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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

Miho Nishitani (MD)[a], Kazunori Shimada (MD, FJCC)[a,b,*], Masayuki Masaki (MD)[a], Satoshi Sunayama (MD)[a], Atsumi Kume (MD)[a], Kosuke Fukao (MD)[a], Eiryu Sai (MD)[a], Tomo Onishi (PhD)[b], Miki Shioya (MS)[b], Hiroyuki Sato (MD)[b,c], Taira Yamamoto (MD)[d], Atsushi Amano (MD, FJCC)[d], Hiroyuki Daida (MD, FJCC)[a]

[a] *Department of Cardiovascular Medicine, Juntendo University School of Medicine, Tokyo, Japan*
[b] *Juntendo Sports Clinic, Juntendo University Hospital, Tokyo, Japan*
[c] *Department of General Medicine, Juntendo University School of Medicine, Tokyo, Japan*
[d] *Department of Cardiovascular Surgery, Juntendo University School of Medicine, Tokyo, Japan*

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ABSTRACT

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

* Corresponding author at: Department of Cardiovascular Medicine, Juntendo University School of Medicine, 2-1-1 Hongo, Bunkyo-ku, Tokyo 113-8421, Japan. Tel.: +81 3 5802 1056; fax: +81 3 5689 0627.
E-mail address: shimakaz@juntendo.ac.jp (K. Shimada).

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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.

were treated with oral anti-diabetic agents and insulin, respectively. No significant differences were observed between the two groups in exercise duration in the CR program (data not shown). No subject in either group showed any worsening of symptoms or had cardiovascular events during the 6 months of the study.

Serum lipid profiles and glucose parameters

Serum lipid profiles and glucose parameters at baseline and the end of CR are presented in Table 2. Fasting blood glucose and HbA1c levels before and after CR were significantly higher in the DM group than in the non-DM group (both $p < 0.05$). Lipid profiles were not significantly different between the two groups at both baseline and the end of CR.

Anthropometric parameters

The anthropometric parameters at baseline and after CR in both groups are presented in Table 3. The anthropometric parameters at baseline were not significantly different between the two groups. In the non-DM group, waist circumference (from 84.5 ± 7.8 to 82.2 ± 6.7 cm, $p < 0.05$) was significantly decreased, and thigh circumference (from 48.9 ± 4.1 to 50.7 ± 3.7 cm, $p < 0.05$), arm forced circumference (from 29.0 ± 2.6 to 30.0 ± 2.4 cm, $p < 0.05$), mid-upper arm muscle circumference (from 25.7 ± 2.5 to 26.5 ± 2.4 cm, $p < 0.05$), and MAMA (from 53.2 ± 10.3 to 56.5 ± 10.0 cm^2, $p < 0.05$) were significantly increased. In the DM group, waist circumference (from 83.4 ± 8.3 to 80.2 ± 5.7 cm, $p < 0.05$) was significantly decreased, however, thigh circumference, arm forced circumference, mid-upper arm muscle circumference, and MAMA were not significantly altered. At the end of CR, thigh circumference (47.3 ± 2.5 cm vs. 50.7 ± 3.7 cm, $p < 0.05$), arm forced circumference, (28.4 ± 1.6 cm vs. 30.0 ± 2.4 cm, $p < 0.05$), mid-upper arm muscle circumference (25.0 ± 1.8 cm vs. 26.5 ± 2.4 cm, $p < 0.05$), and MAMA (49.9 ± 7.1 cm^2 vs. 56.5 ± 10.0 cm^2, $p < 0.05$) were significantly lower in the DM group than in the non-DM group.

Exercise tolerance and muscle strength

Exercise tolerance and muscle strength at baseline and after CR in each group are presented in Table 4. At the beginning of CR, the levels of peak VO_2 (13.7 ± 4.0 ml kg^{-1} min^{-1} vs. 16.0 ± 4.7 ml kg^{-1} min^{-1}, $p < 0.05$) and thigh muscle strength (136.3 ± 42.7 Nm kg^{-1} × 100 vs. 162.7 ± 47.9 Nm kg^{-1} × 100, $p < 0.05$) were significantly lower in the DM group than in the non-DM group. No significant differences in HGP (28 ± 9 kg vs. 31 ± 9 kg, NS) were observed between the two groups. At the end of CR, both groups showed significant improvements in exercise tolerance and muscle strength. Improvements in exercise tolerance and muscle strength were identical in the DM and non-DM groups. However, the levels of peak VO_2 (19.4 ± 3.8 ml kg^{-1} min^{-1} vs. 22.9 ± 5.4 ml kg^{-1} min^{-1}, $p < 0.05$) and AT (11.3 ± 2.2 ml kg^{-1} min^{-1} vs. 13.3 ± 3.4 ml kg^{-1} min^{-1}, $p < 0.05$) were still significantly lower in the DM group than in the non-DM group. The levels of thigh Ext muscle strength (164.1 ± 43.3 Nm kg^{-1} × 100 vs. 193.3 ± 51.9 Nm kg^{-1} × 100, $p < 0.05$) and HGP (30 ± 7 kg vs. 35 ± 8 kg, $p < 0.05$) were also significantly lower in the DM group than in the non-DM group.

Correlations between muscle mass, muscle strength, and HbA1c

At the end of CR, the values for thigh muscle strength were correlated with thigh circumference ($r = 0.44$, $p < 0.01$) and MAMA ($r = 0.37$, $p < 0.05$) (Fig. 1). The values of HGP were correlated with thigh circumference ($r = 0.52$, $p < 0.01$), and MAMA ($r = 0.48$, $p < 0.05$) (Fig. 1). The same trends were observed at the beginning of CR [9]. Moreover, the percent change in Ex muscle strength was

Table 2
Comparison of glucose, lipid, and other parameters between the DM and non-DM groups.

	DM group ($n = 37$)		Non-DM group ($n = 41$)	
	Baseline	After	Baseline	After
Fasting blood glucose (mg/dl)	143 ± 57	167 ± 68	103 ± 14	112 ± 20
HbA1c (%) (JDS)	7.0 ± 1.3	7.2 ± 1.4	5.1 ± 0.4	5.2 ± 0.5
LDL-C (mg/dl)	116 ± 37	97 ± 22	124 ± 40	89 ± 16
HDL-C (mg/dl)	48 ± 15	50 ± 14	51 ± 12	49 ± 12
TG (mg/dl)	161 ± 97	168 ± 191	149 ± 66	158 ± 97
Creatinine (mg/dl)	1.4 ± 2.3	1.1 ± 1.3	0.8 ± 0.2	0.8 ± 0.2
CRP (mg/dl)	0.6 ± 1.4	0.6 ± 1.3	0.2 ± 0.2	0.7 ± 2.0

Data are presented as the mean value ± SD. DM, diabetes mellitus; HbA1c, hemoglobin A1c; LDL-C, low-density lipoprotein cholesterol; HDL-C, high-density lipoprotein cholesterol; TG, triglycerides; CRP, C-reactive protein.
*$p < 0.05$ compared with at baseline.
**$p < 0.05$ compared with the DM group at baseline.
#$p < 0.05$ compared with the DM group after 6 months.

Table 3
Comparison of anthropometric parameters between the DM and non-DM groups.

	DM group ($n = 37$)		Non-DM group ($n = 41$)	
	Baseline	After	Baseline	After
Body mass index (kg m^{-2})	23.3 ± 2.7	22.6 ± 1.9	23.4 ± 2.9	23.7 ± 2.5
Lean body weight (kg)	48.4 ± 9.8	45.2 ± 5.2	49.4 ± 7.7	49.6 ± 7.3
Waist circumference (cm)	83.4 ± 8.3	80.2 ± 5.7*	84.5 ± 7.8	82.2 ± 6.7*
Thigh circumference (cm)	47.2 ± 4.3	47.3 ± 2.5	48.9 ± 4.1	50.7 ± 3.7*,#
Arm forced circumference (cm)	28.3 ± 2.7	28.4 ± 1.6	29.0 ± 2.6	30.0 ± 2.4*,#
Mid-upper arm muscle circumference (cm)	24.9 ± 2.4	25.0 ± 1.8	25.7 ± 2.5	26.5 ± 2.4*,#
Mid-upper arm muscle area (cm^2)	49.7 ± 9.5	49.9 ± 7.1	53.2 ± 10.3	56.5 ± 10.0*,#

Data are presented as the mean value ± SD. DM, diabetes mellitus.
* $p < 0.05$ compared with at baseline.
# $p < 0.05$ compared with the DM group after 6 months.

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Table 4
Comparison of exercise tolerance and muscle strength between the DM and non-DM groups.

	DM group (n = 37)		Non-DM group (n = 41)	
	Baseline	After	Baseline	After
Anaerobic threshold (ml kg^{-1} min^{-1})	8.3 ± 1.6	11.3 ± 2.2*	9.7 ± 2.7	13.3 ± 3.4*,#
Peak VO_2 (ml kg^{-1} min^{-1})	13.7 ± 4.0	19.4 ± 3.8*	16.0 ± 4.7**	22.9 ± 5.4*,#
Anaerobic threshold workload (W)	34 ± 15	52 ± 21*	39 ± 20	66 ± 22*,#
Peak workload (W)	73 ± 23	107 ± 21*	81 ± 29	124 ± 29*,#
Knee extension (Nm kg^{-1} × 100)	136.3 ± 42.7	164.1 ± 43.3*	162.7 ± 47.9**	193.3 ± 51.9*,#
Knee flexion (Nm kg^{-1} × 100)	80.0 ± 26.7	102.4 ± 30.3*	91.2 ± 29.2	115.1 ± 30.7*
Power of hand grip (kg)	28 ± 9	30 ± 7*	31 ± 9	35 ± 8*,#

Data are presented as the mean value ± SD. DM, diabetes mellitus.
* $p < 0.05$ compared with at baseline.
** $p < 0.05$ compared with the DM group at baseline.
# $p < 0.05$ compared with the DM group after 6 months.

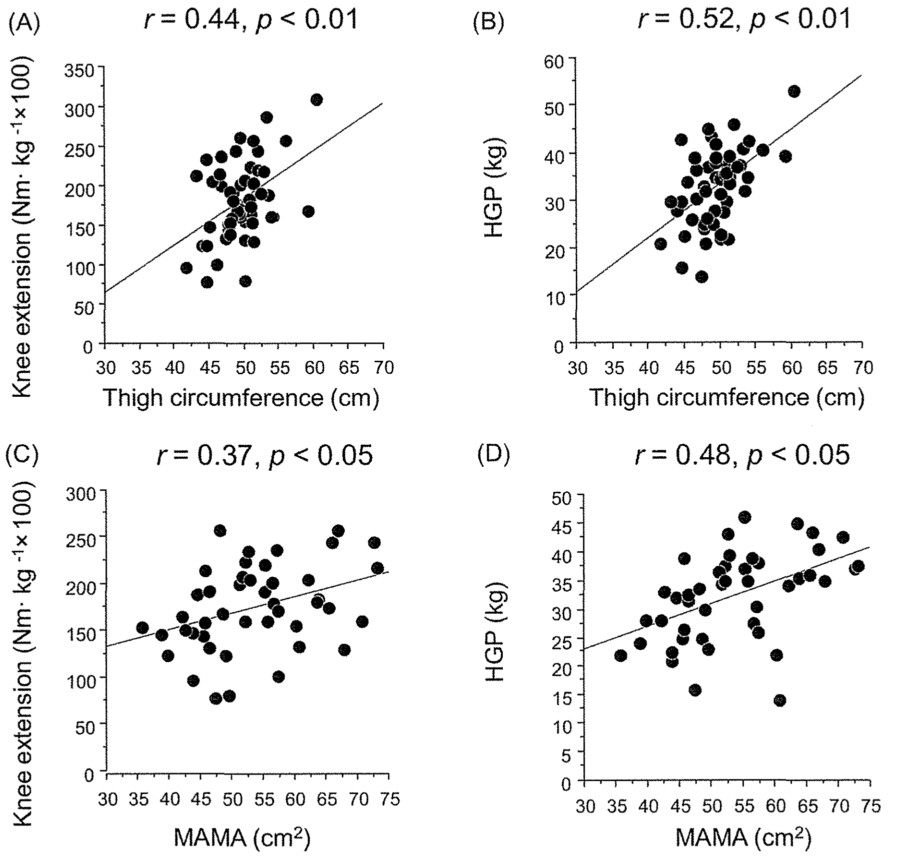

Fig. 1. Correlations between muscle strength and muscle mass. At the end of cardiac rehabilitation, the levels of muscle strength of thigh were correlated with thigh circumference ($r = 0.44$, $p < 0.01$) (A) and MAMA ($r = 0.37$, $p < 0.05$) (C). The values of HGP were correlated with thigh circumference ($r = 0.52$, $p < 0.01$) (B), and MAMA ($r = 0.48$, $p < 0.05$) (D). MAMA, mid-upper arm muscle area; HGP, hand grip power.

correlated with MAMA ($r = 0.47$, $p < 0.005$) and HbA1c ($r = -0.41$, $p < 0.05$) (Fig. 2).

