JCSMICR
ISSN 2837-7567
Journal of Clinical Studies and Medical Images, Case Reports
Received: Oct 22, 2023
Published: Nov 24, 2023
Original Article
Volume 2, Issue 1
DOI: 10.55920/2837-7567/1026

Post-training changes in the distance/heart rate ratio in patients undergone cardiovascular surgery.

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Abstract

BACKGROUND: Exercise-based cardiac rehabilitation (CR) leads to an improvement in clinical outcomes.The distance/heart rate ratio,measured immediately after a 6-minute walk test (6MWT), has not been evaluatedin patients undergone CR after cardiovascular surgery.

METHODS: This retrospective study included patients, who had undergone coronary artery bypass grafting (CABG), valve surgery with or without CABG, surgery of the ascending aorta with or without CABG, or Bentall procedure. They had completed a formal program of CR following hospital discharge and had performed a 6MWT before and after CR.

RESULTS: Changes in the distancewalked(259.1±70.8 versus 429.4±88.5;p<0.001) were associated to subjective improvement in post-exercise fatigue (4.3±1.7 versus 1.1±0.7 meters;p<0.001) and dyspnea (5.4±1.6 versus 1.7±0.7;p<0.001), decreased systolic blood pressure(133.9 ±14.3 versus 128.4±9.3 mmHg;p<0.01), reduced heart rate (99.1±12.7 versus 91.7±11.7 beats per minute;p<0.001), increased distance/heart rate ratio (0.4±0.1 versus 0.8±0.2 meters/ beats per minute;p<0.001)and, enhanced oxy-hemoglobin saturation (96.6±2.0 versus 98.0±3.9;p<0.05).

CONCLUSIONS: Findings from the present study highlight the clinical benefits of CR in a patient population undergone cardiac surgery. In particular, longer distance walked associated to changes in the heart rate response to exercise did lead to an enhancement in the distance/heart rate ratio.

Introduction

Cardiac rehabilitation (CR) plays a key role in the care of patients with a broad range of cardiovascular diseases, providing multidisciplinary and individually tailored programs that aim to encourage healthy behaviors, to optimize cardiovascular risk reduction and to promote an active lifestyle[1-5]. Physical activity counseling and supervised exercise training represent central components in all rehabilitation interventions, leading to significant improvement in exercise capacity and health-related quality oflife[4-6]. CR following a cardiac event is a Class I recommendation from the European Society of Cardiology and the American Heart Association.It should be offered to all eligible patients with cardiovascular disease[7-9]. Participation in exercise-based CR is associated to improved clinical outcomes in patients with coronary heart disease, heart failure, and valve disease[5-6,9]. Benefits from training have been reported after coronary artery bypass grafting (CABG), heart valve surgery,and concomitant heart valve surgery and CABG[5-6,10]. Given the significant differences in the etiology and pathophysiology of cardiovascular diseases, it cannot be ruled out that the clinical benefits of CR may vary depending on the underlying pathology.

Scientific evidence supports the role of the 6-minute walk test (6MWT) in assessing clinical changes following CR[11]. Being able to evaluate functional capacity, in particular in patients who cannot perform more complex exercise tests, the 6MWT is used as a one-time measure to stage disease, as a predictor of morbidity and mortality, and as a tool to assess the response to medical interventions[12-13]. Its main outcome is represented by the 6 minute walk distance (6MWD), the distance that a patient can walk on a flat and hard surface in a period of 6 minutes[12-13]. Together to the distance walked, other measures, as heart rate (HR) and a new parameter called distance/HR ratio, give important information about patient's physical fitness[12-14]. Aim of the present study was to evaluate exercise functional capacity using the 6MWT before and after CR in patients undergone different cardiac surgery procedures.

Methods

This retrospective cohort study included adult patients, who had undergone cardiac surgery (CABG, valve surgery±CABG, surgery of the ascending aorta± CABG, Bentall procedure) and had completed a formal program of exercise-based CR following hospital discharge. Patients who did not perform a 6MWT before and after CR for inability and/or contraindications for field walking tests (according to the current European Respiratory Society and American Thoracic Society guidelines) were excluded[12]. The health records of patients included in the study were reviewed,and basic demographic information, risk factors, and comorbid conditions were collected. The 6MWT was performed following the guidelines,12 with standardized instructions provided to patients. They were asked to complete as many laps as possible on a flat indoor course, walking at their own pace for 6 minutes or until the severity of symptoms precluded them from continuing the test. They were permitted to slow down, to stop, and to rest if needed, but they should have resumed walkingas soon as they were able. A pulse oximeter was placed on the index finger during the test to assess oxy-hemoglobin saturation (SpO2) and HR. During the walk, research staff walked behind the patient. After 6 min, the patient was told to stop, and 6MWD, systolic blood pressure (SBP), diastolic blood pressure (DBP), HR, and SpO2 were recorded.

