Supervised Phase II Cardiac Exercise Therapy Shortens the Recovery of Exercise Capacity in Patients with Acute Myocardial Infarction

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Abstract. [Purpose] To investigate the effects of Phase II cardiac exercise therapy (CET) on exercise capacity and changes in coronary risk factors (CRFs) of patients with acute myocardial infarction (AMI). [Subjects] Thirty male subjects with AMI were divided into an experimental group (EG) and a control group (CG). Another 30 age-matched subjects with patent coronary arteries served as a normal-control group (NCG). [Methods] Subjects in EG (n=20) trained using a stationary bicycle for 30 min at their target heart rate twice a week for 8 weeks. Exercise capacity was defined as the maximal metabolic equivalents (METs) that subjects reached during the symptom-limited maximal exercise test. HR, BP and RPP were recorded. Subjects in EG and CG received exercise tests and screening for CRFs at the beginning of, end of, and 3 months after Phase II CET, while subjects in NCG participated only in the 1st test. [Results] METs of CG did not improve until the 3rd test, while RPP at the 2nd test showed a significant increase. However, EG showed increased METs at the 2nd test without increase of RPP, and increased their high density lipoprotein cholesterol (HDL-C) during the follow-up period between the 2nd and 3rd tests. [Conclusion] Phase II CET shortens the recovery time of exercise capacity, helps to maintain the gained exercise capacity and increases HDL-C in phase III.
Key words: Patent coronary artery, Exercise capacity, Phase II CET

INTRODUCTION

Following acute myocardial infarction (AMI), recovery of exercise capacity and control of coronary risk factors (CRFs) are highly critical for prognosis post AMI[1]. Long-term follow-up research has shown that the improvement of exercise capacity is negatively related to future cardiac events[2], and that the improvement of CRFs is beneficial for preventing the development of atherosclerosis.

Supervised, hospital-based Phase II cardiac exercise therapy (CET) allows patients to exercise safely following personalized exercise prescriptions and monitoring of CRFs. Home-based Phase III CET following hospital-based Phase II continues to prepare patients with the ability and confidence to go back to the society as soon as possible. Furthermore, CET prevents the recurrent infarction and improves quality of life[3].

Does supervised, hospital-based Phase II CET help patients to achieve levels of exercise capacity equal to those of age-matched normal subjects with patent coronary arteries? Research results are inconsistent about the long-term changes in CRFs. This study used age-matched subjects with patent coronary arteries as a normal-control group (NCG). It was designed to investigate the effects of Phase II and III CET on exercise capacity, and on the long-term changes in CRFs of patients with AMI in comparison with age-matched normal subjects.

SUBJECTS AND METHODS

The subjects were patients with AMI who had been admitted to Tzu-Chi Medical Center, and had undergone coronary angiography (CAG) for evaluation and treatment of coronary artery lesions. Subjects in the experimental group (EG) were defined as those who were admitted to hospital after AMI, who had participated in the Phase II hospital-based CET and continued to do the Phase III home-based exercise program. Subjects in the control group (CG) were defined as those who were admitted to hospital after AMI but did not participate in the hospital-based Phase II CET because of inconvenience of travel or for personal reasons.

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Table 1. Test items examined at different times in the normal control group (NCG), exercise group (EG), and control group (CG)

Period		Acute stage			Phase II CET			Phase III CET		
		During admission			Beginning	End			Home exercise	
	Test item	Disease severity	CRFs	Medica-tion	METs	METs	CRFs	CRFs	METs	Medica-tion	Ques-tionnaire
Group										
NCG		-	*	-	*	-	-	-	-	-	-
EG		*	*	*	*	*	*	*	*	*	*
CG		*	*	*	*	*	*	*	*	*	*

CRFs, coronary risk factors; METs, metabolic equivalents; CET, cardiac exercise therapy

Both groups of subjects received education about exercise when they were discharged. After discharge from hospital, EG patients participated in an 8-week CET program designed specifically for each patient by the same experienced physical therapist. There was no Coronary artery bypass surgery (CABG) given to EG or CG, and no stroke during the period when the study was conducted.