Discussion

In the present study, we demonstrated that: (1) the levels of muscle strength and exercise tolerance at the beginning and end of CR were significantly lower in the DM group than in the non-DM group; (2) exercise tolerance and muscle strength after CR were significantly improved in both groups; (3) muscle mass was significantly increased after CR in the non-DM group, but not in the DM group; and (4) percent change in muscle strength was correlated with that of HbA1c in patients undergoing CR after CABG. Our group and others previously reported a relationship between muscle strength and peak VO_2 in patients with cardiovascular disease [15,16]. However, to the best of our knowledge, this is the first report to simultaneously demonstrate the effects of CR on muscle mass, muscle strength, and exercise tolerance, and to compare DM and non-DM patients undergoing CR after CABG.

CR is described as a class I recommendation in most contemporary cardiovascular clinical practice guidelines. Following CR, patients show increased exercise tolerance and muscle strength, which have proven to be the strongest predictors of the risk of death among subjects both with and without known cardiovascular disease [17,18]. Boulé et al. reported in a meta-analysis that

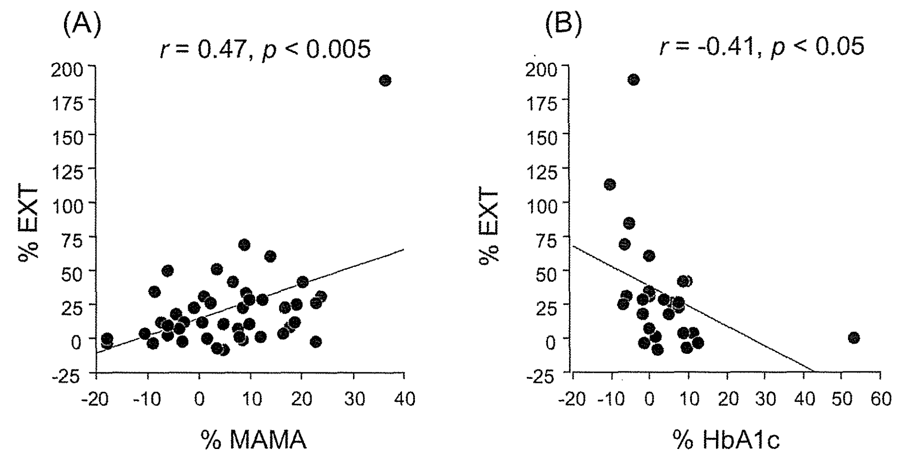

Fig. 2. Correlations between percent change in muscle strength and those in MAMA and HbA1c. A significant relation between the percent change in the muscle strength and those in MAMA was observed ($r = 0.47$, $p < 0.005$) (A). A significant inverse relation between the percent change in the muscle strength and those in HbA_1c was observed ($r = -0.41$, $p < 0.05$) (B). % EXT, percent change of knee extension; % MAMA, percent change of mid-upper arm muscle area; % HbA_1c, percent change of hemoglobin A_1c.

structured exercise training in DM patients achieved an 11.8% increase in peak VO_2 [19]. This is particularly important, because an improvement in peak VO_2 of 1.44 ml kg^{-1} min^{-1} was equivalent to a 7.9% reduction in overall mortality [20]. Moreover, exercise has many potential benefits, including not only improving exercise tolerance, but also improving glucose metabolism, insulin signaling, lipid profile, endothelial function, and blood pressure, reducing vascular inflammation and facilitating weight maintenance [7]. Either aerobic or resistance training alone improves glycemic control in DM patients, however, a combination of both may be more beneficial for improving risk factors than each alone [18]. Williams et al. have reported a combination of aerobic and resistance training exercise improved through neuromuscular adaptation, muscle fiber hypertrophy, and increased muscle oxidative capacity [21]. A previous study demonstrated the beneficial effects of resistance training on muscle mass and strength in chronic heart failure [18]. We also reported that CR with aerobic and resistance training had beneficial effects not only on the modification of metabolic risk factors, but also on improvement in exercise tolerance and muscular strength in patients with metabolic syndrome following CABG [12].

Levels of exercise tolerance and muscle strength were lower in DM than in non-DM patients in the present study. A previous report showed that endothelial dysfunction associated with high glucose levels is caused by the increased production of vasoconstrictor prostanoids as a consequence of protein kinase C activation [22]. Other studies have demonstrated that DM patients have impaired metabolism of both glucose and fatty acids in skeletal muscles. In addition, the bioenergetic capacity of skeletal muscle mitochondria was found to be impaired in DM patients [23]. We previously observed a significant inverse relationship between fasting glucose levels and thigh muscle strength at the beginning of CR in DM patients after CABG [9].

The DM group showed no increase in muscle mass such as MAMA and thigh circumference (Table 3), both of which correlated with thigh muscle strength and HGP (Fig. 1). Vergès et al. reported that the effects of CR on exercise capacity were significantly lower in DM than in non-DM patients, and the response to CR was influenced by blood glucose levels [7]. Moreover, we showed a significant inverse relationship between percent change for HbA1c and that for thigh muscle strength in the DM group (Fig. 2). Park et al. demonstrated that functional muscle quality was relatively low in DM patients. Furthermore, long duration of diabetes and poor glycemic control were associated with deterioration in muscle quality. Diabetes with poor glycemic control is related to the presence and severity of peripheral neuropathy and inflammatory cytokines, which have detrimental effects on muscle function [8]. Chronic hyperglycemia induces a condition of oxidative stress that is causally involved in the development of skeletal muscle depletion [24]. The increased production of reactive oxygen species induced by hyperglycemia has also been suggested to be involved in the redox regulation of glucose transport in skeletal muscle [25]. Hyperglycemia leads to the production of Amadori products between glucose and reactive amino groups of serum proteins [26]. These products undergo further irreversible reactions to form advanced glycation end products that promote insulin resistance and trigger inflammation, which leads to diabetic vascular complications [26]. The DM group had 11.0 ± 6.7 years' duration of DM history in the present study, and the prevalence of microvascular complications, including retinopathy, nephropathy, and neuropathy was 38%. These data may explain the mechanisms by which improvements in muscle mass and strength, and exercise tolerance, were impaired in the DM group. Thus, not only exercise but also glycemic control may be important in improving muscle structure.

Several studies have shown a U-shaped association between BMI and mortality. Increased risk was independent of abdominal and general obesity, and lifestyle and cardiovascular risk factors such as blood pressure and lipid levels were related to early cardiovascular morbidity and mortality. Additionally, Heitmann et al. reported that this risk was related more to thigh than waist circumference [13]. A study in a cohort of community-dwelling Japanese elderly demonstrated that low arm muscle area was an independent risk factor for 2-year mortality [27]. We would like to clarify whether arm muscle area after CR can predict morbidity and mortality in DM patients after CABG.

There are some limitations to the present study. First, because this was a single-center study with a small sample size, studies of larger sample size are required to confirm these findings. Second, the exercise session at the outpatient clinic was encouraged once a week with at least 2 exercise sessions at home. However, while the mean number of CR sessions in hospital was 16–18 times, we have no data regarding home-based exercise frequency and intensity for either group, and we need to assess the effects of exercise frequency and intensity in a future study. The program used in this study may not have been sufficiently rigorous to alter parameters such as glucose control and lipid profiles. Third, we enrolled patients undergoing CR after CABG. Therefore, the results may not necessarily be representative of all DM patients with CAD. In a future study,

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we need to investigate DM patients undergoing percutaneous intervention and/or those with acute coronary syndrome. Finally, we need to investigate whether different treatments, including intensive glucose control and a combination of aerobic and resistance training, can enhance muscle mass and ameliorate future cardiovascular events and long-term mortality in DM patients after CABG.

Conclusions

Patients with DM had lower muscle strength and lower exercise tolerance than non-DM patients at the beginning of CR after CABG. Both groups showed improved exercise tolerance and muscle strength after undergoing CR. However, DM patients had lower muscle mass, lower muscle strength, and lower exercise tolerance than non-DM patients at the end of CR. Moreover, improvement in muscle strength may be influenced by changes in muscle mass and high glucose levels in DM patients. Further studies are needed to assess whether a CR program including muscle mass intervention and aggressive glucose control would improve muscle mass and ameliorate future cardiovascular events in DM patients after CABG.

