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ORIGINAL ARTICLE

Relationship between exercise tolerance and muscle strength following cardiac rehabilitation: Comparison of patients after cardiac surgery and patients with myocardial infarction

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KEYWORDS
Cardiac rehabilitation;
Valvular heart disease;
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Summary
Background and purpose: Previous studies have demonstrated that cardiac rehabilitation (CR) improves exercise tolerance and muscle strength in patients with myocardial infarction (MI) and in patients after cardiac surgery. However, the association between exercise tolerance and muscular strength following CR and the comparison of relationships among various disease categories has not been fully examined. The purpose of the present study was to assess the relationship between exercise tolerance and muscle strength following CR in patients after cardiac surgery and patients with MI.
Methods and results: One hundred and four patients who participated in CR for 6 months were enrolled [post-cardiac valve surgery (VALVE), $n = 28$; post-coronary artery bypass grafting (CABG), $n = 42$; post-acute MI, $n = 34$]. The exercise tolerance, thigh/calf circumferences, and muscle strength were measured before and after CR. At the baseline, the thigh circumference was significantly smaller in the VALVE

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group than in the MI group. There were significant positive correlations between peak $\dot{V}O_2$ and muscle torques of the lower muscles in all groups. After 6 months, peak $\dot{V}O_2$ and muscle torque were significantly increased in all groups ($p < 0.001$). A positive significant correlation between percent increases in peak $\dot{V}O_2$ and muscular strength was observed in the VALVE group ($r = 0.51$, $p < 0.01$), but not in the other groups. In addition, the changes in peak $\dot{V}O_2$ and calf circumference after CR were significantly higher in the VALVE group than in the MI group.
Conclusions: These data suggest that exercise intolerance in patients after heart valve surgery may in part depend on decreased muscular strength. Further studies are needed to assess whether the strategy of increasing muscular strength of lower limb by programmed resistance training could be effective for improving exercise intolerance in patients after heart valve surgery and symptomatic patients with heart failure.

Introduction

Cardiac rehabilitation (CR) has been applied to patients receiving open-heart surgeries such as cardiac valvular surgery and coronary artery bypass grafting (CABG), and patients with ischemic heart disease following myocardial infarction (MI). It has been clearly established that CR reduces mortality and morbidity in patients with chronic heart failure [1,2].

Physical deconditioning is frequently observed in patients after cardiac surgery and in patients with MI [3,4]. These patients often have skeletal muscle abnormalities including demand-perfusion mismatch, muscle atrophy, shifts in the muscle fiber type, and metabolic dysfunction [5]. Indeed, skeletal muscle strength is closely correlated with exercise tolerance, in patients with chronic heart failure [6]. Previous studies have clearly demonstrated that CR improves exercise tolerance and muscle strength in patients with MI and in patients after cardiac surgery. However, the association between exercise tolerance and muscular strength following CR and the comparison of relationships among various disease categories has not been fully examined. The purpose of the present study was to assess the relationship between exercise tolerance and muscle strength before and after CR in patients who had cardiac valve surgery, CABG, or acute MI.

Methods

Patients

One hundred and four patients who participated in CR for 6 months at Juntendo University Hospital between February 2002 and April 2005 were enrolled. They were divided into three groups: patients after valve surgery (VALVE) ($n = 28$), after CABG ($n = 42$), and with acute MI ($n = 34$). Preoperative diagnoses in the VALVE group were as follows: six patients with aortic stenosis, nine with aortic regurgitation, 11 with mitral regurgitation, and two with aortic and mitral regurgitation. Ten patients were in New York Heart Association functional classification I, 15 patients were in class II, and three patients were in class III. Written informed consent was obtained from each patient before participation. This study was approved by the Ethical Committee of Juntendo University Hospital.

Study protocol

All patients performed a symptom-limited cardiopulmonary exercise test using an electronically braked upright ergometer (Corival 400, Lode B.V., Groningen, Netherlands). After a period of resting, warm-up was performed for a few minutes at 20 W, followed by ramp loading (15 W/min) until patients felt fatigued. Heart rate and rhythm were monitored continuously by a 12-lead electrocardiographic system (Marquette CASE 8000, GE Healthcare Bio-Sciences Corp., Piscataway, NJ, USA), and blood pressure was assessed every minute throughout the test. The respiratory gas exchange was measured by the breath-by-breath method using a gas analyzer system (Vmax-29S, SensorMedics Co., Yorba Linda, CA, USA). Oxygen uptake ($\dot{V}O_2$), carbon dioxide production ($\dot{V}CO_2$), minute ventilation, and the respiratory exchange ratio were measured. Peak $\dot{V}O_2$ was determined as highest $\dot{V}O_2$ achieved during exercise. The anaerobic threshold was measured by the V-slope method. To measure the isokinetic muscle strength of the quadriceps and hamstrings, we used the Cybex-770