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

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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

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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.

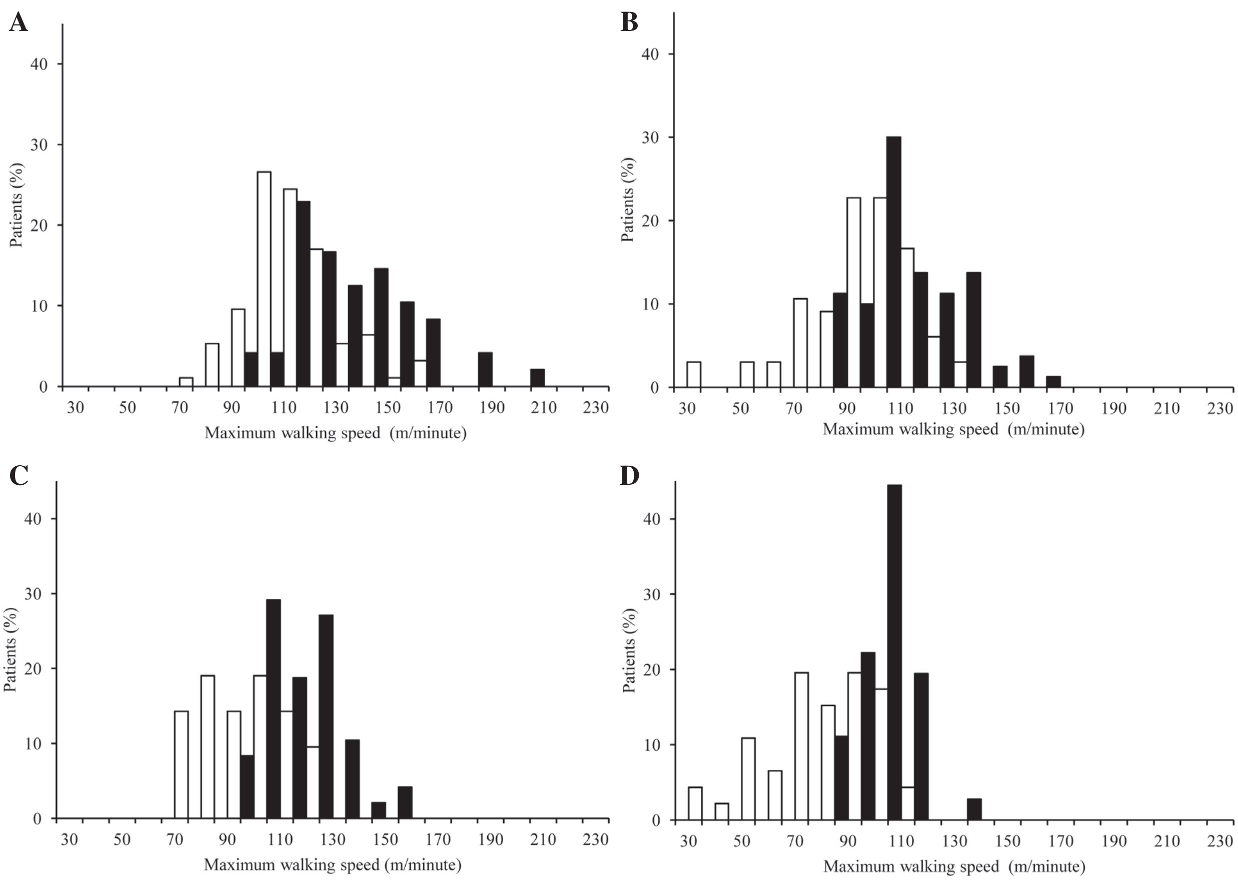

Figure. Histograms of maximum walking speed. Subjects walked a distance of 10 m at maximum speed without running. Maximum walking speed was calculated in meters per minute. Open and closed bars indicate AMI and non-AMI subgroups, respectively. **A:** Middle-aged men. **B:** Elderly men. **C:** Middle-aged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

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 $R^2 = 0.652$, $P < 0.01$).

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.

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.

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