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References

[1] Haffner SM, Lehto S, Rönnemaa T, Pyörälä K, Laakso M. Mortality from coronary heart disease in subjects with type 2 diabetes and in nondiabetic subjects with and without prior myocardial infarction. N Engl J Med 1998;23:229–34.
[2] Tsuruta R, Miyauchi K, Yamamoto T, Dohi S, Tambara K, Dohi T, Inaba H, Kuwaki K, Daida H, Amano A. Effect of preoperative hemoglobin A1c levels on long-term outcomes for diabetic patients after off-pump coronary artery bypass grafting. J Cardiol 2011;57:181–6.
[3] BARI Investigators. The final 10-year follow-up results from the BARI randomized trial. J Am Coll Cardiol 2007;49:1600–6.
[4] Taylor RS, Brown A, Ebrahim S, Jolliffe J, Noorani H, Rees K, Skidmore B, Stone JA, Thompson DR, Oldridge N. Exercise-based rehabilitation for patients with coronary heart disease: systemic review and meta-analysis of randomized controlled trials. Am J Med 2004;116:682–92.
[5] Kavanagh T, Mertens DJ, Hamm LF, Beyene J, Kennedy J, Corey P, Shephard RJ. Prediction of long-term prognosis in 12169 men referred for cardiac rehabilitation. Circulation 2002;106:666–71.
[6] Savage PD, Antkowiak M, Ades PA. Failure to improve cardiopulmonary fitness in cardiac rehabilitation. J Cardiopulm Rehabil Prev 2009;29:284–91.
[7] Vergès B, Patois-Vergès B, Cohen M, Lucas B, Galland-Jos C, Casillas JM. Effects of cardiac rehabilitation on exercise capacity in Type 2 diabetes patients with coronary artery disease. Diabet Med 2004;21:889–95.
[8] Park SW, Goodpaster BH, Strotmeyer ES, de Rekeneire N, Harris TB, Schwartz AV, Tylavsky FA, Newman AB. Decreased muscle strength and quality in older adults with type 2 diabetes: the health, aging, and body composition study. Diabetes 2006;55:1813–8.
[9] Nishitani M, Shimada K, Sunayama S, Masaki Y, Kume A, Fukao K, Sai E, Yamashita H, Ohmura H, Onishi T, Shioya M, Sato H, Shimada A, Yamamoto T, Amamo A, et al. Impact of diabetes on muscle mass, muscle strength, and exercise tolerance in patients after coronary artery bypass grafting. J Cardiol 2011;58:173–80.
[10] Kuzuya T, Nakagawa S, Satoh J, Kanazawa Y, Iwamoto Y, Kobayashi M, Nanjo K, Sasaki A, Seino Y, Ito C, Shima K, Nonaka K, Kadowaki T. Committee of the Japan Diabetes Society on the diagnostic criteria of diabetes mellitus. Report of the Committee on the classification and diagnostic criteria of diabetes mellitus. Diabetes Res Clin Pract 2002;55:65–85.
[11] Seki E, Watanabe Y, Shimada K, Sunayama S, Onishi T, Kawakami K, Sato M, Sato H, Mokuno H, Daida H. Effects of a phase III cardiac rehabilitation program on physical status and lipid profiles in elderly patients with coronary artery disease: Juntendo Cardiac Rehabilitation Program (J-CARP). Circ J 2008;72:1230–4.
[12] Onishi T, Shimada K, Sunayama S, Ohmura H, Sumide T, Masaki Y, Fukao K, Nishitani M, Kume A, Sato H, Naito H, Kawai S, Amano A, Daida H. Effects of cardiac rehabilitation in patients with metabolic syndrome after coronary artery bypass grafting. J Cardiol 2009;53:381–7.
[13] Heitmann BL, Frederiksen P. Thigh circumference and risk of heart disease and premature death: prospective cohort study. BMJ 2009;339:b3292.
[14] Landi F, Russo A, Liperoti R, Pahor M, Tosato M, Capoluongo E, Bernabei R, Onder G. Midarm muscle circumference, physical performance and mortality: results from the aging and longevity study in the Sirente geographic area (ilSIRENTE study). Clin Nutr 2010;29:441–7.
[15] Sumide T, Shimada K, Ohmura H, Onishi T, Kawakami K, Masaki Y, Fukao K, Nishitani M, Kume A, Sato H, Sunayama S, Kawai S, Shimada A, Yamamoto T, Amano A, et al. Relationship between exercise tolerance and muscle strength following cardiac rehabilitation: comparison of patients after cardiac surgery and patients with myocardial infarction. J Cardiol 2009;54:273–81.
[16] Volterrani M, Clark AL, Ludman PF, Swan JW, Adamopoulos S, Piepoli M, Coats AJ. Predictors of exercise capacity in chronic heart failure. Eur Heart J 1994;15:801–9.
[17] Vanhees L, Fagard R, Thijs L, Amery A. Prognostic value of training-induced change in peak exercise capacity in patients with myocardial infarcts and patients with coronary bypass surgery. Am J Cardiol 1995;76:1014–9.
[18] Braith RW, Stewart KJ. Resistance exercise training: its role in the prevention of cardiovascular disease. Circulation 2006;113:2642–50.
[19] Boulé NG, Kenny GP, Haddad E, Wells GA, Sigal RJ. Meta-analysis of the effect of structured exercise training on cardiorespiratory fitness in Type 2 diabetes mellitus. Diabetologia 2003;46:1071–81.
[20] Blair SN, Kohl III HW, Barlow CE, Paffenbarger Jr RS, Gibbons LW, Macera CA. Changes in physical fitness and all-cause mortality. A prospective study of healthy and unhealthy men. JAMA 1995;273:1093–8.
[21] Williams MA, Stewart KJ. Impact of strength and resistance training on cardiovascular disease risk factors and outcomes in older adults. Clin Geriatr Med 2009;25:703–14.
[22] Tesfamariam B, Brown ML, Cohen RA. Elevated glucose impairs endothelium-dependent relaxation by activating protein kinase C. J Clin Invest 1991;87:1643–8.
[23] Kelley DE, He J, Menshikova EV, Ritov VB. Dysfunction of mitchondria in human skeletal muscle in type 2 diabetes. Diabetes 2002;51:2944–50.
[24] Aragno M, Mastrocola R, Catalano MG, Brignardello E, Danni O, Boccuzzi G. Oxidative stress impairs skeletal muscle repair in diabetic rats. Diabetes 2004;53:1082–8.
[25] Bonnefont-Rousselot D. Glucose and reactive oxygen species. Curr Opin Clin Nutr Metab Care 2002;5:561–8.
[26] Yamagishi S. Cardiovascular disease in recent onset diabetes mellitus. J Cardiol 2011;57:257–62.
[27] Enoki H, Kuzuya M, Masuda Y, Hirakawa Y, Iwata M, Hasegawa J, Izawa S, Iguchi A. Anthropometric measurements of mid-upper arm as a mortality predictor for community-dwelling Japanese elderly: the Nagoya Longitudinal Study of frail Elderly (NLS-FE). Clin Nutr 2007;26:597–604.

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Walking Speed in Patients With First Acute Myocardial Infarction Who Participated in a Supervised Cardiac Rehabilitation Program After Coronary Intervention

Shuhei YAMAMOTO,[1] MS, Atsuhiko MATSUNAGA,[1,2] PhD, Kentaro KAMIYA,[1,3] MS, Kazumasa MIIDA[3], Yukari EBINA[3], Kazuki HOTTA,[1] MS, Ryosuke SHIMIZU,[1] MS, Ryota MATSUZAWA,[1] MS, Yoshifumi ABE,[1] MS, Masahiko KIMURA,[2] PhD, Shinobu SHIMIZU,[2] PhD, Hiroyuki WATANABE,[2] PhD, Chiharu NODA,[4] MD, Minako YAMAOKA-TOJO,[2] MD, Takashi MASUDA,[1,2] MD, *and* Tohru IZUMI,[4] MD

SUMMARY

This study aimed to evaluate the degree of reduction in walking speed in patients with acute myocardial infarction (AMI) compared to age-matched community-dwelling people and identify factors associated with walking speed. The subjects were 210 middle-aged and 188 elderly patients with a first AMI (AMI group) and 198 age-matched community-dwelling people with no medical events (non-AMI group). We measured maximum walking speed in all subjects and collected clinical data, including that related to motor function, at the end of a supervised cardiac rehabilitation program in the AMI group. Data were analyzed based on age and sex. Walking speed in men and women in the middle-aged AMI subgroup decreased to 77.9% and 75.7% relative to that of the non-AMI subgroup matched by sex, respectively; walking speed in men and women in the elderly AMI subgroup decreased to 78.7% and 74.2% relative to that of the non-AMI subgroup matched by sex, respectively. Moreover, 6.4% of men and 23.8% of women in the middle-aged AMI subgroup, and 28.8% of men and 43.5% of women in the elderly AMI subgroup, had a slower walking speed compared to their respective non-AMI groups, which may contribute to an increased risk for cardiovascular mortality. Stepwise multiple regression analysis for motor function revealed that only leg strength in the middle-aged AMI subgroup, and both leg strength and standing balance in the elderly AMI subgroup, were associated with walking speed, regardless of sex after adjusting for clinical characteristics. These results suggest that evaluation and management of walking speed are necessary in implementing effective disease management for patients with first AMI. (Int Heart J 2012; 53: 347-352)

Key words: Standing balance, Leg strength

Walking speed, or gait speed, is a parameter of growing interest for the clinical evaluation of prognosis after adverse health-related events such as falls, hospital admission, and difficulty performing physical activities of daily living (ADL) among community-dwelling people.[1-5] A recent prospective cohort study reported that a slower walking speed was strongly associated with cardiovascular mortality in a population of well-functioning elderly people.[5] The Heart Failure and A Controlled Trial Investigating Outcomes of Exercise TraiNing (HF-ACTION) showed that greater clinical benefits, such as reduced mortality or hospitalization, were observed among patients with heart failure who adhered to a higher volume of exercise, which was calculated by multiplying exercise intensity by the time spent exercising.[6,7] Patients with chronic heart failure in this trial participated in supervised exercise training, followed by a 3-month home-based exercise program. Walking speed, an indicator of exercise intensity, was closely related to the volume of exercise in HF-ACTION, as walking was the preferred physical activity at home that required no special exercise equipment. Furthermore, many studies have shown that walking ability, as reflected by maximum walking speed, is strongly associated with the total volume of physical ADL in community-dwelling people.[8,9] Accordingly, evaluation and management of walking speed may be necessary for implementing effective disease management and secondary prevention interventions for cardiac patients. Despite this, only a few studies have examined walking speed among cardiac patients in the recovery phase. Ostir, *et al*[10] reported that the degree of deterioration in lower extremity performance during hospitalization was approximately 5- to 8-fold higher in cardiac patients compared to well-functioning elderly people. Thus, decreased walking speed may persist in cardiac patients even in the recovery phase.

The aim of this study was to evaluate the degree of reduction in walking speed in patients with a first myocardial infarction (AMI) who participated in a supervised cardiac rehabilitation program after coronary intervention, compared to age- and

From the [1] Graduate School of Medical Sciences, and [2] Department of Rehabilitation, School of Allied Health Sciences, Kitasato University, [3] Cardiovascular Center, Kitasato University Hospital, and [4] Department of Internal Medicine and Cardiology, School of Medicine, Kitasato University, Sagamihara, Kanagawa, Japan.

Address for correspondence: Atsuhiko Matsunaga, PhD, Department of Rehabilitation, School of Allied Health Sciences, Kitasato University, 1-15-1 Kitasato, Minami-ku, Sagamihara-shi, Kanagawa 252-0373, Japan.

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sex-matched community-dwelling adults who presented with no medical conditions. In addition, factors associated with walking speed were identified based on clinical data, including motor function, obtained at the end of the supervised cardiac rehabilitation program.

Methods

Study population: The study protocol was approved by the Ethics Committee of Kitasato University, and informed written consent was obtained from all participants after the study protocol was explained in detail. This study was conducted in accordance with the standards set forth by the latest revision of the Declaration of Helsinki. A consecutive series of 982 patients with AMI (age range, 40-79 years) who were admitted to the Cardiovascular Center of Kitasato University Hospital from March 2001 to October 2009 were recruited; these patients underwent percutaneous coronary intervention or coronary artery bypass surgery following coronary angiography to detect significant coronary lesions, and fully participated in a supervised cardiac rehabilitation program during hospitalization. Patients who were previously hospitalized for myocardial infarction or heart failure, who had uncontrolled arrhythmias, uncontrolled hypertension, chronic renal failure and had been on hemodialysis, peripheral artery disease, or diabetic retinopathy, who needed assistance with walking at hospital discharge, who had other conditions that limited walking ability (eg, dementia, low vision or blindness, orthopedic abnormalities, and paralysis due to stroke), were excluded from the study. Consequently, 210 middle-aged patients (178 men and 32 women) and 188 elderly patients (134 men and 54 women) with a first AMI (AMI group) were eligible for inclusion in the study.

Community-dwelling adults (age range, 40-79 years) registered at a temporary employment agency in Kanagawa, Japan, who were able to walk independently without any assistance or aid, had no history of cardiovascular disease, cerebrovascular disease, neuromuscular disease, or fractures in the spine or lower limbs, were recruited as controls. The temporary employment agency is an organization established to provide work or volunteer activities. Given that some individuals registered at the agency might demonstrate a higher level of daily physical activity than average people, those who self-reported that their physical activity levels were higher (eg, those who participated in regular or vigorous exercise or sports) were excluded from the study. Consequently, 87 middle-aged subjects (49 men and 38 women) and 111 elderly subjects (82 men and 29 women) were enrolled as controls (non-AMI group).

Subject characteristics: Age, sex, height, weight, and body mass index (BMI) were assessed for all subjects. In addition, the number of patients with coronary artery bypass graft surgery (CABG), left ventricular ejection fraction (LVEF) by echocardiography, peak serum creatine kinase (CK), brain natriuretic peptide (BNP) at hospital admission, and duration of hospital stay were assessed using clinical records for the AMI group.

Assessment of walking speed in AMI and non-AMI groups: Maximum walking speed was measured twice while subjects walked a distance of 10 m at maximum speed without running. The highest value for the maximum walking speed, expressed in meters per minute, was recorded. The measurement of maximum walking speed for the AMI group was performed at the end of a supervised cardiac rehabilitation program.

Assessment of motor function in AMI and non-AMI groups: Leg strength and standing balance were evaluated in the AMI and non-AMI groups. Maximum voluntary isometric knee extensor strength was measured twice with a hand-held dynamometer (μTas MT-1; Anima, Tokyo) while subjects sat on a chair with the hip and knee flexed at 90 degrees. Leg strength was expressed as a percentage of body weight (%BW) by dividing the average value of the right and left maximum isometric leg strength by body weight.

