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Human Kinetics
ORIGINAL RESEARCH

Effects of Aerobic Exercise Applied Early After Coronary Artery Bypass Grafting on Pulmonary Function, Respiratory Muscle Strength, and Functional Capacity: A Randomized Controlled Trial

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Background: Physical activity is beneficial in several clinical situations and recommended for patients with ischemic heart disease, as well as for those undergoing cardiac surgery. **Methods:** In a randomized controlled trial, 34 patients underwent coronary artery bypass grafting. A randomized control group (n = 15) submitted to conventional physiotherapy. The intervention group (n = 19) received the same protocol plus additional aerobic exercise with cycle ergometer. Pulmonary function by spirometry, respiratory muscle strength by manovacuometry, and functional capacity through 6-minute walking test was assessed before surgery and at hospital discharge. **Results:** There was significant reduction in pulmonary function in both groups. In both groups, inspiratory muscle strength was maintained while expiratory muscle strength significantly decreased. Functional capacity was maintained in the intervention group (364.5 [324.5 to 428] vs. 348 [300.7 to 413.7] meters, $P = .06$), but it decreased significantly in control group patients (320 [288.5 to 393.0] vs. 292 [237.0 to 336.0] meters, $P = .01$). A significant difference in functional capacity was also found in intergroup analyses at hospital discharge ($P = .03$). **Conclusion:** Aerobic exercise applied early on coronary artery bypass grafting patients may promote maintenance of functional capacity, with no impact on pulmonary function and respiratory muscle strength when compared with conventional physiotherapy.

Keywords: cardiac surgery, cycle ergometer, physiotherapy, rehabilitation

Coronary artery bypass grafting (CABG) is a therapeutic modality widely applied for treatment of coronary artery disease.[1] In Brazil, in 2014, more than 22,000 surgeries were performed.[2] This procedure has been proposed to (i) minimize symptoms, (ii) improve heart function, and (iii) increase survival.[3]

Physical activity is beneficial in several clinical situations and recommended for patients with ischemic heart disease and also for those undergoing cardiac surgery.[4] Herdy et al[5] conducted a controlled clinical trial, which evaluated cardiopulmonary rehabilitation composed by preoperative advices and muscle and breathing exercises after CABG. Herdy et al observed significant reduction in pulmonary complications and incidence of arrhythmias, as well as improvement in functional capacity.[5]

In a search of the PubMed database, few studies were found concerned with the role of aerobic exercise in critically ill patients. Patients were initially perceived as "too weak" or "very clinically unstable" for mobilization,[6] although they demonstrated beneficial effects from exercise, especially when started early.[7]

Early mobilization is feasible and safe even in mechanical ventilated critical patients.[8–10] Schweickert et al[11] reported that early mobilization is associated with decreasing hospital length of stay, delirium, days of mechanical ventilation, and better functional outcomes. In addition, lack of early mobilization in the intensive care unit (ICU) may increase readmission and death rates in the first-year follow-up.[12]

One strategy for rehabilitation in ICU is to perform aerobic exercise with a cycle ergometer.[13] This modality of activity is safe and feasible in bedridden patients with chronic obstructive pulmonary disease (COPD),[14] during hemodialysis in patients with terminal renal failure,[15] and in mechanically ventilated patients.[7]

After cardiac surgery, Cordeiro et al[16] showed that the use of cycle ergometer at the ward, from the third postoperative day, is feasible, safe, and well accepted. However, the effects of this resource applied at ICU since the first postoperative day have not been demonstrated.

In the current article, the effects of aerobic exercise with a cycle ergometer applied early in patients undergoing CABG were investigated. Pulmonary function, respiratory muscle strength, and functional capacity compared to conventional physiotherapy were assessed. It was hypothesized that, in CABG patients, the addition of early aerobic exercise during hospital stay may lead to significant improvements in assessed outcomes.

Methods

Subjects

A nonprobabilistic sample of 42 patients that underwent CABG between January and October 2015 were included, of which 34 completed the entire study (Figure 1). Demographic, clinical, and surgical data from these patients are presented in Tables 1 and 2.

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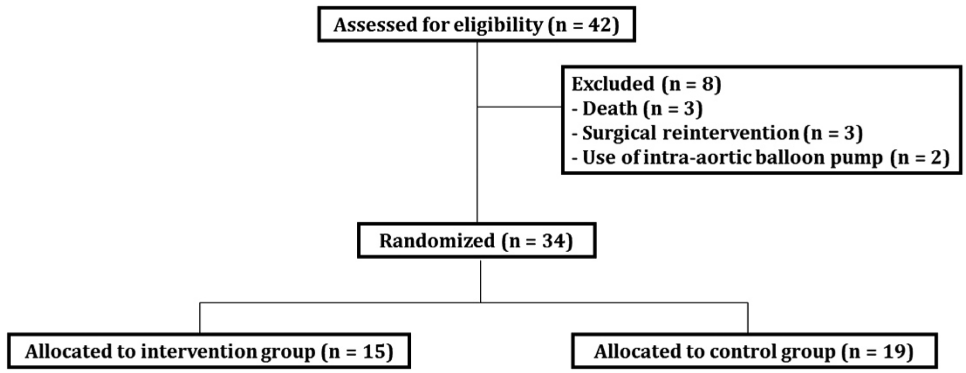

Figure 1 — Study flowchart.

