### Data analysis

Regions of interest (ROIs) were drawn over the entire heart and upper mediastinum depicted in the planar images. The heart-to-mediastinum (H/M) ratio and global washout rate (WR) of $^{99m}$Tc-sestamibi were calculated from the pixel counts in the ROIs using the following equations: H/M = mean pixel count of the cardiac ROIs/mean pixel count of the mediastinal ROIs; WR (%) = [(mean early cardiac pixel count  mean delayed cardiac pixel count)/mean early cardiac pixel count] × 100. Backgrounds or time-decay corrections were not applied to the calculation of the WR.

Once the SPECT images were acquired and reconstructed from the early images, quantitative gated SPECT (QGS) software (Cedars-Sinai Medical Center, Los Angeles, CA) was used to evaluate the ventricular edges and calculate the left ventricular end-diastolic volume (LVEDV), left ventricular end-systolic volume (LVESV), and left ventricular ejection fraction (LVEF) [19].

### Cardiac rehabilitation, exercise test, and skeletal muscle volume

All patients received inpatient cardiac rehabilitation for 2-3 weeks, underwent the first cardiopulmonary exercise testing (CPX), and then exercise-based cardiac rehabilitation on an outpatient basis. Symptom-limited CPX was performed at 1 and 6 months after the onset of AMI using an MAT-2500 treadmill (Fukuda Denshi Co., Tokyo, Japan). After the initial 3-minute rest on the treadmill and 3-minute warm-up (speed 1.6 km/h; grade 0%), the CPX was performed with a gradual increase in the exercise intensity at 1-minute intervals. The 12-lead ECG was monitored continuously; heart rate (HR) was measured by the R-R interval on the electrocardiogram (ECG; ML-9000, Fukuda Denshi Co., Tokyo, Japan). Systolic blood pressure was measured with a cuff via an automatic blood pressure monitor (FB-300, Fukuda Denshi Co., Tokyo, Japan) at 1-minute intervals. Oxygen uptake ($VO_2$), carbon dioxide output ($VCO_2$), and the rate of respiratory airflow were measured during the test using an AE-300 cart (Minato Medical Science, Osaka, Japan). Anaerobic threshold (AT), peak $VO_2$ and the minute ventilation/$VCO_2$ ($VE/VCO_2$) slope were calculated based on the CPX results. AT was determined by the original V-slope method [20]. An apparent leveling off of the $VO_2$ ($VO_2$ plateau in spite of increasing exercise intensity) was used as a sign for terminating the exercise. The appropriate intensities of the outpatient rehabilitation exercise in each patient were determined using the HR measured at the AT in the CPX conducted at 1M.

Before the start of the CPX, the skeletal muscle volume was measured using a single-cycle bioelectrical impedance data acquisition system (Muscle-α, Art Haven 9 Co., Kyoto, Japan), as previously described [21].

### Statistical analysis

The results are expressed as means ± SD. The significances of differences between the ≥ 70 beats per minute (bpm) and < 70 bpm groups were assessed using an unpaired *t* test. A paired *t* test was used to compare the parameters in each patient obtained in the early and delayed phases. A linear regression analysis was conducted to evaluate the significance of the changes in the rHR and the $^{99m}$Tc-sestamibi myocardial scintigraphic parameters. Values of $p$ of less than 0.05 were considered to indicate statistical significance.

## Results

### Patient characteristics and laboratory findings

Table I shows the characteristics of the patients enrolled in this study. All patients were stratified into the ≥ 70 bpm ($n$ = 15) or < 70 bpm ($n$ = 14) group according to the rHR at 6M. Data obtained were analyzed and compared between the two groups.

In the < 70 bpm group, the culprit lesion was in the left anterior descending coronary artery (LAD) in 5 patients, and in the non-LAD vessels in 9 patients. In the ≥ 70 bpm group, the culprit lesion was in the LAD in 5 patients, and in the non-LAD vessels in 10 patients. All patients received appropriate primary PCI. Thrombolysis in Myocardial Infarction (TIMI) [22] grade 3 flow was obtained in all patients after the PCI.

No significant differences in the age, gender ratio, body mass index, medical history, cardiac enzyme level on admission, time from onset to revascularization, or peak cardiac enzyme level were found between the two groups (Table I). In all patients, loading doses of 200 mg of acetylsalicylic acid and 300 mg of clopidogrel sulfate were administered after the PCI, followed by maintenance doses of 100 mg of acetylsalicylic acid and 75 mg of clopidogrel sulfate. Most of the patients received an angiotensin-converting enzyme inhibitor, angiotensin receptor blocker, β-blocker, and/or some type of statin as prophylaxis against secondary cardiac events and deterioration of cardiac function. There were no significant differences in the medications administered between the two groups (Table I).