Standing balance was evaluated with two balance indices: one-leg standing time and the postural stability index. One-leg standing time reflects the ability of subjects to maintain the center of pressure within the base of support of their body. The length of time that subjects can stand on one leg with their eyes open, while holding their hands on their waist without any aid or falling, was measured using a stopwatch. The measurement was stopped if subjects hopped, stepped, put the raised foot on the other foot or on the floor, or released their hands from the waist to balance. Subjects underwent a second trial if they were unable to stand on one leg for 60 seconds in the first trial. The postural stability index reflects the ability to shift the center of pressure in a desired direction as far as possible within the base of support, and hold the center of pressure at the farthest position in the desired direction without falling. A stabilometer (gravicorder G-6100; Anima, Tokyo) was used to measure the postural stability index.[11] At first, subjects were asked to stand on the stabilometer platform barefoot with a stance width of 10 cm with their eyes open and their arms relaxed at their sides (neutral position) for 10 seconds. Subjects were then instructed to shift the center of pressure in the anterior, posterior, right, and left direction as far as possible, and hold the center of pressure at the farthest position in each direction for 10 seconds without lifting their feet off the stabilometer platform. The following equation was used: postural stability index = log {(area of stability limit + area of postural sway)/(area of postural sway)}. A low index score indicates poor standing balance.

Motor function measurements for the AMI group were performed at the end of a supervised cardiac rehabilitation program.

Supervised cardiac rehabilitation program for the AMI group: The supervised cardiac rehabilitation program at the Cardiovascular Center of Kitasato University Hospital consists of two exercise stages. The first stage comprises basic activity training, such as sitting up in bed, sit-to-stand motions, self-care, and walking within the ward, which are usually started on the second day after AMI. After patients complete the first stage, they proceed to the second stage, which involves a progressive combined exercise, in which stretching, resistance, and aerobic training are performed according to the American College of Sports Medicine's guidelines for exercise testing and prescription[12] and the Japanese Circulation Society's guidelines for rehabilitation in patients with cardiovascular disease (JCS 2007).[13] The cardiac rehabilitation exercise program is carried out for approximately 2 weeks during hospitalization unless the patient develops adverse symptoms or events after coronary intervention.

Statistical analysis: Differences in subject characteristics (age, height, weight, and BMI), maximum walking speed, and motor function (leg strength and standing balance) between the AMI and non-AMI groups were assessed for significance using Student's unpaired *t*-test; subjects were subdivided by age (middle-aged subjects, aged < 65 years; elderly subjects, aged ≥ 65 years) and sex. Data on maximum walking speed for all subjects by age and sex were assigned using a histogram of speed intervals (10 m/minute). To compare the degree of reduction in walking speed between middle-aged and elderly patients, or between men and women, maximum walking speed was expressed for each AMI subgroup by age and sex as a percentage of the mean value for the non-AMI subgroup matched by age and sex.

Univariate and multivariate regression analyses were conducted to identify factors associated with maximum walking speed in the AMI group. Correlations between age, BMI, LVEF, peak CK, BNP, duration of hospital stay, leg strength, one-leg standing time, index of postural stability, and maximum walking speed were analyzed in each AMI subgroup using Pearson's correlation coefficients. Stepwise multiple regression analysis was performed to identify independent factors associated with maximum walking speed using BMI, LVEF, BNP, duration of hospital stay, number of patients with CABG, leg strength, one-leg standing time, and index of postural stability in each AMI subgroup.

All analyses were performed using the Statistical Package for Social Sciences (SPSS version 12.0; SPSS, Chicago, IL, USA). $P < 0.05$ was considered statistically significant.

RESULTS

Subject characteristics: The background characteristics, maximum walking speed, and motor function in all subjects by age and sex are shown in Tables I and II. No differences in height, weight, and BMI were found between the AMI and non-AMI groups regardless of age and sex.

Walking speed: Maximum walking speed in all AMI subgroups was significantly lower than that of non-AMI subgroups matched by age and sex ($P < 0.01$, respectively). The histograms of maximum walking speed by age and sex are shown in the Figure. The maximum walking speed in men and women in the middle-aged AMI subgroup decreased to 77.9% and 75.7%, respectively, relative to that of the non-AMI subgroup matched by sex; maximum walking speed in men and women in the elderly AMI subgroup decreased to 78.7% and 74.2%, respectively, relative to that of the non-AMI subgroup matched by sex.

Motor function: In the middle-aged AMI subgroup, leg strength and the postural stability index in men were significantly lower than those of non-AMI subgroups matched by age and sex ($P < 0.01$ and $P < 0.05$, respectively). Leg strength, one-leg standing time, and the postural stability index in women were significantly lower ($P < 0.01$, respectively). In the elderly AMI subgroup, leg strength, one-leg standing time, and the postural stability index in men and women were significantly lower than those of non-AMI subgroups matched by sex ($P < 0.01$, respectively).

Factors associated with maximum walking speed in the AMI group: Correlation coefficients for subject characteristics, motor function, and maximum walking speed in the AMI group by age and sex are shown in Table III. In the middle-aged AMI subgroup, the maximum walking speed in men was significantly correlated with the duration of hospital stay, leg strength, and one-leg standing time ($P < 0.01$, $P < 0.01$, and $P < 0.05$, respectively), and in women, with the duration of hospital stay, BNP, and leg strength ($P < 0.05$, $P < 0.05$, and $P < 0.01$, respectively). In the elderly AMI subgroup, the maximum walking speed in men was significantly correlated with the duration of hospital stay, BNP, leg strength, one-leg standing time, and the postural stability index ($P < 0.01$, $P < 0.01$, $P < 0.01$, $P < 0.01$, and $P < 0.01$, respectively), and in women, with height, leg strength, one-leg standing time, and the pos-

Table I. Subject Characteristics, Walking Speed, and Motor Function in Men in AMI and Non-AMI Groups

	Middle-aged		Elderly	
	non-AMI group	AMI group	non-AMI group	AMI group
Number of patients (n)	49	178	82	134
Age (years)	53.7 ± 7.0	53.7 ± 5.6	70.5 ± 3.8	70.8 ± 4.3
Height (cm)	168.7 ± 5.6	167.1 ± 6.0	162.4 ± 5.6	161.9 ± 6.1
Weight (kg)	67.8 ± 9.1	68.4 ± 9.6	62.1 ± 7.8	61.0 ± 10.3
BMI (kg/m^2)	23.7 ± 2.9	24.5 ± 3.1	23.5 ± 2.6	23.2 ± 3.2
LVEF (%)		49.5 ± 11.2		50.1 ± 11.2
Peak CK (IU/L)		2881.4 ± 2248.9		2155.4 ± 2137.0
BNP (pg/mL)		75.3 ± 123.4		231.0 ± 293.9
Percentage of patients				
CABG (%)		16.9		26.1
Diabetes mellitus (%)		53.9		34.6
Dyslipidemia (%)		86.5		49.3
Duration of hospital stay (days)		22.1 ± 10.0		25.4 ± 14.7
Maximum walking speed (m/minute)	145.4 ± 16.5	113.3 ± 17.1**	123.1 ± 20.2	96.9 ± 20.5††
Leg strength (%BW)	63.9 ± 16.7	56.3 ± 13.7**	60.2 ± 15.0	47.6 ± 13.4††
One-leg standing time (seconds)	58.2 ± 5.6	55.6 ± 12.6	48.3 ± 19.2	36.2 ± 23.8††
Postural stability index	1.73 ± 0.35	1.62 ± 0.31*	1.61 ± 0.30	1.22 ± 0.43††

Values are presented as mean ± SD. $^{*}P < 0.05$ and $^{**}P < 0.01$ versus middle-aged non-AMI group, $^{††}P < 0.01$ versus elderly non-AMI group. AMI indicates acute myocardial infarction; BMI, body mass index; LVEF, left ventricular ejection fraction; CK, creatine kinase; BNP, brain natriuretic peptide; CABG, coronary artery bypass graft; and BW, body weight.

Table II. Subject Characteristics, Walking Speed, and Motor Function in Women in AMI and Non-AMI groups

	Middle-aged		Elderly	
	non-AMI group	AMI group	non-AMI group	AMI group
Number of patients (*n*)	38	32	29	54
Age (years)	55.8 ± 5.2	57.4 ± 4.7	69.6 ± 3.3	70.9 ± 3.6
Height (cm)	156.2 ± 5.5	153.8 ± 5.0	150.7 ± 4.5	150.8 ± 4.5
Weight (kg)	53.0 ± 7.7	56.3 ± 9.9	52.1 ± 5.5	52.7 ± 8.4
BMI (kg/m^2)	21.7 ± 3.2	23.7 ± 3.8	23.0 ± 2.3	23.2 ± 3.4
LVEF (%)		50.4 ± 10.5		53.0 ± 13.4
Peak CK (IU/L)		1842.8 ± 1275.8		2261.9 ± 1779.2
BNP (pg/mL)		243.6 ± 358.6		200.3 ± 217.5
Percentage of patients				
CABG (%)		11.5		20.4†
Diabetes mellitus (%)		34.6		42.6†
Dyslipidemia (%)		53.8		59.3
Duration of hospital stay (days)		23.4 ± 10.9		25.5 ± 9.3
Maximum walking speed (m/minute)	127.1 ± 13.8	96.3 ± 18.6**	112.7 ± 9.2	83.6 ± 13.3††
Leg strength (%BW)	54.6 ± 12.2	41.7 ± 11.6**	52.6 ± 9.7	35.3 ± 9.9††
One-leg standing time (seconds)	60.0 ± 0.0	41.9 ± 23.9**	50.8 ± 15.7	22.9 ± 19.4††
Postural stability index	1.86 ± 0.20	1.37 ± 0.30**	1.56 ± 0.31	0.95 ± 0.50††

Values are presented as mean ± SD. $^{**}P < 0.01$ versus middle-aged non-AMI group, $^{\dagger}P < 0.01$ and $^{\dagger\dagger}P < 0.01$ versus elderly non-AMI group. AMI indicates acute myocardial infarction; BMI, body mass index; LVEF, left ventricular ejection fraction; CK, creatine kinase; BNP, brain natriuretic peptide; CABG, coronary artery bypass graft; and BW, body weight.

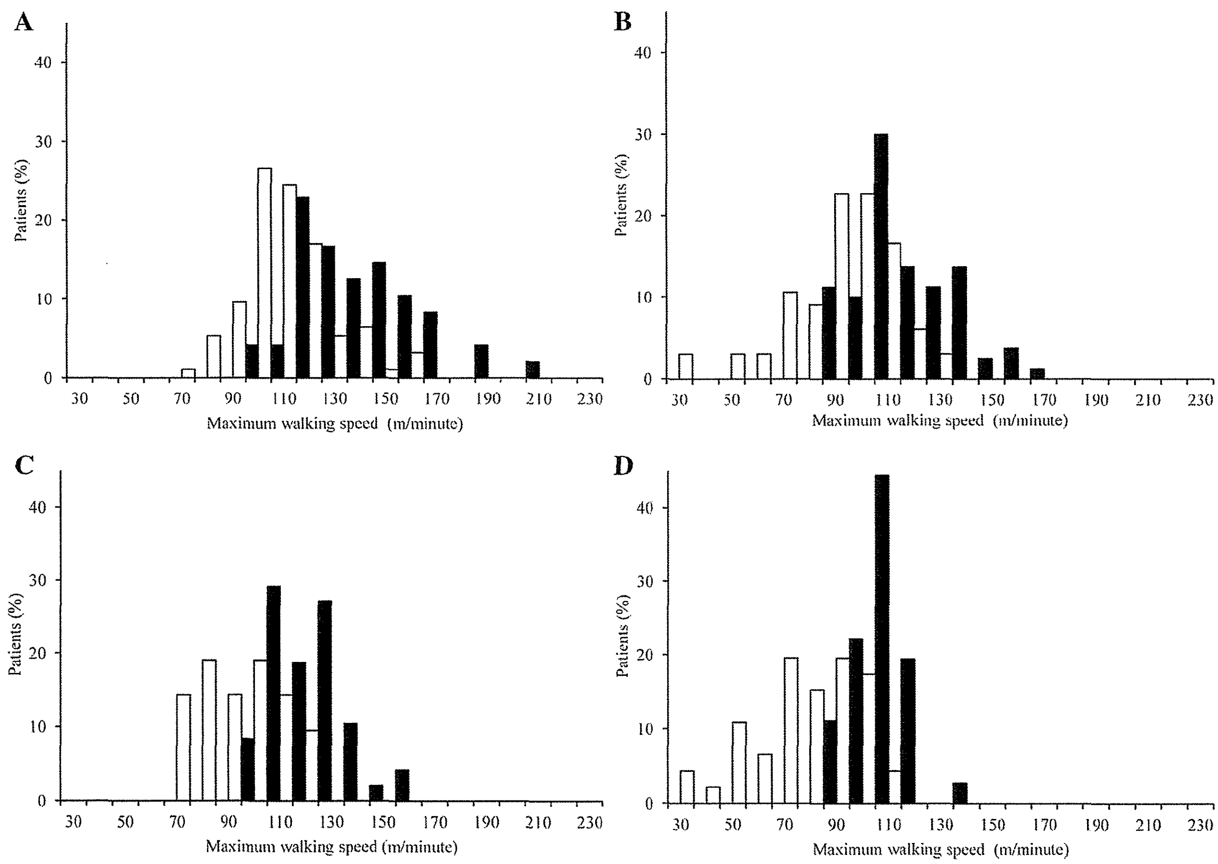

Figure. Histograms of maximum walking speed. Subjects walked a distance of 10 m at maximum speed without running. Maximum walking speed was calculated in meters per minute. Open and closed bars indicate AMI and non-AMI subgroups, respectively. **A:** Middle-aged men. **B:** Elderly men. **C:** Middle-aged women. **D:** Elderly women.