Another group, the normal control group (NCG), took part in this study. Subjects in NCG were whose who had received CAG and had proven patent coronary arteries. The reason for CAG was either suspicion of coronary artery lesions or pre-examination for possible congenital heart disease. Subjects in NCG were age-matched with the subjects with AMI in EG and CG. The criterion for age matching was an age within 3 years of the target subject.

In order to carefully understand how the home-based exercise was performed, we used a questionnaire to specifically ask subjects the mode, the frequency and duration of exercise. Subjects who performed the exercise at least 3 times a week, 30 minutes a time and reached their target heart rate were defined as regular exercise performers.

This study was approved by the Institutional Review Board of Tzu Chi Medical Center, and written informed consent to participation in the study was obtained from each subject.

Data for duration of hospital stay, medication, cigarette smoking, hypertension (HTN), diabetes mellitus (DM), body mass index (BMI), and fasting plasma serum levels of total cholesterol (T-Chol), triglyceride (TG), high density lipoprotein cholesterol (HDL-C) and low density lipoprotein cholesterol (LDL-C) were collected during hospitalization. Severity of disease, such as numbers of stenotic vessels, with or without Q wave, and infarcted wall are recorded shown in Table 1. Smoking habits, BMI and plasma serum lipids were re-evaluated at the times of the second (the 2nd test) and third examinations (the 3rd test). The 2nd and 3rd tests were done at two and five months after discharge from hospital, respectively. Patient medication was re-evaluated at the third examination. Coronary stenosis was defined as greater than 50% according to CAG.

All three groups performed the symptom-limited maximal exercise test. Subjects' blood was collected to measure serum lipids, and anthropometric measurements were taken to calculate BMI. The maximal exercise test was performed by both EG and CG at the beginning of Phase II CET (the 1st test), at the end of Phase II CET (the 2nd test) and at 3 months after the end of Phase II CET (the 3rd test). NCG only performed the maximal exercise test at the time of the 1st test.

EG and CG patients performed an exercise test on a treadmill (Marquette MAX1, Milwaukee WI, USA). The symptom-limited maximal exercise capacity, expressed in metabolic equivalent (METs), was obtained at the end of the exercise test[4]. The ECG was monitored continuously, with HR, BP and rate-pressure product (RPP) measured every three minutes during the exercise test, and throughout the five-minute recovery period. The Borg scale of rating of perceived exertion (RPE), which is reported to be highly related to maximal oxygen consumption and metabolic demand, were quantified at the same time.

All subjects followed the required medication advice before taking the maximal exercise test. We requested the patients to abstain from food, coffee, and cigarettes for a minimum of two hours before each test. They watched a real test to learn how the maximal exercise test is conducted before they performed the test. Before the maximal exercise test started, subjects were asked to lie supine for 3 minute so that we could collect measurements of their resting state.

The Bruce protocol starts at an intensity of 4.6 METs, and increases by 2–3 METs every 3 minutes, and it is considered unsuitable for patients with AMI[5]. Therefore, the Modified Naughton protocol was adopted as the 1st test for its lower beginning intensity (3 METs) and smaller increment (1 MET every 3 minutes).

Criteria for terminating the 1st exercise test included ischemic signs and/or symptoms, inability to continue the exercise due to fatigue, HR reaching 140 bpm for subjects under 40 years old, or HR reaching 130 bpm for subjects over 40 years old. For the 2nd and 3rd exercise tests, criteria for terminating the exercise test included ventricular arrhythmia (such as ventricular tachycardia and fibrillation), ST segment depression ($\geq$ 2 mm) or elevation ($\geq$ 1 mm), target HR exceeded (90% of the predicted age-adjusted maximal HR), or BP over 220 $^{mm}/_{Hg}$ or lower than that determined at the beginning of the test.