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Citation: Pietro Cataldo. Post-training changes in the distance/heart rate ratio in patients undergone cardiovascular surgery. Jourl of Clin Stud and Med Imag, Cas Rep. 2023; 2(1): 1026.

The distance/HR ratio was calculated according to the following formula: (6MWD/6)/HR,which represents the distance walked in 1 minute divided by the number of heart beats in 1 minute[14]. Fatigue and shortness of breath were rated using Borg category-ratio scale (CR10)[15]. Patients were asked to mark their level of fatigue and dyspnea on a scale from 0 point (none) to 10 point (maximum). After the 6MWT, patients seated at rest for an observational period of at least 10 minutes. Following the first 6MWT, study participants underwent a supervised rehabilitation program with a personalized exercise schedule consisting of [20-25]. minutes sessions on a cycle ergometer and/or a treadmill for 4 weeks. A phase of stretching and calisthenics was included in each session.After completion of the CR program patients underwent a second 6MWT. On the basis ofpresence/absence of coronary involvement, the study sample was subdivided in the following categories: exclusive coronary involvement (ECOR), concomitant coronary involvement (CCOR), and no coronary involvement (NCOR). According to the surgical procedure, the sample was subdivided into the following groups:CABG, valve surgery with CABG, valve surgery without CABG,surgery of the ascending aorta with CABG, surgery of the ascending aorta without CABG, and Bentall procedure. According to the type of training, the sample was subdivided into three groups: cycle ergometer training (CT) group, treadmill training (TT) group, and cycle ergometer and treadmill (CTT) group. Patients were also categorized according to the 6MWT performance (6MWD ≤ 300 or >300 meters). The cut-off of 300 meters was chosen on the basis of previous scientific literature.16Patients who walked ≤ 300 meters were classified as having low endurance (LE). The study was conducted at the Department of Cardiac Rehabilitation, Maria Eleonora Hospital - GVM Care e Research, Palermo, in collaboration with the Unit of Sport and Exercise Sciences, Department of Psychology, Educational Science and Human Movement, University of Palermo. Statistical analysis.Dataof the sample were described using means and standard deviations (sd) for continuous variables and percentages for categorical variables. Intergroup differences for continuous variables were evaluated by the unpaired Student's t test for comparisons between two groups and by theOne-way analysis of variance(ANOVA) for multi-group comparisons. Within group differences between pre- and post-training values were assessed using the paired Student's t test. Categorical variables were compared by the χ^2test.

Analysis of covariance (ANCOVA) was used to assess CR effects on changeof all 6MWT parameters, with post-training (T1) values as outcomes and training group as predictor.The unadjusted model included only corresponding pre-training(T0) values as covariates. The adjusted model included also age, sexand, risk factors as covariates.

Regression analysis was applied to check for association between variables. The Pearson's correlation coefficient was used to assess the strength and direction of association between two continuous variables. P-values of less than 0.05 were considered significant. All statistical analyses were performed usingthe computer software package R (R Development Core Team 2009)[17].

Results

Hospital discharge records of 64 patients were reviewed. After exclusion of 13 patients, the final study sample included 51 patients; 41.2% of patients had undergone CABG, 29.4% valve surgery, 5.9% surgery of the ascending aorta, 15.7% concomitant procedure of CABG and valve surgery, 1.96% concomitant procedure of CABG and surgery of the ascending aorta, and 5.9% Bentall procedure. Baseline characteristics and pre- and post-training parameters of the 6MWT are summarized respectively in table 1 and in table 2.

The exercise sessions were performed on a cycle ergometer by 19.6% of patients, on a treadmill by 7.8% of patients, both on cycle ergometer and treadmill by 72.6% of patients. Exercise programs were well tolerated; none of the patients showed adverse events.

Following exercise training, parameters of the 6MWT improved, with the exclusion of DBP (table2 and figure 1).

