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Original article

Effect of cardiac rehabilitation on muscle mass, muscle strength, and exercise tolerance in diabetic patients after coronary artery bypass grafting

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A R T I C L E I N F O

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A B S T R A C T

Background: The effects of cardiac rehabilitation (CR) on muscle mass, muscle strength, and exercise tolerance in patients with diabetes mellitus (DM) who received CR after coronary artery bypass grafting (CABG) have not been fully elucidated.
Methods: We enrolled 78 consecutive patients who completed a supervised CR for 6 months after CABG (DM group, $n = 37$; non-DM group, $n = 41$). We measured mid-upper arm muscle area (MAMA), handgrip power (HGP), muscle strength of the knee extensor (Ext) and flexor (Flex), and exercise tolerance at the beginning and end of CR.
Results: No significant differences in confounding factors, including age, gender, ejection fraction, or number of CR sessions, were observed between the two groups. At the beginning of CR, the levels of Ext muscle strength and peak VO_2 were significantly lower in the DM group than in the non-DM group. At the end of CR, significant improvement in the levels of muscle strength, HGP, and exercise tolerance was observed in both groups. However, the levels of Ext muscle strength, HGP, peak VO_2, thigh circumference, and MAMA were significantly lower in the DM group than in the non-DM group. In addition, no significant improvement in thigh circumference and MAMA was observed in the DM group. At the end of CR, the levels of thigh circumference and MAMA correlated with Ext and Flex muscle strength as well as with HGP. Percent changes in the levels of Ext muscle strength were significantly correlated with those of MAMA and hemoglobin A1c.
Conclusions: These data suggest that improvement in muscle strength may be influenced by changes in muscle mass and high glucose levels in DM patients undergoing CR after CABG. A CR program, including muscle mass intervention and blood glucose control, may improve deterioration in exercise tolerance in DM patients after CABG.

Introduction

Patients with diabetes mellitus (DM) are at increased risk of coronary artery disease (CAD) [1]. Patients with DM are at 2–4 times higher risk of developing CAD and mortality due to CAD compared with non-DM patients [2]. Patients with CAD are treated by lifestyle modification, medical therapy, and coronary revascularization such as percutaneous coronary intervention and coronary artery bypass grafting (CABG). However, the benefits of revascularization are less and the risks and complications are greater than those in non-DM patients. Previous studies have also reported a high incidence of bypass graft dysfunction and a high mortality even in DM patients who underwent CABG [3].

Cardiac rehabilitation (CR) has numerous benefits such as modification of risk factors and prevention of future cardiovascular events [4]. Improvement in peak VO_2 after CR reduced cardiovascular morbidity and mortality in patients with CAD [5]. However, a previous study demonstrated that the presence of DM was a negative factor for improvement in peak VO_2 [6]. Another report showed a significant inverse relationship between fasting blood glucose

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levels and changes in peak VO_2 in CR participants with DM after coronary events [7]. Park et al. reported that a low level of muscle strength was a predictor of physical limitation, and diabetes was associated with a low level of skeletal muscle strength and deterioration in quality [8]. We recently reported that muscle strength and exercise tolerance were significantly lower in DM patients than non-DM patients at the beginning of CR after CABG [9]. However, the effects of CR on muscle mass, muscle strength, and exercise tolerance in DM patients undergoing CR after CABG has not been fully elucidated. The aim of this study was to investigate the effects of CR on muscle mass, muscle strength, and exercise tolerance in DM patients who received CR after CABG.

Methods

Subjects

We enrolled 78 consecutive patients who completed a supervised CR for 6 months after CABG at Juntendo University Hospital from July 2002 to February 2005. The patients were divided into 2 groups: those with DM (DM group, $n = 37$) and those without DM (non-DM group, $n = 41$), according to the guidelines of the Japan Diabetes Society (JDS), which includes history of medical treatment, fasting plasma glucose ≥ 126 mg/dl or casual plasma glucose ≥ 200 mg/dl, and hemoglobin (Hb) A1c ≥ 6.1% [10]. All patients participated in the CR program 6–8 days after CABG. All subjects gave written informed consent and the ethical committee of the institution approved this study.