Table 1 Demographic and Clinical Data of Patients Undergoing Coronary Artery Bypass Grafting

Variables	Intervention (n = 15)	Control (n = 19)	*P*
Gender (n)			0.15[a]
Male	12	10	
Female	3	9	
Age (years)	62.5 ± 7.1	62.8 ± 4.2	0.85[b]
BMI (kg/m^2)	26 ± 3.2	26 ± 4	0.88[b]
Comorbidities (n)			
Hypertension	11	17	0.37[a]
Smoking	4	6	0.99[a]
AMI	8	7	0.49[a]
Diabetes mellitus	5	11	0.18[a]
Dyslipidemia	8	5	0.16[a]
InsCor			0.49[c]
Low risk	14	17	
Medium risk	1	1	
High risk	0	1	
MV duration (hours)	13.4 ± 4.1	13.7 ± 4.4	0.64 [b]
ICU stay (days)	3.2 ± 1.4	3.6 ± 1.4	0.31 [b]
Hospital stay (days)	8.1 ± 0.9	8.3 ± 2.2	0.53 [b]

Abbreviations: BMI, body mass index; AMI, acute myocardial infarction; InsCor, mortality risk in cardiac surgery; MV, mechanical ventilation; ICU, intensive care unit.

[a] Fisher's exact test; [b] Mann-Whitney test; [c] Kruskal-Wallis test.

Table 2 Surgical Data of Patients Undergoing Coronary Artery Bypass Grafting

	Intervention (n = 15)	Control (n = 19)	
Variables	Median (Q25; Q75)*	Median (Q25; Q75)*	*P*
Bypasses	3 (2; 3)	3 (2.5; 3)	0.06
Drainage tubes	2 (2; 2)	2 (1.5; 2)	0.15
Pump time (min)	90 (67.5; 92.5)	110 (77.5; 122.5)	0.06
Cross-clamp time (min)	63 (47; 68.5)	66 (54.5; 98.5)	0.13
Surgery time (min)	221 (187.5; 245)	242 (207.5; 265)	0.09

* ANOVA one-way.

Exclusion criteria were the use of an intra-aortic balloon pump or other invasive femoral device, surgical reintervention, death, and prolonged hospital stay (more than 10 days). Patients were informed about the nature and risks of procedures before their written informed consent was obtained. This study was approved by the Institutional Research Ethics Committee (No. 691.625).

Study Design

This was a prospective randomized controlled trial with parallel interventions. All patients participated in a physiotherapy program, starting within 24 hours after CABG. Participants were randomly assigned by simple randomization (a single sequence of random assignments by draw) to (i) the control group (n = 19), who received conventional physiotherapy, or (ii) the intervention group (n = 15), who received the same protocol plus additional aerobic exercise with a cycle ergometer. Patients, physiotherapists who supervised the sessions, and investigators who performed the measurements were not blinded for treatment allocation. Pulmonary function by spirometry, respiratory muscle strength by manovacuometry, and functional capacity through 6-minute walking test (6MWT) were assessed prior to surgery and at hospital discharge.

Measurements

Identification. Patients were identified by demographic and clinical data.

Mortality Risk. Mortality risk was assessed using InsCor, a Brazilian score that considers as risk factors the following: age, gender, associated surgery, recent myocardial infarction, reoperation, aortic valve treatment, tricuspid valve treatment, creatinine, ejection fraction, and events before surgery, such as intra-aortic balloon, cardiogenic shock, ventricular tachycardia or fibrillation, orotracheal intubation, acute renal failure, inotropic drugs, and heart massage.[17]

Manovacuometry. A digital manovacuometer (MVD300, Globalmed, Porto Alegre, Brazil) was used to assess respiratory muscle strength through maximal inspiratory and expiratory pressures (MIP and MEP) according to guidelines for respiratory muscle testing.[18] To calculate predicted values, equations were used as described by Neder et al.[19]

Spirometry. A spirometer Microlab (Cardinal Health, Dublin, OH) was used to measure pulmonary function: FVC—forced vital capacity; FEV_1—forced expiratory volume in the first second; FEV_1/FVC—forced expiratory coefficient in the first second; and PEF—peak expiratory flow, according guidelines for lung function testing.[20]

Six-Minute Walk Test. A 6MWT was used to verify functional capacity according to American Thoracic Society guidelines.[21] Before and after the test, arterial blood pressure (ABP) was measured with a digital sphygmomanometer (G-Tech RW450, Rossmax International, Taipei, Taiwan). During the test, patients used a digital oxymeter (SB100, Rossmax International, Taipei, Taiwan) to monitor heart rate and peripherical oxygen saturation.