During the second 6MWT after the training period,patients walked significantly longer distance (+65.7%), describing significantly lower levels of post-exercise fatigue (-74.4%) and dyspnea (-68.5%). Moreover, they showed significantly lower SBP (-4.1%) and HR (-7.5%), andsignificantly higher SpO2 (+1.4%) and distance/HR ratio(+79.5%). LE patients decreased from 72.5% in the pre-training to 1.96% in the post-training.

Some differences emerged between patients with and without risk factors. In particular, sedentary patients,compared to subjects who were not sedentary, showed higher fatigue scores both in the pre-training(respectively 5.2±1.6 versus 4.0±1.6;p<0.05) and in the post-training (respectively, 1.4±0.5 versus 0.97±0.7;p<0.05). Overweight/obese patients showed higher fatigue scores in the pre-training when compared to normal weight patients (respectively, 5.5±1.7 versus 4.0±1.6;p<0.05).The difference was not significant in the post-training (respectively, 1.3±0.6 versus 1.1±0.7;p>0.05). Regression analysis found an association between post-training distance walked and the following baseline characteristics: male sex (p<0.01) and age (p<0.05). Pearson's correlation analysis demonstrated an inverse correlation between post-training 6MWD and age (p<0.05) with a correlation coefficient of 0.35. Post-CR6MWD was not related (p>0.05) topathophysiological characteristics of the underlying disease, type of surgical procedure, or type of training (cycle ergometer, treadmill, or cycle ergometer and treadmill) in multivariate models, where the post-training distance was adjusted for selected potentially confounding factors as age, sex, risk factors, and pre-training distance.

Parameters regarding the 6MWT before and after rehabilitation in the different training groups are illustrated in table 3. The ANCOVA test demonstrated that post-training values of distance walked (p<0.001), HR (p<0.001), SBP (p<0.001), fatigue (p=0.001) and dyspnea (p=0.001) scores, stratified for age, sex, risk factors, and type of surgery were affected by their corresponding pre-training values. No parameter was affected by the type of training with the exclusion of the dyspnea score (p<0.05). The decrease in dyspnea score was: 72.2% in the CTT group, 65.1% in the CT group, and 48.6% in the TT group. However, it must be stated that patients of the TT group showed lower pre-training levels of dyspnea compared to the other two groups (p=0.01; ANOVA), so that the reduction between pre- and post-training values was less evident.

Parameters of the 6MWT in the ECOR, CCOR, and NCOR groups are reported in table 4.No differences among the groups emerged from ANOVAeither in the pre-training or in the post-training period. Distance, distance/HR ratio, fatigue and dyspnea scores improved in all groups. Table 5 illustrates changes in the 6MWT parameters in the sample subdivided on the basis of the surgical procedure. The groups shown are five, because only one single patient underwent CABG associated to surgery of the ascending aorta. No group difference was evident using ANOVA, with the exclusion of the pre-training distance/HR ratio (p<0.05).Moreover, SBP almost reached the statistical significance (p=0.08). Applying unpaired Student's T test, it was demonstrated that patients with valve disease had significantly higher SBP (p=0.01) and DBP (p<0.05) compared to the rest of the sample.

Regardless of the type of surgery, patients showed after training an enhancement of 6MWD associated to a reduction in post-walk fatigue and dyspnea levels (table 5). The percentage of LE patients decreased significantly in all groups (71.4% versus 4.8% in the CABG group; 73% versus 0% in the valve surgery group; 75% versus 0% in the CABG with concomitant valve surgery group; 100% versus 0% in the surgery of the ascending aorta group; 66.7% versus 0% in the Bentall procedure group). Other beneficial effects of exercise training were not homogeneously distributed among the groups, as shown in table 5.