Rehabilitation protocol

The CR program consisting of warm-up stretching, aerobic exercise, resistance training, and cool-down, was scheduled once or twice a week for 6 months, as described previously [11,12]. Aerobic exercise consisted of a cycle ergometer, treadmill, and walking on an indoor track with a total duration of approximately 60 min exercise intensity was prescribed individually at the anaerobic threshold (AT) level, as measured by an ergometer test using expiratory gas analysis or a rating of 11–13 on a standard Borg's perceived exertion scale. Resistance training, which was gradually added to the exercise program at least 6 weeks after participation, included sit-ups, back kicks and front raises, squats, and push-ups, using the patient's own weight. This training consisted of 1–2 sets of 10–15 repetitions for each muscle group with 3–5 min rest between sets. Patients were encouraged to perform home-based aerobic exercise twice a week for more than 20 min at a rating of 11–13 of perceived exertion on Borg's scale. All subjects were instructed to follow the phase II diet of the American Heart Association at the beginning of CR. An educational program regarding CAD and its risk factors at baseline was also provided for each subject by physicians, nurses, and dietitians.

Measurements

We assessed body composition, muscle strength, and exercise tolerance at the beginning and end of CR. Anthropometric parameters were assessed using body mass index (BMI), waist size, thigh circumference, triceps skin fold thickness measured on the dominant hand, and mid-upper arm circumference. Thigh circumference was measured directly below the gluteal fold of the right thigh according to WHO standards [13]. Mid-upper arm muscle area (MAMA) was calculated according to a standard method [14]. The percentages of body fat and lean body weight were measured by BOD POD® (Life Measurement, Inc., Concord, CA, USA), as described previously [11,12]. The power of the thigh muscles was measured using the Cybex770 system (Cybex Division of Lumex, Ronkonkoma, NY, USA), as also reported previously [11,12]. The isokinetic peak torques of the knee extensor (Ext) and flexor (Flex) muscles were measured at 60°/s, and those were adjusted by body weight according to the following formula: strength (Nm) × 100/kg body weight. Handgrip power (HGP) in the dominant hand was also measured. To measure peak oxygen consumption (peak VO_2) and oxygen uptake at the AT, patients underwent ergometer testing (Corival 400, Lobe B.V., Groningen, Netherlands) using an expiratory gas analysis machine (Vmax-295, SensorMedics Co., Yorba Linda, CA, USA). After a period of resting, warm-up was performed for a few minutes at 20 W, followed by ramp loading (15 W/min) until subjective exhaustion, progressive angina, ST-segment depression (≥2 mm), or sustained tachyarrhythmia. The point of AT was determined by the "V-slope" method.

Statistical analyses

The results are expressed as mean ± standard deviation and were analyzed using the StatView software (Version 5.0J for Windows, SAS Institute, Cary, NC, USA). Comparisons between the DM and non-DM groups were performed by Student's *t*-test. Data at baseline and after 6 months of CR were compared for each patient by paired *t*-test to evaluate the singular effects of CR. Correlation coefficients were determined by linear regression analysis. Statistical significance of correlation coefficients was determined by the method of Fisher and Yates. A *p*-value of less than 0.05 was considered significant.

Results

Characteristics of CR subjects

The clinical characteristics of the subjects are presented in Table 1. Thirty-seven patients were diagnosed as having DM. No significant differences with regard to age, gender, coronary risk factors, number of diseased vessels, ejection fraction, or physiological variables, were observed between the DM and non-DM groups. Thirty-six patients received complete revascularization using the off-pump operation. One patient who had received re-CABG was in the DM group. No significant differences in the concomitant use of drugs, including antiplatelets, calcium channel blockers, β-blockers, angiotensin-converting enzyme inhibitors, angiotensin II receptor blockers, or statins, were observed between the two groups. In the DM group, 24 patients (65%) and 13 patients (35%)

Table 1
Clinical characteristics of the study subjects.

	DM	Non-DM	*p*-Value
N	37	41	
Age (year)	63.5 ± 10	64.1 ± 9	NS
Male (%)	29 (78)	39 (95)	NS
Hypertension (%)	22 (61)	30 (73)	NS
Dyslipidemia (%)	28 (76)	31 (76)	NS
Current smoker (%)	17 (49)	21 (53)	NS
Familial history (%)	11 (26)	9 (26)	NS
History of MI (%)	2 (5)	0 (0)	NS
History of PCI (%)	2 (5)	0 (0)	NS
History of previous CABG (%)	1 (3)	0 (0)	NS
Diseased vessels			
LMT (%)	9 (25)	2 (5)	NS
3VD (%)	18 (48)	28 (68)	NS
1–2VD (%)	10 (27)	11 (27)	NS
Ejection fraction (%)	59.7 ± 16	65.3 ± 12	NS
Off-pump CABG (%)	36 (97)	41 (100)	NS
Exercise in hospital (times)	16 ± 14	18 ± 14	NS

Data are presented as the mean value ± SD. DM, diabetes mellitus; MI, myocardial infarction; PCI, percutaneous coronary intervention; CABG, coronary arterial bypass grafting; LMT, left main trunk; VD, vessel disease.