Physiotherapy Protocols

Patients were randomly assigned to conventional physiotherapy (control group) or aerobic exercise (intervention group). The physiotherapy protocol[22] were identical in both groups. In the intervention group, aerobic exercise with a cycle ergometer was added.

Sessions were performed twice a day in the ICU and once a day at the ward, until hospital discharge. At the ICU, arterial blood pressure, heart rate, and peripherical oxygen saturation were assessed by multiparametric monitor (Infinity Delta XL, Dräger Medical, Lübeck, Germany). ABP was assessed at the ward before and after sessions by a digital sphygmomanometer. During exercise patients used a digital oximeter to monitor heart rate and peripheral oxygen saturation. Borg Scale[23] was used to assess perceived exertion.

Conventional physiotherapy protocol involved secretion removal techniques, diaphragmatic breathing exercises, assisted and active exercises for upper and lower limbs, and progressive ambulation.[22]

Intervention protocol involved the same procedures with additional aerobic exercise with a cycle ergometer without load. At the ICU, patients were positioned in Fowler 45° to perform 5 minutes of exercise. At the ward, patients performed aerobic exercise seated in a chair for 10 minutes in first and second days, and for 20 minutes from third day until hospital discharge. Patients performed the exercise at their own pace, although they were asked to pedal as fast as possible, keeping the same rhythm during the intervention period.[13,16,24] All patients received the same analgesia protocol, with intravenous morphine (2–5 mg every 4 hours).

Statistical Analysis

Data were statistically analyzed using Stata/SE 12.1 (Stata Corp, College Station, TX). To verify normality, Shapiro-Wilk was used. Quantitative variables were expressed as mean and standard deviation or median and interquatile range and their differences were assessed using Mann-Whitney, Wilcoxon, or ANOVA one-way tests, according to normality. For categorical variables, Fisher's exact and Kruskal-Wallis tests were performed. Statistical significance was set at $P < .05$.

Results

Thirty-four participants (age 62.7 ± 15.6 years, 64.7% male, body mass index 26 ± 2.6 kg/m^2) completed the study. Left internal thoracic artery (LITA) was used as graft in all patients and 91.2% of them had low mortality risk. Intubation time, ICU stay, and hospital stay was 13.6 ± 4.2 hours, 3.4 ± 1.4 days, and 8.2 ± 1.7 days, respectively, with no differences between the studied groups (Table 1).

In both groups, there was a significant decrease in FVC, FEV_1, and PEF at hospital discharge compared with the preoperative period. Inspiratory muscle strength was maintained in both groups, while expiratory muscle strength significantly decreased (Table 3).

Functional capacity, measured by predicted distance walked in the 6MWT, was maintained in the intervention group (364.5 [324.5 to 428.0] vs. 348.0 [300.7 to 413.7] meters, $P = .06$), but decreased significantly in patients submitted to conventional physiotherapy (320.0 [288.5 to 393.0] vs. 292.0 [237.0 to 336.0] meters, $P = .01$) (Figure 2). A significant difference was also found in intergroup analyses at hospital discharge ($P = .03$).

Table 3 Pulmonary Function and Respiratory Muscle Strength at Baseline and After Early Aerobic Exercise and Control Groups

	Intervention (n = 15)	Control (n = 19)	*P*
FVC (%)			
Preoperative	81.9 ± 16.6	79.4 ± 20.3	0.71
Hospital discharge	54 ± 14	51.4 ± 11.4	0.57
P	0.001	0.001	
FEV_1 (%)			
Preoperative	83 ± 15	80.8 ± 18.6	0.72
Hospital discharge	56.6 ± 14.9	54.4 ± 12.6	0.66
P	0.001	0.001	
FEV_1/FVC (%)			
Preoperative	103.9 ± 8.7	103.1 ± 11.1	0.71
Hospital discharge	105.2 ± 9.3	105.5 ± 12.2	0.93
P	0.13	0.27	
PEF (%)			
Preoperative	60.4 ± 17.1	64.3 ± 22.4	0.60
Hospital discharge	46.8 ± 14.3	51.9 ± 17.9	0.61
P	0.02	0.01	
MIP (%)			
Preoperative	78.2 ± 32.6	68 ± 22.5	0.29
Hospital discharge	68.3 ± 34.2	52.8 ± 13.5	0.08
P	0.14	0.16	
MEP (%)			
Preoperative	95.7 ± 38.6	92.3 ± 29.2	0.77
Hospital discharge	69.1 ± 20.3	71 ± 20.9	0.79
P	0.006	0.004	

Abbreviations: FVC, forced vital capacity; FEV_1, forced expiratory volume in the first second; FEV_1/FVC, forced expiratory coefficient in the first second; PEF, peak expiratory flow; MIP, maximal inspiratory pressure; MEP, maximal expiratory pressure.