Discussion

Patients undergone cardiac surgery represent a particularly challenging population for exercise-based CR. In our study sample, trainingwas not only well toleratedbut also able to improve 6MWT parameters, regardless of the type of surgical procedure patients underwent before CR.The percentage of patients who walked less than 300 meters decreased from 72.5% in the pre-training to 1.96% in the post-training. Changes in the distance walked were associated to subjective improvement in post-exercise fatigue and dyspnea,decreased SBP andHR, and increased SpO2 and distance/HR ratio.DBP was the only parameter, whose post-training changes were not statistically significant. The distance walked was inversely correlated to age and it was longer in men than in women, in accordance with the previous scientific literature[18]. Before CR men exhibited longer distance walked andlower levels of fatigue than women. Both men and women did benefit from training, increasing 6MWD and reducing exercise-induced fatigue and dyspnea. However, the differences in terms of distance walked between men and women persisted also in the post-training. Other parameters were influenced by sex. In particular, men exhibited lower HR and higher distance/HR ratio than women in the pre-training 6MWT. It is well known that resting HR varies by age and sex, being much faster in infants and slowing in the adulthood and being higher in women than in men. Sex differences have been shownalso in the regulation of HR by the autonomic nervous system, as measured by the HR variability (HRV)[19-20]. Although women show higher resting HR, their power spectral analysis of HRVreflects higher levels of cardiac vagal control.20 These sex differences are evidentuntil menopause, thereafter a decline of HRVtowards higher sympathetic control has been demonstrated in women[21].

The relationship between impaired autonomic function, increased HR and cardiovascular, cerebrovascular, and all-cause mortality has been reported in the general population, as well as in patients with cardiovascular diseases[22-23]. Exercise training is able to affect positively the autonomic control of the heart toward vagal dominance[24-25]. as demonstrated by the lower HR athletes show when compared to sedentary subjectsof the same age[26-27]. In our sample,training induced both in women and in men a decrease in HR measured immediately after the walk, and the difference regarding this parameter between women and men,observed in the pre-training, disappeared in the post-training. As a contrast, the difference in terms of distance/HR ratio persisted also in the post-training, because of higher distance walked by men compared to women. Evaluating 6MWT parameters in patients with and without risk factors, some differences emerged. In particular, sedentary patients referred higher pre-training levels of fatigue compared to the rest of the sample. Despite a significant improvement in the fatigue scores after CR, this discrepancy persisted in the post-training. Alsooverweight/obese participants describedhigher pre-training levels of fatigue compared to normal-weight patients. However, this intergroup difference disappeared in the post-training, with significantly lower fatigue scores in the post-exercise both in the overweight/obese and in the normal-weight group. Regardless of the presence/absence of coronary involvement patients did benefit from training in terms of distance walked, fatigue and dyspnea, whereas an enhancement of SpO2 was detected only in patients with coronary artery disease. Longer 6MWD, associated to a reduction in post-walk fatigue and dyspnea, was evident in the study sample, regardless of the type of surgical procedure patients underwent before CR. Only in patients undergone isolated surgery of the ascending aorta, the change in dyspnea score did not achieve the statistical significance. A post-training increase in SpO2 was demonstrated only in patients undergone CABG with or without concomitant valve surgery. As a contrast, post-training changes in SBP were evident only in patients undergone valve surgery, whoshowed higher pre-training values of BP than the rest of the sample.

Regardless of the type of training (cycle-ergometer, treadmill, or both cycle-ergometer and treadmill), participants increased significantly the distance walked and exhibited lower post-exercise dyspnea. Also if the statistically significant improvement of other parameters was not homogeneous among the training groups, this was essentially due to differences already present in the pre-training period.The analysis of risk factors showed for example that patients of the CT group were significantly more sedentary than the other two groups; in fact they showed significantly lower 6MWD than the rest of the sample in the pre-training. As a contrast, the TT group, which did not include any sedentary patient, reported in the pre-training period significantly lower post-exercise levels of fatigue and dyspnea. As a consequence, the analysis adjusted for baseline values did not show any effect of the type of training on post-CR variables of the 6MWT, with the exclusion of dyspnea score. The lowest decrease in dyspnea score was found in the TT group, however, patients of this group had significantly lower pre-training levels of post-exercise dyspnea compared to the other two groups, so that the reduction between pre- and post-training values was less evident.

Conclusions

The efficacy of exercise-based CR demonstrated in this study resonates with a multitude of scientific literature highlighting the utility of training in patients with cardiovascular disease.5-10Findings from the present study demonstrate clinical benefits and safety of exercise-based CR in a patient population undergone cardiac surgery.

Regardless of the type of surgical procedure, the pathophysiologic characteristic of the underlying disease, the presence of risk factorand the type of training CR is an effective strategy to enhance patients' functional capacity, as documented by the improvement in 6MWT performance.

Limitations. Certain limitations, as the fact that study data are from a single-center research with a small sample size, should also be recognized and the results should be interpreted in light of these limitations.

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