Venous blood samples were collected after a 12-hour fast and used for the determination of lipids (serum T Chol, TG, HDL-C, and LDL-C). Serum T Chol was measured using the enzymatic method and automatic multi-channel chemical analyzer (747 Automatic Analyzer, Hitachi, Tokyo, Ja-

pan), with the AU500/550 T-Chol reagent Kit (Katayama, Osaka, Japan). Serum HDL-C levels were determined using the precipitation method with phosphotungstic acid and magnesium chloride[6]. Serum TG was measured using the kinase reaction and an auto-analyzer[7]. Serum LDL-C was calculated using the values of T-Chol, TG and HDL-C in the following formula:

$$LDL\text{-}C = T\text{-}Chol - ((1/5TG) + HDL\text{-}C)$$

Phase II CET began 19(9) (range 6–39) days after AMI, and continued for eight weeks at a frequency of two times per week. Phase II CET consisted of three stages. A warm-up was performed of 10–15 minutes of calisthenics (gentle stretching). The main exercise was performed on a treadmill, at an exercise intensity individually prescribed on the basis of baseline data, and the graded treadmill exercise test results. The exercise intensity was gradually increased to a goal of 60 to 79% of the predicted age-adjusted maximum heart rate (HR), and the exercise continued for 20 minutes at an intensity below that which would cause symptomatic or silent ischemia. A cool-down, consisting of ten minutes of calisthenics was also performed. During the period of CET, patient safety was always the primary consideration. Subjects were often given real-time feedback of HR as exercise proceeded, and learned to monitor their own HR. After Phase II CET finished, Phase III CET programs were designed specifically for each individual, and data were collected for 3 months.

During Phase III CET, patients were asked to continue leisure-time physical activities chosen by themselves, with an exercise formula prescribed according to the results of the second of the exercise tests performed at the end of Phase II CET. Based on the over-riding emphasis on safety, an exercise type familiar to each individual was chosen for Phase III CET.

All EG patients were telephoned by the same investigator each month to provide relevant information and personal support.

Subjects in CG performed the 1st and 2nd maximal exercise test and were given an exercise prescription based on the results of the tests. Subjects were telephoned by the same investigator each month to provide relevant information and personal support, and if needed, to change the exercise intensity to ensure its effectiveness and safety.

Subjects in CG were advised to exercise regularly after discharge, and were followed for the status of home-based exercise during Phase II and Phase III by questionnaire.

SPSS for Windows, release10.0, (SPSS Inc. Chicago, IL, USA) was used to statistically analyze the data. One-way ANOVA was used to compare differences among the three groups. Scheffe's test was used for post hoc comparisons. Two-way repeated measures ANOVA was used to compare the differences in CRFs for group effect (two levels: EG vs. CG) and training effect (three levels: 1st test, 2nd test and 3rd test) with repeated measures of the second factor. Significant interaction effects were analyzed using univariate repeated measures and mean comparisons with the LSD method. Statistical significance was accepted for values of $p < 0.05$.

RESULTS

Sixty subjects completed the study, 20 AMI patients in EG (age: 55.3±10.6 years), 10 AMI patients in CG (age: 56.6±9.5 years), and the 30 age-matched normal subjects with patent coronary arteries in NCG (age: 57.1±9.6 years). Table 2 shows the subjects, anthropometric characteristics. METs, RPP and systolic BP of NCG were significantly higher than those of EG and CG. Maximal HR of NCG also was higher than that of EG. The percentage of smokers was lower in NCG than in the other two groups.

As shown in Table 2, exercise capacity increased 54% (6.5 vs. 10.0 METs, p<0.01) in EG from the 1st to the 2nd test without any increase in RPE. Exercise capacity and RPE did not change in CG, but, RPP increased. There were no significant changes from the 2nd to the 3rd test. Both EG and CG showed improvements in their exercise capacities (EG: 6.5 to 9.7 METs; CG: 7.1 to 9.8 METs) from the 1st to the 3rd test, with improvements of approximately 49% and 38%, respectively.

The only significant difference found between EG and CG appeared in systolic BP at the stop point of the maximal exercise test. The 2nd test of HDL-C is significantly higher than the first in EG.