Note. Data showed as mean ± standard deviation. Wilcoxon test (intragroup) and ANOVA one-way (intergroup).

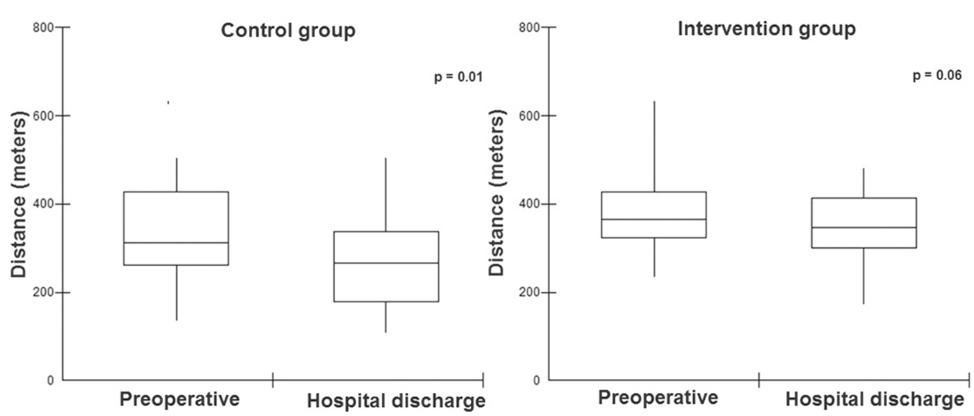

Figure 2 — Functional capacity assessed by 6-minute walk test (Wilcoxon test).

Discussion

This study verified the effects of aerobic exercise applied early in CABG patients on pulmonary function, respiratory muscle strength, and functional capacity. The findings were as follows: (i) maintenance of functional capacity in patients who performed aerobic exercise compared to those who performed conventional physiotherapy; (ii) no additional beneficial effects on respiratory muscle strength and pulmonary function were observed.

A significant decrease in spirometric values (see Table 3) was observed, showing deterioration of pulmonary function after cardiac surgery as also reported by Oliveira et al.[25] Prior research, such as Morsch et al[26] and Renault et al,[27] indicates that these disorders are frequent and last until the seventh day after surgery.

Prior research has found that a reduction in VFC and FEV_1 occurs due to the increased work of breath and superficial breathing, as a consequence of pain, decreased pulmonary expansion, median sternotomy, and surgical handling, resulting in restrictive ventilatory dysfunction.[28,29] This current study showed decreased pulmonary function (see Table 3), as expected, and neither conventional physiotherapy nor aerobic exercise minimized this dysfunction.

Respiratory muscle strength may be compromised after CABG, especially when a LITA graft is used. It represents an additional surgical trauma and leads to reduction in blood supply to intercostal muscles.[30] All patients in this current study required this type of graft, which could justify alterations in respiratory muscle strength.

Borghi-Silva et al[31] reported that respiratory muscle strength decreases after cardiac surgery and does not reverse to preoperative levels until hospital discharge. Some resources have been described to improve respiratory muscle strength, such as threshold and incentive spirometry.[32] In our study, early aerobic exercise did not show better effects compared with conventional physiotherapy (see Table 3).

Nery et al[4] recommend physical activity both in prevention and treatment of patients with ischemic heart disease, including those who underwent CABG. The 6MWT is a submaximal, easy, and low-cost method for assessing functional capacity, which identifies poor prognosis and determines adequate treatment.[33,34]

In this current study, functional capacity, measured by the 6MWT, was maintained in patients who performed aerobic exercises, demonstrating some benefit compared with conventional physiotherapy. Oliveira et al[35] showed that the type of surgery, cardiopulmonary bypass time, Functional Independence Measure, and body mass index were determinants of distance walked in the 6MWT at hospital discharge in patients undergoing cardiac surgery. Both groups were homogeneous in terms of demographic, clinical, and surgical variables. So, we consider that the impact observed in the intervention group was consequent to performed exercise.

Oliveira et al[25] studied 18 patients who underwent cardiac surgery and found that those who walked longer distances had a decreased hospital stay; however, we did not observe differences between studied groups (see Table 1).

In conclusion, aerobic exercise applied early on CABG patients may promote maintenance of functional capacity, with no impact on pulmonary function and respiratory muscle strength when compared with conventional physiotherapy.

Acknowledgments

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