Table III. Univariate Analysis of Subject Characteristics and Motor Function Associated With Maximum Walking Speed in The AMI Group

	Pearson's correlation coefficient			
	Middle-aged men	Middle-aged women	Elderly men	Elderly women
Height	0.04	0.13	0.21	0.44*
Weight	0.03	-0.09	0.06	0.20
BMI	0.03	-0.22	-0.04	-0.03
Duration of hospital stay	-0.29**	-0.48*	-0.55**	-0.24
Peak CK	0.07	-0.35	0.03	-0.23
LVEF	0.05	0.26	-0.15	-0.29
BNP	-0.13	0.02*	-0.34**	0.22
Leg strength	0.42**	0.68**	0.58**	0.35*
One-leg standing time	0.23*	0.42	0.54**	0.36*
Postural stability index	0.17	0.08	0.46**	0.63**

*$P < 0.05$, **$P < 0.01$. AMI indicates acute myocardial infarction; BMI, body mass index; CK, creatine kinase; LVEF, left ventricular ejection fraction; and BNP, brain natriuretic peptide.

Table IV. Multivariate Analysis of Subject Characteristics and Motor Function Associated With Maximum Walking Speed in The AMI Group

	Unstandardized regression coefficient	Standardized regression coefficient	P
Middle-aged AMI subgroup			
Men			
Leg strength	0.66	0.43	< 0.01
Duration of hospital stay	-0.69	-0.25	< 0.05
Women			
Leg strength	1.30	0.71	< 0.01
Elderly AMI subgroup			
Men			
Leg strength	0.59	0.43	< 0.01
Postural stability index	16.36	0.35	< 0.01
BNP	-0.01	-0.21	< 0.05
Women			
Postural stability index	17.97	0.56	< 0.01
One-leg standing time	0.35	0.44	< 0.01
Leg strength	0.69	0.44	< 0.01

AMI indicates acute myocardial infarction and BNP, brain natriuretic peptide.

tural stability index ($P < 0.05$, $P < 0.05$, $P < 0.05$, and $P < 0.01$, respectively).

Independent factors associated with maximum walking speed identified by stepwise multiple regression analysis in the AMI group are shown in Table IV. In the middle-aged AMI subgroup, the duration of hospital stay and leg strength were significant and independent factors associated with maximum walking speed in men (adjusted $R^2 = 0.287$, $P < 0.01$), whereas leg strength was the only significant and independent factor associated with maximum walking speed in women (adjusted $R^2 = 0.452$, $P < 0.01$). In the elderly AMI subgroup, BNP, leg strength, and the postural stability index were significant and independent factors associated with maximum walking speed in men (adjusted $R^2 = 0.472$, $P < 0.01$), whereas leg strength, one-leg standing time, and the postural stability index were significant and independent factors associated with maximum walking speed in women (adjusted $R^2 = 0.652$, $P < 0.01$).

Discussion

The summary performance score consisting of scores for tests of repetitive chair stands, standing balance, and walking speed has been used to categorize community-dwelling people at risk for adverse events.[14-17] The summary performance score strongly reflects changes in lower-extremity physical function during hospitalization in subjects who suffered an AMI, chronic heart failure, and stroke.[10,18] On the other hand, recent reports demonstrated that walking speed alone could provide similar information on risk for adverse outcomes as does a more comprehensive summary measure of physical performance.[3,4] Accordingly, walking speed is considered a quick, safe, inexpensive, and highly reliable parameter in routine clinical practice for prognosis of the onset of adverse health-related events.

We assessed the degree of reduction in walking speed in patients with AMI compared to well-functioning adults who presented with no medical events. Walking speed in AMI subgroups according to age and sex were significantly lower than age- and sex-matched non-AMI subgroups; walking speed in the AMI group decreased to approximately 70% relative to that of the non-AMI group regardless of age and sex. Subjects included only those who had their first AMI and had not had any other conditions that limited walking ability, such as a stroke or orthopedic abnormality. Thus, our findings suggest that walking speed decreases occurred after AMI onset. Moreover, decreases in walking speed in patients with AMI might not improve even after participation in the supervised cardiac rehabilitation program following coronary intervention.

A recent cohort study on walking speed reported that community-dwelling people with a slow walking speed (≤ 90 m/minute for men and ≤ 81 m/minute for women) had an almost 3-fold higher risk for cardiovascular mortality compared to those with a fast walking speed (> 111 m/minute for men and > 90 m/minute for women).[5] As shown in the histograms of the Figure, our results indicate that 6.4% of men and 23.8% of women in the middle-aged AMI subgroup, and 28.8% of men and 43.5% of women in the elderly AMI subgroup, had a walking speed slower than those reported in the previous cohort study; this was not the case in the non-AMI group. The recommended walking speed for crossing over the road at a signalized intersection is reported to be 1.0-1.2 m/second (60-70 m/minute) for community-dwelling people.[19,20] In this study, only 9.1% of men and 24.4% of women in the elderly AMI subgroup had a walking speed less than 70 m/minute. The main goals of cardiac rehabilitation are to reduce the risk of another cardiovascular event or worsening of existing cardiovascular conditions, and to improve health-related quality of life and daily physical activity levels.[13,21] Our results suggest that evaluation and management of walking speed are necessary to implement effective disease management and secondary prevention interventions for cardiac patients.

We assessed factors associated with walking speed in the AMI group by multiple regression analysis to develop an effective disease management program for cardiac patients. Although motor function in the AMI subgroups according to age and sex were significantly lower than the age and sex matched non-AMI subgroups, the only motor function associated with walking speed in the middle-aged AMI subgroup was leg strength, whereas both leg strength and standing balance were associated with walking speed in the elderly AMI subgroup, regardless of sex after adjusting for clinical characteristics. The postural stability index, which reflects dynamic balance ability to shift the center of pressure as far as possible within the base of support of the body,[11] was associated with walking speed in both men and women in the elderly AMI subgroup. Our results were in line with previous studies reporting an association between dynamic standing balance and maximum walking speed in elderly community-dwelling people.[22-24] Thus, an improvement in standing balance may be necessary for maintaining or increasing walking speed in elderly patients with AMI.

We instituted a progressive combined exercise program involving stretching, resistance, and aerobic training according to guidelines for patients with AMI. However, only a few guidelines are available on improving walking speed in elderly cardiac patients. A specific exercise regimen aimed at improving standing balance should thus be recommended in a formal cardiac rehabilitation program for elderly patients.

Study limitations: This study has some limitations worth noting. First, we could not precisely measure the degree of reduction in walking speed in patients with AMI because walking speed prior to AMI onset was not available. Further studies will be needed to investigate the daily level of physical activity prior to AMI onset given the difficulties of assessing walking speed prior to or just after onset. Second, this study had a cross-sectional design; therefore, future studies should investigate changes in walking speed, physical function, and clinical characteristics in patients with AMI with a longitudinal study design.

References

1. Shinkai S, Watanabe S, Kumagai S, *et al.* Walking speed as a good predictor for the onset of functional dependence in a Japanese rural community population. Age Ageing 2000; 29: 441-6.
2. Ostir GV, Berges I, Kuo YF, *et al.* Assessing gait speed in acutely ill older patients admitted to an acute care for elders hospital unit. Arch Intern Med 2012; 172: 353-8.
3. Abellan van Kan G, Rolland Y, Andrieu S, *et al.* Gait speed at usual pace as a predictor of adverse outcomes in community-dwelling older people an International Academy on Nutrition and Aging (IANA) Task Force. J Nutr Health Aging 2009; 13: 881-9. (Review)
4. Montero-Odasso M, Schapira M, Soriano ER, *et al.* Gait velocity as a single predictor of adverse events in healthy seniors aged 75 years and older. J Gerontol A Biol Sci Med Sci 2005; 60: 1304-9.
5. Dumurgier J, Elbaz A, Ducimetière P, Tavernier B, Alpérovitch A, Tzourio C. Slow walking speed and cardiovascular death in well functioning older adults: prospective cohort study. BMJ 2009; 339: b4460.
6. Keteyian SJ, Miller NH, Ellis SJ, *et al.* A dose-response analysis of patients with Heart Failure enrolled in A Controlled Trial Investigating Outcome of Exercise Training (HF-ACTION). American College of Cardiology 2009.
7. O'Connor CM, Whellan DJ, Lee KL, *et al.* Efficacy and safety of exercise training in patients with chronic heart failure: HF-ACTION randomized controlled trial. JAMA 2009; 301: 1439-50.
8. Suzuki T, Yoshida H, Kim H, *et al.* Walking speed as a good predictor for maintenance of I-ADL among the rural community elderly in Japan: A 5-year follow-up study from TMIG-LISA. Geriatrics & Gerontology International 2003; 3: S6-S14.
9. Kumahara H, Schutz Y, Ayabe M, *et al.* The use of uniaxial accelerometry for the assessment of physical-activity-related energy expenditure: a validation study against whole-body indirect calorimetry. Br J Nutr 2004; 91: 235-43.
10. Ostir GV, Volpato S, Fried LP, *et al.* Reliability and sensitivity to change assessed for a summary measure of lower body function: results from the Women's Health and Aging Study. J Clin Epidemiol 2002; 55: 916-21.
11. Mochizuki H, Mineshima T. Reliability and validity of the index of postural stability using forceplates. J Jpn Phys Ther Assoc 2000; 27: 199-203.
12. American College of Sports Medicine. *ACSM's guidelines for exercise testing and prescription.* 7th ed. Baltimore Lippincott Williams & Wilkins, 2005.
13. The Japanese Circulation Society. Guidelines for rehabilitation in patients with cardiovascular disease (JCS 2007). Available at: http://www.j-circ.or.jp/guideline/index.htm. Accessed December 2, 2007.
14. Guralnik JM, Simonsick EM, Ferrucci L, *et al.* A short physical performance battery assessing lower extremity function: association with self-reported disability and prediction of mortality and nursing home admission. J Gerontol 1994; 49: M85-94.
15. Guralnik JM, Ferrucci L, Simonsick EM, Salive ME, Wallace RB. Lower-extremity function in persons over the age of 70 years as a predictor of subsequent disability. N Engl J Med 1995; 332: 556-61.
16. Ostir GV, Markides KS, Black SA, Goodwin JS. Lower body functioning as a predictor of subsequent disability among older Mexican Americans. J Gerontol A Biol Sci Med Sci 1998; 53: M491-5.
17. Rolland Y, Lauwers-Cances V, Cesari M, Vellas B, Pahor M, Grandjean H. Physical performance measures as predictors of mortality in a cohort of community-dwelling older French women. Eur J Epidemiol 2006; 21: 113-22.
18. Penninx BW, Ferrucci L, Leveille SG, Rantanen T, Pahor M, Guralnik JM. Lower extremity performance in nondisabled older persons as a predictor of subsequent hospitalization. J Gerontol A Biol Sci Med Sci 2000; 55: M691-7.
19. Langlois JA, Keyl PM, Guralnik JM, Foley DJ, Marottori RA, Wallace RB. Characteristics of older pedestrians who have difficulty crossing the street. Am J Public Health 1997; 87: 393-7.
20. Rantanen T, Guralnik JM, Izmirlian G, *et al.* Association of muscle strength with maximum walking speed in disabled older women. Am J Phys Med Rehabil 1998; 77: 299-305.
21. Fletcher GF, Balady G, Froelicher VF, Hartley LH, Haskell WL, Pollock ML. Exercise standards. A statement for healthcare professionals from the American Heart Association. Writing Group. Circulation 1995; 91: 580-615.
22. Tiedemann A, Sherrington C, Lord SR. Physiological and psychological predictors of walking speed in older community-dwelling people. Gerontology 2005; 51: 390-5.
23. Ringsberg K, Gerdhem P, Johansson J, Obrant KJ. Is there a relationship between balance, gait performance and muscular strength in 75-year-old women? Age Ageing 1999; 28: 289-93.
24. Rantanen T, Guralnik JM, Ferrucci L, *et al.* Coimpairments as predictors of severe walking disability in older women. J Am Geriatr Soc 2001; 49: 21-7.