Medications used by the subjects are shown in Table 2. There were no differences in βblocker, ACE-I, diuretics, Ca^{++} channel blocker and hypolipemic drug use among the groups.

In EG, six subjects chose walking as their home exercise, six chose walking/jogging, five chose cycling and one each chose table-tennis, golf and rope skipping.

DISCUSSION

Lifelong exercise is the main recommendation for CET after AMI. A well designed Phase II CET not only increases the confidence of patients to proceed to Phase III, but also increases compliance and safety during Phase III.

METs were the index chosen to represent exercise capacity in the present study. METs are calculated from oxygen consumption during exercise and they are easy to convert to the energy consumption for activities. The values of METs are related to genetics, fitness, disease level, age, and gender, and it is one of the best indexes for measuring exercise capacity and cardiovascular function[8]. METs and HR/SBP at the point of maximal exercise are highly correlated with left ventrical perfusion and abnormal left ventrical function, which have been proven to be highly important in predicting the prognosis after AMI[9]. The hemodynamic parameter, RPP, the product of HR and SBP, can be used to evaluate both dynamic and static exercise, and is not influenced by the use of βblockers. It is agreed that HR and SBP are increased by the increase of exercise intensity; however, the degree of increase can be reduced by proper exercise therapy[10].

As shown in Table 2, the average maximal METs for NCG was 9.4 (SD 2.1). Early intervention of Phase II CET increases maximal METs. Phase II CET also stabilizes the autonomic nervous system and this is reflected in hemodynamic parameters[11]. In the present study, both EG and CG

Table 2. Hemodynamic parameters, exercise capacity and CRFs of each group

		NCG (n=30)	EG (n=20)			CG (n=10)		
Variables			1st test	2nd test	3rd test	1st test	2nd test	3rd test
Age (yrs)		57.1±9.6	55.3±10.6	-	-	56.6±9.5	-	-
Exercise capacity	METs	9.4±2.1	6.5±1.5*	10.0±1.4$^{\Omega}$	9.7±1.5$^{\Omega}$	7.1±1.2*	8.5±1.7	9.8±1.0$^{\Omega}$
Hemodynamic parameters	RPP*1000	24.5±5.1	19.3±6.5*	22.3±4.1	24.4±4.9$^{\Omega}$	21.8±3.0*	26.0±3.7$^{\Omega}$	25.1±1.6$^{\Omega}$
	Maximal HR	140.1±20.7	126.8±20.4*	139.9±13.1	149.5±16.5	137.6±8.1	146.5±16.5	148.9±10.4
	Maximal BP	174.4±22.4	149.9±28.0*	159.1±23.6	162.8±22.7	159.1±14.3*	181.6±15.2#	171.0±18.1
	Borg scale	-	13.8±0.8	14.1±1.0	14.3±0.8	13.8±1.0	13.9±1.1	14.5±1.1
CRFs	Smoking (%)	33	78§	6&	17&	56§	22	22
	DM (%)	17	22	-	-	22	-	-
	HTN (%)	50	33	-	-	36	-	-
	Total cholesterol (mg/dl)	179.9±45.2	184.0±43.4	178.4±30.9	196.6±49.3	208.8±55.4	207.5±57.0	207.0±48.6
	Triglyceride (mg/dl)	178.4±110.4	164.2±82.0	182.9±134.5	155.1±103.9	154.6±120.3	178.0±157.1	153.6±121.2
	HDL-C (mg/dl)	43.2±12.4	38.1±10.8	38.4±9.1	42.5±10.3$^{\neq}$	44.9±10.0	46.7±10.3	46.2±7.3
	LDL-C (mg/dl)	103.3±43.8	113.0±36.4	102.8±35.5	124.5±51.8	139.5±51.1	126.2±60.8	133.1±46.3
	BMI	27.5±4.3	25.2±4.0	25.2±4.1	25.3±3.9	25.4±4.8	24.2±3.3	24.5±3.6
Disease severity	Admission days	-	10.4±5.5	-	-	8.7±3.3	-	-
	Number of stenotic vessels	0	1.5±0.8	-	-	2.0±0.9	-	-
EKG	Q wave (n)	-	16	-	-	8	-	-
	Non-Q wave (n)	-	4	-	-	2	-	-
Infarcted wall	Anterior (n)	-	8	-	-	3	-	-
	Lower/posterior (n)	-	7	-	-	5	-	-
	Lateral (n)	-	1	-	-	0	-	-
Angioplasty	Phase I (n)	-	9	-	-	5	-	-
	Phase II (n)	-	0	-	-	0	-	-
	Phase III (n)	-	2	-	-	1	-	-

