination reached during the treadmill test.²⁷

Therefore, the training study is extremely important to both athletes, to reach high performance, and patients,

such as those with heart disease, to reduce the risk of mortality, which has great social relevance.

Conclusion

The present study showed that, within the cardiac rehabilitation programs for coronary disease patients, periodization of the training can improve the results as compared to the conventional model, when considering the following variables: VO_2 peak, VO_2 for the VT2, VO_2 for the VT1, %fat and body weight. These findings are very important for future studies involving physical training and cardiac rehabilitation.

We believe that, at the present moment, before evolving into comparative studies between continuous exercises of moderate intensity versus high intensity exercises with intervals, periodization should be included as a prescription tool aimed at improving the results of the intervention or treatment of those with coronary disease with physical exercise.

Study limitations

Some of the study limitations were the small size of the sample and not using the Faulkner protocol to evaluate body composition. In addition, inflammatory biomarkers, oxidative stress analysis and drug reduction for hypertension were not performed.

Author contributions

Conception and design of the research and analysis and interpretation of the data: Macedo RM; Acquisition of data: Macedo RM, Sebastião Neto F; Statistical analysis: Macedo RM, Macedo ACB, Olandoski M; Obtaining financing: Macedo RM, Guarita-Souza LC, Silveira RP; Writing of the manuscript: Macedo RM, Macedo ACB, Faria-Neto JR, Costantini CR, Costantini CO, Guarita-Souza LC, Carvalho KAT; Critical revision of the manuscript for intellectual content: Macedo RM, Macedo ACB, Faria-Neto JR, Guarita-Souza LC.

Potential Conflict of Interest

No potential conflict of interest relevant to this article was reported.

Sources of Funding

There were no external funding sources for this study.

Study Association

This article is part of the thesis of Post Doctoral submitted by Rafael Michel de Macedo, from *Pontifícia Universidade Católica do Paraná*.

Ethics approval and consent to participate

This study was approved by the Ethics Committee of the *Pontifícia Universidade Católica do Paraná* under the protocol number 434/2010. All the procedures in this study were in accordance with the 1975 Helsinki Declaration, updated in 2013. Informed consent was obtained from all participants included in the study.

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