パネルディスカッション5

日本の心臓リハビリテーションの現状と将来：わが国における心臓リハビリテーションの問題点

Issues of Cardiac rehabilitation in Japan

東北大学大学院医学系研究科 機能医科学講座 内部障害学分野 上月正博（こうづきまさひろ）

抄録

心臓リハビリテーション（心臓リハ）は多くの研究によりその有用性が確認され，循環器疾患に対する「有効な治療」としての地位を確立した．心臓リハは，わが国の厚生労働省が推進している4疾患・5事業の「心筋梗塞」治療ならびに再発予防の重要な要素でもあるが，著しく普及が遅れている．その主な要因に，施設基準の厳しさ，採算性の問題がある．循環器病研究委託費（15-指2）研究班の調査では，年間AMI入院患者数が平均値（48例）の施設での心リハの参加患者数は1日3〜5例にすぎないことが明らかになった．この少数の症例のためにリハ従事者1名を「専従」で配置したり，循環器科または心臓血管外科の医師が常時勤務することは不経済である．当学会では，平成22年度の診療報酬改訂に備え，①トレッドミルまたはサイクルエルゴメータによる負荷心肺機能検査における連続呼気ガス分析加算，②心大血管疾患リハビリテーション料に関わる施設認定基準の見直しを，他学会と協力して要求している．平成22年度の診療報酬改訂に期待するとともに，心臓リハのエビデンスを患者・医療関係者双方に周知徹底させ，患者・医療関係者への心臓リハ，特に回復期心臓リハの重要性の啓蒙することが心臓リハの普及に欠くことができないと考えられる．

〔心臓リハビリテーション（JJCR）15（1）：72-74，2010〕

Key words：心臓リハの普及，普及の阻害因子，施設認定基準，診療報酬改訂

はじめに

心臓リハビリテーション（心臓リハ）は多くの研究によりその有用性が確認され，循環器疾患に対する「有効な治療」としての地位を確立した．心臓リハは，わが国の厚生労働省が推進している4疾患・5事業の一つである「心筋梗塞」治療ならびに再発予防の重要な要素である．本稿では心臓リハのわが国での現状と問題点を明らかにし，今後の対策を提言する．

心臓リハの有用性に関するエビデンス

心臓リハは「医学的な評価，運動処方，冠危険因子の是正，教育およびカウンセリングからなる長期的で包括的なプログラムである．このプログラムは，個々の患者の心疾患に基づく身体的・精神的影響をできるだけ軽減し，突然死や再梗塞のリスクを是正し，症状を調整し，動脈硬化の過程を抑制あるいは逆転させ，心理社会的ならびに職業的な状況を改善することを目的とする」と定義されている[1]．すなわち，脳卒中リハのように，単に在宅生活や復職をゴールとするのではなく，再発防止や生命予後の延長までをめざすものである．

従来のリハといえば「疾病罹患後の廃用症候群の回復」というイメージが強かったが，多要素プログラムを擁する包括的回復期心臓リハにより，「日常生活動作の自立と社会復帰」，「要介護の軽減」のみならず，冠動脈硬化・冠循環の改善，冠危険因子の是正，生命予後の改善，機能予後の改善，QOLや不安・鬱の改善などの目覚ましい成果がもたらされた[2]．すなわち，リハに「危険因子の軽減による攻めの医療」という概念が加わった[3]．米国心臓学会のガイドラインでは心筋梗塞患者の

表1　平成22年度診療報酬改訂への要望事項

1. 心臓リハビリ担当の理学療法士が他のリハの担当できない！
 ⇒心臓リハ患者がいない時は脳卒中や運動器疾患患者のリハもできたほうが良い
  ⇒医療職専従・専任要件の緩和
   a) 医療職（常勤看護師・理学療法士）の専従要件を専任に緩和
   b) 心大血管リハ専任理学療法士が他のリハの専従を禁止している点を撤廃
   c) 専任医療職として医師の直接監視下を条件に臨床検査技師の追加

2. 施設Ⅰにおいて循環器・心臓血管外科医師の「常時勤務」(24時間，365日勤務）が必要である！
 ⇒リハビリの時に勤務していれば十分
  ⇒「常時勤務」から「常勤」へ変更

3. 心臓リハビリ専用の機能訓練室が必要である！
 ⇒リハビリ室に専用スペースが確保されていれば良い
  ⇒機能訓練室の面積要件を「部屋」から「場所（スペース)」として確保への変更

4. 連続呼気ガス分析に点数がついていない！
 ⇒適切な運動処方のための検査に点数が必要
  ⇒心肺運動負荷試験施行時の連続呼気ガス分析加算

長期予後を改善する方法として，回復期・維持期には，心臓リハがスタチン（高脂血症治療薬）と並んでクラス1（確実に有効なもの）として挙げられているほどである[4]．

わが国での心臓リハ普及率

厚生労働省循環器病研究委託費「わが国における心疾患リハビリテーションの実態調査と普及促進に関する研究」班（後藤葉一班長）で，わが国における心臓リハの実態について全国調査を2004年に実施した[5]．その結果，循環器専門医研修施設の97％が急性心筋梗塞（AMI）入院を受け入れ，90％以上の施設が冠動脈造影，PCI，緊急PCIを実施していたのに対し，心臓リハ実施率は明らかに低かった．すなわち「AMIに何らかのリハビリを実施している」「AMIに急性期心臓リハを実施している」施設は約半数，「AMIに回復期心臓リハを実施している」施設は20％，「外来通院型心臓リハを実施している施設」は9％にすぎなかった．日米の人口や冠動脈疾患発生率の差を考慮しても，わが国における外来通院型心臓リハ実施施設の少なさが目立つ．

わが国での心臓リハプログラム内容

さらに同じ調査で心臓リハの内容に関して検討したところ，「心臓リハ患者教育プログラム」「運動耐容能検査に基づく運動処方」「呼気ガス分析による心肺運動負荷試験（CPX)」など，心臓リハのガイドライン[2]で推奨されている重要な診療内容を実施している施設の比率は低かった．心臓リハは，単に心電図監視下で身体運動トレーニングのみを実施すればよいというものではない．心臓リハは二次予防教育や運動負荷試験に基づく適切な運動強度の設定などを含む包括的患者マネジメントである．運動療法だけでは禁煙効果はほとんどなく，また，脂質・肥満・血圧には効果が一定していないなど，再発予防のための危険因子の軽減が十分ではないことは周知の事実である[1]．今後のわが国の心臓リハは，単なる運動療法のみならず，教育や心理的ケアなど多要素的に包括的心臓リハとして行われるよう徹底する必要がある．

わが国での心臓リハ普及の阻害因子

AMIに対する心臓リハを実施していないと回答した循環器専門医研修施設における心臓リハを実施しない理由を調査したところ，その三大理由は「スタッフ不足」「設備がない」「施設基準を取得していない」であった[5]．これらの背景要因には，施設基準の厳しさと採算性の問題があると考えられる（表1)．

すなわち，施設基準を取得するためには条件を満たしたスタッフが必要であり，これには，心臓リハ担当の理学療法士が他のリハの担当ができない制度になっていること，運動負荷試験やリハの場面で機器の扱いや心電図の解釈に威力を発揮する臨床検査技師が，診療報酬上はスタッフとして認められていないこと，また，施設Ⅰの基準において循環器・心臓血管外科医師の常時勤務が必要であることなど，人件費の面で問題になり，スタッフを雇用できずに実施に至らない場合が多い．実際，循環器病研究委託費（15-指2）研究班の調査では，年間AMI入院患者数が平均値（48例）の施設での心リハの

参加患者数は1日3〜5例にすぎない[6]．この少数の症例のためにリハ従事者1名を「専従」で配置したり，循環器科または心臓血管外科の医師を常時勤務させることは不経済である．一方，施設基準を取得するための設備の面に関しては，心臓リハビリ専用の機能訓練室が必要であることがネックになっている．また，適切な運動処方のための検査に高価な連続呼気ガス分析装置が必要であるが，心肺運動負荷試験施行時に連続呼気ガス分析加算がついておらず，採算面で厳しいことが挙げられる．さらに，心臓リハのエビデンス自体が患者・医療関係者双方で十分周知徹底されていないことも，心臓リハの普及を阻害する大きな要因の1つであると考えられる．

わが国での今後の対策

以上のような現状分析を基に，当学会では診療報酬対策委員会を中心に，他学会と協力して，平成22年度の診療報酬改訂に備え，①トレッドミルまたはサイクルエルゴメータによる負荷心肺機能検査における連続呼気ガス分析加算，②心大血管疾患リハビリテーション料に関わる施設認定基準の見直しを要求しているところである（表1）．

同時に，心臓リハのエビデンスを患者・医療関係者双方に周知徹底させ，患者・医療関係者への心臓リハ，特に回復期心臓リハの重要性の啓蒙することが重要である．また，患者自身が自立・継続してリハを行えるようにする工夫が必要である．さらに，リハの効果を維持するためには継続が必要不可欠であり，フォローアップのシステムをつくり継続させるような方策をとることが望ましい．

おわりに

心臓リハのゴールは単に自宅退院，ADLの自立，復職のみにあるのではない．この点が脳卒中リハなどと大きく異なる点である．すなわち，心臓リハは，長期的な包括的リハによる原疾患の再発防止，生命予後の改善，動脈硬化性疾患の予防・治療，動脈硬化巣そのものの改善など，「攻めの医療」としての役割も担っている．心臓リハの効果を最大限に享受するためには，患者が生活習慣を改善し，自宅退院後に十分な運動量を確保し，食事療法や薬物療法を自発的かつ長期的に自信をもって行えるように指導することが肝要である．解決すべき課題も多いが，心臓リハは今後ますます重要な「不可欠の治療」となると考えられる．平成22年度の診療報酬改訂に期待するとともに，心臓リハの有する様々な課題に取り組み，時間的・経済的・内容的に，さらに魅力的な患者主体の新しいプログラム・システムの作成を行う必要もあろう．

文　献

1) Wenger NK et al：Cardiac rehabilitation. Clinical Practice Guideline No 17（AHCPR Publication No 96-0672）. pp1-26, 1995
2) 循環器病の診断と治療に関するガイドライン2006年度合同研究班報告. 心血管疾患におけるリハビリテーションに関するガイドライン（2007年改訂版）available from http://www.j-circ.or.jp/guideline/pdf/JCS2007_nohara_h.pdf
3) 上月正博：変わるリハビリ―攻めのリハビリと拡大する対象疾患―．ヴァンメディカル社，2006
4) American College of Cardiology；American Heart Association Task Force on Practice Guidelines；Canadian Cardiovascular Society. ACC/AHA guidelines for the management of patients with ST-elevation myocardial infarction：a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines. Circulation 110：e82-292, 2004
5) Goto Y et al：Poor implementation of cardiac rehabilitation despite broad dissemination of coronary interventions for acute myocardial infarction in Japan：a nationwide survey. Circ J 71：173-179, 2007
6) 後藤葉一 他：急性心筋梗塞全国実態調査に基づく心臓リハビリテーション1セッションあたり参加患者数の検討：施設基準および採算性を念頭に．心臓リハビリテーション 14：191-196, 2009