CRFs: Coronary risk factors, Phase I: Acute stage during the admission, Phase II: Supervised, hospital-based Phase II cardiac exercise therapy, Phase III: home-based Phase III cardiac exercise therapy. *: Significantly lower than NCG (p<0.05): §: Significantly higher than NCG (p<0.05).
Ω: Significantly higher than the 1st test (p<0.05); &: Significantly lower than the 1st test (p<0.05); $\neq$: Significantly higher than the 2nd test (p<0.05); #: Significant difference between groups (p<0.05).

showed similar conditions at the onset. In the 1st test, there was no significant difference in maximal METs, medication or the successful rate of percutaneous coronary intervention. However, between the 1st and the 2nd test, METs increased only in EG and without any change in RPE or RPP. METs continued to increase up to the 3rd test. CG did not show an improvement in METs until the 3rd test, while RPP increased in the 2nd test. Without the intervention of Phase II CET, the hemodynamic parameters at the maximal METs in CG were poorer than those of EG, especially SBP at the point of maximal exercise. This shows that sustainable regular exercise is helpful for the improvement of METs, and for the same reason, that Phase II CET successfully shortens the natural recovery time of exercise capacity.

Oxygen consumption is the most direct measurement of exercise intensity. HR is linearly related to oxygen con-sumption and is very easy to measure. Besides, HR is representative of the physical load exacted on the heart[11]. In the present study, 60–79% of maximal HR was used as the target HR intensity in Phase II CET. Target HR is the training intensity needed to get the best training effect. Target HR was determined based on the results of ECG, hemodynamic parameters, exercise capacity and RPE obtained in the symptom-limited maximal exercise test. EG completed 8 weeks of supervised, hospital-based CET. This helped to ensure the Phase III home exercise program was feasible and safe. CET, based on exercise training, has changed the emphasis from long-term prognosis to short-term effects. However, long-term prognosis is highly correlated to life-long regular exercise and control of CRFs[12]. EG chose an exercise activity they were familiar with, and trained at 60–79% of their maximal HR in the Phase III home CET.

One of the authors called all the subjects every month to ask if they had any difficulty in continuing their exercise program. Holmback et al. found that the benefits of a 12-week Phase II CET were not maintained after 6 months[13]. In the present study, subjects in EG continued to show improvements in their maximal METs until 3 months after the end of Phase II CET. It would have been better to have performed a longer follow-up, but it is difficult to control subjects in long-term clinical studies. The authors wish to further investigate Phase III CET in the future, and hopefully as time proceeds, there will be more subjects and longer periods of follow-up providing data which will allow a better understanding of the mechanism behind the outcomes. We found that maximal METs in CG increased during the Phase III CET and eventually reached the same level as the shown by NCG in the 1st test.

Using an exercise that subjects are already familiar with can provide fitness and wellbeing. It has been reported to be of physiological benefit[14]. According to the questionnaire regarding exercise status, 67% of subjects in EG chose to do walking-related activities, such as walking (6 subjects), and brisk walking/ jogging (6 subjects). All the subjects in CG chose to walk as their home exercise program (walking: 7, brisk walk: 1, jogging: 1, and treadmill walking: 1). We found that moderate intensity of home exercise, 3 times a week with a duration of at least 30 minutes, was safe, flexible and did not discourage the subjects so it would be well accepted by most people. Previous research has shown that walking can prevent recurrence of heart attack and has been used as a secondary prevention method for patients with AMI[15].

There were no reinfarction or cardiac events in either EG or CG during Phases II and III CET, and maximal METs were improved and maintained,

The effects of exercise therapy on total cholesterol (T-Cho) and low density lipoprotein (LDL-C) are controversial[16], but it is agreed that exercise is mostly beneficial for controlling triglyceride no matter how long the training period is. Possible mechanisms for this include lowering the synthesis of very low density lipoprotein (VLDL), speeding up catabolism, and greater metabolism of free fatty acids to provide energy source for skeletal muscles[16]. We note that neither EG nor CG had high triglyceride to begin with, and this is likely why there was not much exercise effect on triglyceride. Possible reasons why sustainable walking training increased high density lipoprotein cholesterol (HDL-C) by 20–30% are overactive lipoprotein lipase and lecithin-cholesterol-acyltransferase induce greater catabolism of VLDL, and lower the activity of hepatic lipase. In the present study, there was no significant change in HDL-C although it did increase in EG.

In Taiwan, the impact of CRFs on CAD is similar to that reported for the United States and Japan[17]. Especially, HDL-C has been shown to be highly correlated with CAD[18]. HDL-C is influenced by gender, age, medication, smoking, obesity, and the parameters of the exercise prescription[19]. We found that HDL-C changed only in EG.

Smoking changes the function of platelets and may cause embolism. Nicotine increases epinephrine and norepinephrine in the circulation speeding up the development of atherosclerosis. Compared to non-smokers, smokers have 5.7% lower HDL-C and quitting smoking can make HDL-C more normal[20]. Aerobic exercise increases HDL-C. Our results show that the cessation of smoking rate increased at the 2nd test, and continued to increase at the 3rd test. However, a significant increase in HDL-C was only seen in the 3rd test. This shows that quitting smoking alone is not enough to explain the increase in HDL-C. HDL-C is inversely related to BMI[21]. Our results show that the maximal METs increased in EG during the Phase II CET, but BMI did not change. This could explain why HDL-C did not increase during the Phase II CET.

In addition to smoking and BMI, the intensity, duration, and frequency of exercise during CET also affect HDL-C[22, 23]. Mendoza et al. showed that 3–12 months of exercise are needed to elicit an increase in HDL-C[16]. Berg et al. Showed that at least 3 months is required to improve HDL-C. Therefore, the reason that HDL-C did not improve during the Phase II CET might be because exercise, 2 times a week for a total of 8 weeks is insufficient. In contrast, exercise, 2 times a week elicited a difference in exercise capacity in the present study. After Phase II and Phase III CET, HDL-C showed an increase at the end of Phase III CET. Possible reasons for this could be that exercise capacity continued to improve and the cessation of smoking rate was maintained, with no change in BMI. It is also possible that the combination of Phase II and III CET was beneficial for maintaining cessation of smoking and BMI, creating an environment in which an increase of HDL-C could occur. HDL-C in CG did not change with improvement of exercise capacity, despite the fact that BMI was maintained and there was a stop in the smoking cessation rate. The small sample size could be another reason why no change in HDL-C was observed. The authors hope to enroll more subjects in the future to better investigate the temporal change of HDL-C during Phase III CET.

One limitation of our research was the relatively large number of days before exercise was initiated after myocardial infarction. We recognize that this makes the interpretation of the training effect more difficult. However, considering the substantial area and rugged travel conditions of Hualien County and the difficulty of making transportation arrangements for some patients, this was perhaps the best result achievable. It is our hope that this limitation is offset by the fact that this research presents a contribution to clinical medicine from an under-represented corner of Taiwan and of the world.

This study pioneered the enrolment of subjects with patent coronary arteries as a normal control group, and we believe it will provide valuable insights for clinical medicine.

In conclusion, a supervised, hospital-based Phase II CET performed twice a week for 8 weeks shortened the recovery time of exercise capacity in patients with AMI. Successful and regular exercise during Phase III home-based CET maintained the exercise capacity gains of Phase II, improved HDL-C, and also continued to increase exercise capacity in the control group.

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