原　著

急性心筋梗塞の心臓リハビリテーションの現状：宮城県心筋梗塞対策協議会による登録事業を背景に

A survey of cardiac rehabilitation after acute myocardial infarction in Miyagi prefecture

坂田佳子[*1]，伊藤　修[*1]，上月正博[*1]，宮城県心筋梗塞対策協議会

[*1] 東北大学大学院医学系研究科 内部障害学分野

抄　録

【目　的】わが国では急性心筋梗塞（AMI）に対する心臓リハビリテーション（心リハ）の普及の遅れや地域格差が指摘されている．そこで今回，宮城県における AMI 心リハの実施状況を明らかにするために調査を行った．

【方　法】宮城県心筋梗塞対策協議会加盟施設 40 施設を対象に，平成 21 年 4 月から 5 月にかけて質問紙を郵送・回収した．

【結　果】対象とした 40 施設全てから回答を得た．AMI 入院受け入れ施設は 26 施設（65.0％），冠動脈カテーテルインターベンション（PCI）実施施設は 20 施設（50.0％）であった．AMI 心リハ実施施設は 14 施設（全体の 35.0％，AMI 入院受け入れ施設の 53.8％）で，そのうち 11 施設（78.6％）が包括的心リハプログラムを有していたが，いずれの施設でも心リハは AMI 急性期に行われており，回復期心リハや外来通院型心リハは実施されていなかった．

【結　論】宮城県における AMI 心リハは，急性期については積極的かつより包括的に行われるようになっている一方で，回復期心リハは循環器疾患診療施設では行われておらず，回復期心リハの普及への対策が急務である．

〔心臓リハビリテーション（JJCR）16（1）：101-108，2011〕

Key words：急性心筋梗塞，心臓リハビリテーション，実態調査

1．はじめに

宮城県には，1979 年に県の救急医療の一環として，緊急性が特に高い急性心筋梗塞（AMI）に適切に対処しその予後を改善することを目的として設立された宮城県心筋梗塞対策協議会という組織がある．同協議会は設立当初より AMI 患者の登録事業を行っており，県下の AMI 症例がほぼ全例登録されている[1,2]．その 30 年にわたるデータベースによると，宮城県の AMI 患者数は年々増加している一方で，急性期死亡率は著明に改善し，入院期間も大幅に短縮されている[1,2]．この急性期死亡率の改善と入院期間の短縮の要因として，冠動脈カテーテルインターベンション（PCI）の普及と並び，心臓リハビリテーション（心リハ）プログラムの普及が挙げられている[1]．

心リハは，AMI の標準的な治療法の一つとして位置づけられている．しかし，わが国での心リハの普及率は低く，特に，AMI 回復期心リハや外来通院型心リハの普及は著しく遅れていることが指摘されている[3,4]．さらに，心大血管疾患リハビリテーション料（リハ料）届出医療機関数には地域格差が報告されており[5]，心リハの実施状況にも地域による差が存在する可能性が考えられる．

そこで本研究では，宮城県の AMI 診療における心リハの実施状況を明らかにすることを目的として，宮城県心筋梗塞対策協議会に加盟している施設を対象に，AMI 心リハに関するアンケート調査を行った．

表1　施設データ，循環器疾患診療および心臓リハビリテーション実施状況

	研修施設	関連施設	その他の施設	全体
施設数	16（40.0%）	2（5.0%）	22（55.0%）	40（100%）
施設データ				
全科病床数（床）	442 ± 247	228 ± 22	176 ± 134	285 ± 226
担当科病床数（床）	54 ± 37	16 ± 9	37 ± 31	43 ± 34
循環器内科医師数（人）	9.4 ± 8.0	2.5 ± 0.5	1.4 ± 1.1	4.8 ± 6.5
常勤医師（人）	7.1 ± 7.7	2.0 ± 1.0	1.1 ± 0.8	3.6 ± 5.7
非常勤医師（人）	0.7 ± 1.6	0.5 ± 0.5	0.3 ± 0.9	0.5 ± 1.2
研修医・レジデント（人）	1.8 ± 1.9	0.0 ± 0.0	0.0 ± 0.0	0.7 ± 1.5
心臓血管外科医師数（人）	2.8 ± 4.0	0.0 ± 0.0	0.1 ± 0.3	1.2 ± 2.9
常勤医師（人）	2.1 ± 2.2	0.0 ± 0.0	0.0 ± 0.0	0.8 ± 1.7
非常勤医師（人）	0.5 ± 1.3	0.0 ± 0.0	0.1 ± 0.3	0.2 ± 0.8
研修医・レジデント（人）	0.4 ± 1.0	0.0 ± 0.0	0.0 ± 0.0	0.2 ± 0.7
循環器疾患診療状況				
AMI 入院ありの施設	16（100.0%）	1（50.0%）	9（40.9%）	26（65.0%）
AMI 年間患者数（例/年）	67.8 ± 63.3	7.5 ± 7.5	12.2 ± 18.3	34.0 ± 50.9
AMI 平均入院期間（日）	17.9 ± 4.3	10.0 ± 10.0	7.0 ± 12.5	11.5 ± 11.2
CAG 実施施設	16（100.0%）	2（100.0%）	4（18.2%）	22（55.0%）
CAG 実施件数（件/年）	937.0 ± 1199.6	156.0 ± 126.0	152.3 ± 415.7	466.4 ± 905.1
PCI 実施施設	16（100.0%）	1（50.0%）	3（13.6%）	20（50.0%）
PCI 実施件数（件/年）	261.3 ± 306.5	40.0 ± 40.0	55.9 ± 179.1	137.3 ± 256.1
緊急 PCI 実施施設	16（100.0%）	1（50.0%）	3（14.3%）	20（50.0%）
緊急 PCI 実施件数（件/年）	83.7 ± 90.8	10.0 ± 10.0	8.2 ± 26.6	37.3 ± 70.1
CABG 実施施設	11（68.8%）	0（0.0%）	0（0.0%）	10（26.3%）
CABG 実施件数（件/年）	23.3 ± 28.0	0.0 ± 0.0	0.0 ± 0.0	9.3 ± 21.1
CR 実施状況				
AMI の CR を実施している施設	12（75.0%）	0（0.0%）	2（9.1%）	14（35.0%）
急性期 CR	12（75.0%）	0（0.0%）	2（9.1%）	14（35.0%）
回復期 CR	0（0.0%）	0（0.0%）	0（0.0%）	0（0.0%）
外来通院型 CR	0（0.0%）	0（0.0%）	0（0.0%）	0（0.0%）
CR プログラムあり	9（56.3%）	0（0.0%）	2（9.1%）	11（27.5%）
呼気ガス分析併用 CPX 実施	2（12.5%）	0（0.0%）	0（0.0%）	2（5.0%）
心大血管疾患リハ料届出施設	6（37.5%）	1（50.0%）	0（0.0%）	7（17.5%）

AMI＝急性心筋梗塞，CAG＝冠動脈造影，PCI＝冠動脈カテーテルインターベンション，CABG＝冠動脈バイパス術，CR＝心臓リハビリテーション，CPX＝心肺運動負荷試験

2. 対象と方法

a）調査対象施設

2009年4月現在で，宮城県心筋梗塞対策協議会に加盟している40施設（42診療科）を対象とした．各施設の循環器内科または心臓血管外科の代表者宛に，AMI心リハに関する質問紙を2009年4月に郵送し，同年4月から5月かけて返信用封筒を用いて回答を回収した．

b）調査項目

1）施設データ

病床数，担当科病床数，循環器内科医師数，心臓血管外科医師数，心大血管疾患リハ料届出状況など．

2）循環器疾患診療状況

AMI入院受け入れの有無，年間AMI患者数と平均入院期間，冠動脈造影検査（CAG），PCI，緊急PCIおよび冠動脈バイパス術（CABG）の実施の有無と年間実施件数など．

3）心リハ実施状況

AMI心リハの実施の有無，外来通院型心リハ実施の有無，患者教育プログラムの有無，呼気ガス分析併用心肺運動負荷試験（CPX）実施の有無，心リハプログラムの内容など．

c）データ解析

連続変数データは平均値±標準偏差で表示した．

表2　AMI入院を受け入れている26施設のプロフィール

病院データ	
全科病床数（床）	339 ± 246
担当科病床数（床）	47 ± 36
循環器内科医師数（人）	6.7 ± 7.4
専門医研修施設	16（61.5%）
専門医研修関連施設	1（3.8%）
心臓血管外科あり	10（38.5%）
循環器疾患診療状況	
AMI年間患者数平均値（例/年）	49.7 ± 56.2
AMI年間患者数メディアン値（例/年）	50
AMI平均入院期間（日）	17.4 ± 9.4
PCI実施施設	20（76.9%）
PCI実施件数（件/年）	212.5 ± 297.78
CR実施状況	
AMIのCRを実施している施設	14（53.8%）
心大血管疾患リハ料届出施設	7（26.9%）

AMI＝急性心筋梗塞，PCI＝冠動脈カテーテルインターベンション，CR＝心臓リハビリテーション

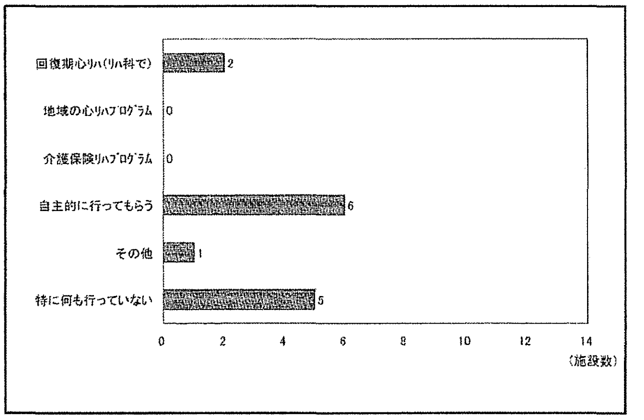

図1　AMI急性期心リハ終了後の心リハについて
AMI急性期心リハを実施している14施設における急性期心リハ終了後のリハ継続は，「リハ科にて回復期心リハを行っている」のは2施設のみで，「患者に自主的に行ってもらっている」や「特に何も行っていない」が大半を占めた．「地域の心リハプログラムへ移行している」施設はなかった．

3. 結果

a）全体集計結果（表1）

1）施設データ

40施設のうち，日本循環器学会専門医研修施設（研修施設）が16施設（40.0%），研修関連施設（関連施設）が2施設（5.0%），その他の施設が22施設（55.0%）で，その他の施設のうち4施設は診療所（有床2施設，無床2施設）であった．

2）AMIの診療状況

AMIの診療状況について見てみると，全体では26施設（65.0%）でAMI入院を受け入れ，20施設（50.0%）でPCIが実施されていた．施設カテゴリー別に見ると，研修施設では全ての施設においてAMI入院を受け入れ，CAG・PCI・緊急PCIが実施されていた．また，研修施設の10施設（62.5%）に常勤の心臓血管外科医師がおり，11施設（68.8%）でCABGが実施されていた．関連施設ではCAGは両施設で実施されていたが，AMI入院の受け入れ・PCI・緊急PCIは同じ1施設のみで実施されていた．その他の施設では9施設（40.9%）がAMI入院を受け入れていたが，CAG実施施設は4施設（18.2%），PCI・緊急PCI実施施設は3施設（13.6%）であった．AMI年間患者数は，全体では34.0 ± 50.9例/年，研修施設では67.8 ± 63.3例/年であった．平均入院期間は，全体では11.5 ± 11.2日，研修施設では17.9 ± 4.3日であった．PCI年間実施件数は，全体では137.3 ± 256.1件/年，研修施設では261.3 ± 306.5件/年であった．

AMI入院受け入れ26施設についてみてみると，研修施設は16施設（61.5%），関連施設は1施設（3.8%），その他は9施設（34.6%），心臓血管外科併設施設は10施設（38.5%），AMI年間患者数の平均値は49.7 ± 56.2例/年，メディアン値（中央値）は50例/年，平均入院期間は17.4 ± 9.4日，PCI実施施設は20施設（76.9%），PCI年間実施件数は211.2 ± 292.0件/年であった（表2）．

3）AMI心リハの実施状況

AMI心リハの実施状況については，「AMIに何らかの心リハを実施している」施設は，全体では14施設（35.0%），研修施設では12施設（75.0%），AMI入院受け入れ施設では14施設（53.8%）であった．いずれの施設でも心リハはAMI急性期に実施されており，AMI回復期心リハや外来通院型心リハを実施している施設はなかった．運動療法や二次予防のための患者教育を含めた心リハプログラムを有している施設は，全体では11施設（27.5%），研修施設では9施設（56.3%），AMI入院受け入れ施設では11施設（42.4%）であった．呼気ガス分析併用CPXを実施している施設は2施設で，いずれも研修施設であった．

AMI急性期心リハを実施している14施設に対して，AMI急性期の心リハ終了後のリハについて尋ねたところ，「患者に自主的に行ってもらっている」施設が6施設（42.9%），「特に何も行っていない」施設が5施設（35.7%），「リハ科に患者を紹介し，リハ科で回復期心

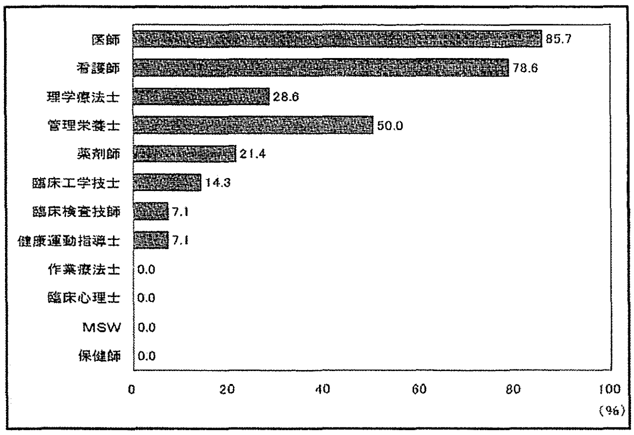

図 2　AMI 心リハに関わっているスタッフの割合
医師は 12 施設で心リハに関わっていたが，心リハは医師の指示の下で実施されるものであり，医師が心リハに関わっていない施設では医師の心リハに対する理解不足が考えられる．コメディカルスタッフでは看護師の関与が大きく，理学療法士の関わっている施設は 3 割に満たなかった．

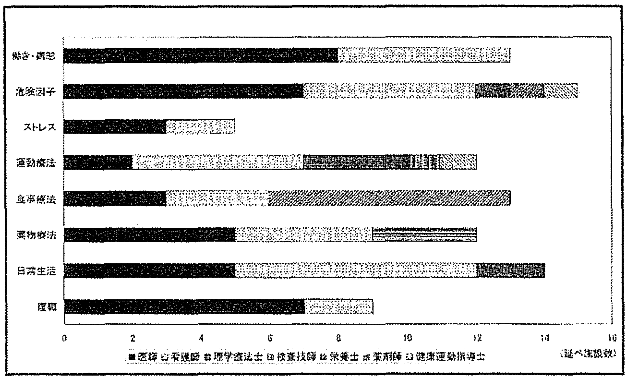

図 3　患者教育の指導担当者の職種
患者教育は医師または看護師が担当している施設が多かったが，運動療法については 3 施設で理学療法士が，食事療法については 7 施設で管理栄養士が，薬物療法については 3 施設で薬剤師がそれぞれ指導を担当していた．

リハを継続している」施設が 2 施設（14.3％）であった．「地域の心リハプログラムへ移行している」施設や「介護保険のリハプログラムへ移行している」施設はなかった（**図 1**）．

b）AMI 急性期心リハの内容

1）心リハに関わっているスタッフ（図 2）

AMI 急性期心リハを実施している 14 施設の心リハに関わっているスタッフの職種としては，医師が 12 施設（85.7％），看護師が 11 施設（78.6％），管理栄養士が 7 施設（50.0％），理学療法士が 4 施設（28.6％），薬剤師が 3 施設（21.4％），臨床工学技士が 2 施設（14.3％），臨床検査技師と健康運動指導士が 1 施設（7.1％）で心リハに参加していた．作業療法士，臨床心理士，メディカルソーシャルワーカー（MSW），保健師が心リハに関わっている施設はなかった．

また，心リハ指導士の有資格者がいる施設は 14 施設中 6 施設（42.9％）で，1 施設あたりの有資格者数は 2.7 ± 1.7 人であった．

2）運動療法について

心リハにおける運動療法において，「呼気ガス分析併用 CPX」に基づいて運動強度を設定している施設は 2 施設（14.3％）のみで「Borg 指数などの自覚的運動強度」で強度を設定している施設が 6 施設（42.9％），「予測最大心拍数に係数をかけたもの」で強度を設定している施設が 4 施設（28.6％）であった．

運動の種類としては，歩行が 11 施設（78.6％），体操と自転車エルゴメータでの運動が 4 施設（28.6％），筋力トレーニングが 2 施設（14.3％）で行われていた（複数回答あり）．トレッドミルでの運動やジョギング，サイクリング，水泳などを行っている施設はなかった．

1 回あたりの運動時間は 27.2 ± 9.2 分，頻度は週 4.9 ± 2.5 回であった．

運動の実施場所は，「病室や病棟の廊下」が 11 施設（78.6％），「機能訓練室」が 3 施設（21.4％），「心リハ専用の機能訓練室」が 1 施設（7.1％）であった．

運動の主な指導者は，看護師が 8 施設（57.1％）と最も多く，次いで医師が 5 施設（35.7％），理学療法士が 3 施設（21.4％）であった（複数回答あり）．

3）患者教育について

患者教育の内容の詳細については，AMI 心リハを実施している 14 施設のうち 10 施設より回答が得られた．教育内容としては，「心臓の働き・AMI の病態」「AMI の危険因子」「食事療法」「薬物療法」「日常生活について」は 10 施設（100.0％），「運動療法」は 9 施設（90.0％），「復職について」は 8 施設（80.0％），「AMI とストレスとの関係」は 4 施設（40.0％）で指導が行われていた．それぞれの教育は医師または看護師が担当している施設が多かったが，運動療法については 3 施設（30.0％）で理学療法士が，食事療法については 7 施設（70.0％）で管理栄養士が，薬物療法については 3 施設（30.0％）で薬剤師がそれぞれ指導を担当していた（**図 3**）．

4）患者の心理的サポートについて

患者の不安や抑うつ状態に対する対応については，「必要に応じて精神科医と連携している」が 4 施設（28.6％），「心リハスタッフが対応している」が 1 施設

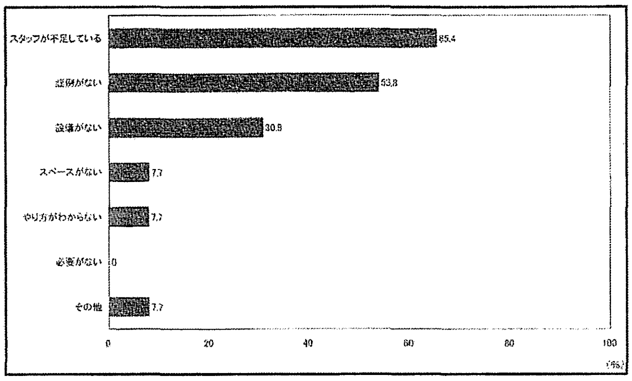

図4　AMI心リハを実施していない理由
AMI心リハを実施していない26施設の非実施の理由は，「スタッフが不足している」が最も多く，次いで「症例がない」，「設備がない」が多かった．

(7.1%) で，8施設 (57.1%) では心理的サポートは行っていなかった．

5) 社会復帰や復職に向けたカウンセリングについて

社会復帰や復職に向けたカウンセリングについては，「積極的に行っている」が1施設 (7.1%)，「ときどき行っている」が2施設 (14.3%)，「あまり行っていない」が5施設 (35.7%)，「全く行っていない」が5施設 (35.7%) であった．カウンセリング担当者はいずれの施設においても医師であった．

6) 緊急時の対応について

緊急時の対応については，「緊急時の対応マニュアルがある」が9施設 (64.3%)，緊急時を想定した訓練を「頻繁に行っている」が1施設 (7.1%)，「時々行っている」が6施設 (42.9%)，「あまり行っていない」が4施設 (28.6%)，「全く行っていない」が1施設 (7.1%) であった．

c) AMI心リハを実施していない理由 (図4)

AMI心リハを実施していない26施設における非実施の理由としては，「スタッフが不足している」が17施設 (65.4%) と最も多く，次いで「症例がない」が14施設 (53.8%)，「設備がない」が8施設 (30.8%)，「スペースがない」「やり方がわからない」「その他」が2施設 (7.7%) ずつであった (複数回答あり)．なお，「心リハは必要がない」と回答した施設はなかった．

今後のAMI心リハの実施予定については，「行う予定」と回答した施設は2施設 (7.7%) に留まり，「行いたいが現状では困難である」が10施設 (38.5%)，「行う予定はない」が13施設 (50.0%) と大半を占めた．

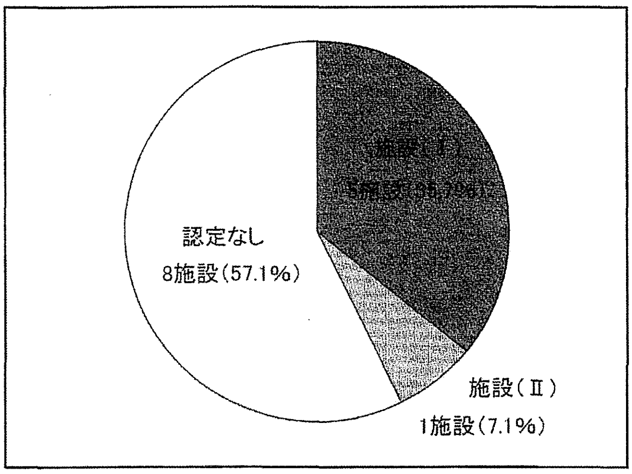

図5　AMI心リハ実施施設における心大血管疾患リハ料の届出状況
AMI心リハを実施している14施設中5施設が施設 (Ⅰ)，1施設が施設 (Ⅱ) の認定を受けていたが，8施設は心リハを実施しているにもかかわらず認定を受けていなかった．

d) AMI以外の心大血管疾患に対する心リハの実施状況

AMI以外の心大血管疾患に対する心リハは，全体では40施設中15施設 (37.5%)，AMI心リハ実施施設では14施設中8施設 (57.1%)，AMI心リハ非実施施設では26施設中7施設 (26.9%) で実施されていた．

心リハが実施されている疾患としては，慢性心不全が最も多く，11施設 (27.5%) で実施されており，続いて，大血管疾患が9施設 (22.5%)，狭心症が7施設 (17.5%)，開心術後が6施設 (15.0%)，末梢動脈疾患 (PAD) が5施設 (12.5%)，その他が2施設 (5.0%) の順であった．

e) 心大血管疾患リハ料の届出状況

心大血管疾患リハ料届出施設は，全体では7施設 (17.5%) で，施設 (Ⅰ) が6施設 (15.0%)，施設 (Ⅱ) が1施設 (2.5%) であった．AMI心リハを実施している14施設について見てみると，8施設 (57.1%) は心リハを実施しているにもかかわらず，心大血管疾患リハ料の施設認定を受けていなかった (**図5**)．その理由としては，「スタッフ不足」が8施設 (100.0%)，「訓練室の確保が困難」が6施設 (75.0%)，「備品不足」が4施設 (50.0%)，「記録の一元管理が困難」が2施設 (25.0%)，「バックアップ体制が整えられない」，「カンファランス開催が困難」，「その他」がそれぞれ1施設 (12.5%) であった (複数回答あり)．この8施設に今後の施設認定の予定を尋ねたところ，半数の4施設が「積極的に考えている」と回答したが，残りの4施設のうち1施設