### Myocardial scintigraphic study

The results of LVEDV, LVESV, and LVEF calculated from the imaging are presented in Table II. No significant differences in the regional WR, global WR,

**Table I.** Patients' characteristics

| Variable | rHR < 70 bpm ($n$ = 14) | rHR ≥ 70 bpm ($n$ = 15) | Value of $p$ |
|---|---|---|---|
| Age [years] | 64.3 ±8.4 | 61.9 ±9.9 | NS |
| M/F ($n$) | 14/0 | 13/2 | NS |
| Body mass index [kg/m$^2$] | 24.4 ±1.6 | 22.6 ±3.0 | NS |
| Diabetes mellitus [%] | 13 | 47 | NS |
| Hypertension [%] | 43 | 60 | NS |
| Hyperlipidemia [%] | 50 | 60 | NS |
| Smoking [%] | 64 | 40 | NS |
| Time to revasc from the onset [h] | 8.7 ±9.6 | 13.4 ±20.9 | NS |
| Culprit: | | | |
| LAD, LCx, RCA (%) | 36, 43, 21 | 34, 13, 53 | NS |
| Laboratory findings: | | | |
| BNP [pg/ml] | 136 ±143 | 128 ±169 | NS |
| Peak CK [IU/l] | 3306 ±2336 | 2516 ±1488 | NS |
| (Sampling time [h]) | (17.7 ±14.1) | (18.1 ±19.6) | |
| Peak CK-MB [IU/l] | 292.0 ±162.8 | 262.0 ±199.3 | NS |
| (Sampling time [h]) | (13.3 ±7.7) | (17.5 ±19.8) | |
| Medications: | | | |
| ACE-I, ARB [%] | 92.9 | 100 | NS |
| β-Blocker [%] | 85.7 | 66.7 | NS |
| Aspirin [%] | 100 | 100 | – |
| Dihydropyridine [%] | 85.7 | 80 | NS |
| Statin [%] | 78.6 | 93.3 | NS |
| Loop diuretics [%] | 0 | 0 | – |
| Antialdosterone [%] | 0 | 20 | NS |
| Calcium blocker [%] | 14.3 | 6.7 | NS |
| Nicorandil [%] | 42.9 | 40 | NS |
| Insulin [%] | 0 | 6.7 | NS |
| Warfarin [%] | 14.3 | 0 | NS |

*Some values are expressed as mean ± SD; rHR – resting heart rate, M/F – male/female, LAD – left anterior descending coronary artery, LCx – left circumflex coronary artery, RCA – right coronary artery, BNP – brain natriuretic peptide, CK – creatinine kinase, CK-MB – MB isoenzyme of CK, ACE-I – angiotensin angiotensin-converting enzyme inhibitor, ARB – angiotensin receptor blocker*

early/delayed global extent scores, or early/delayed severity scores either at 0M or at 6M were observed between the < 70 bpm and ≥ 70 bpm groups. Comparison of the parameters at 0M and 6M revealed no significant improvement of the cardiac imaging parameters in either the < 70 bpm group or the ≥ 70 bpm group (Table III).

### Cardiopulmonary exercise test and muscle volume

At 6M, the mean rHR was 61.4 ±7.3 bpm in the < 70 bpm group and 77.9 ±9.0 bpm in the ≥ 70 bpm group (p < 0.001). At 0M, the rHR and peak rHR were higher in the 70 bpm group (76.9 ±8.9 bpm and 148.9 ±19.5 bpm) than those in the < 70 bpm group (67.4 ±7.4 bpm, $p$ < 0.01 and 136.4 ±16.5 bpm, $p$ < 0.05). Peak HR at 6M was also higher in the ≥ 70 bpm group (154.7 ±21.8 bpm) than that in the < 70 bpm group (138.5 ±22.1 bpm, $p$ < 0.001) (Table IV).

No significant differences in the changes of the CPX parameters were observed after 6 months of rehabilitation in either group. On the other hand, significant differences in the changes of the whole-body muscle volume (1.7 ±2.0 kg vs. –1.1 ±2.9 kg,

**Table II.** The results from the radionuclide study

| Variable | rHR < 70 bpm ($n$ = 14) | | rHR ≥ 70 bpm ($n$ = 15) | | Value of $p$ |
|---|---|---|---|---|---|
| | 0M | 6M | 0M | 6M | |
| LVEDV [ml] | 102.1 ±21.4 | 107.8 ±20.3 | 108.9 ±34.3 | 101.9 ±41.1 | NS |
| LVESV [ml] | 49.4 ±17.8 | 48.5 ±16.6 | 62.7 ±30.4 | 51.0 ±36.8 | NS |
| LVEF [%] | 52.1 ±9.1 | 55.6 ±10.6 | 44.9 ±10.9 | 55.3 ±14.4 | NS |
| Regional washout rate [%] | 33.7 ±7.0 | 30.5 ±7.2 | 36.4 ±11.6 | 31.5 ±14.3 | NS |
| Global washout rate [%] | 28.1 ±7.0 | 26.8 ±5.3 | 32.2 ±10.3 | 28.6 ±11.7 | NS |
| Early global extent [%] | 40.0 ±18.2 | 44.8 ±19.1 | 42.1 ±20.6 | 43.8 ±24.5 | NS |
| Early global severity [%] | 6.3 ±5.9 | 6.2 ±4.9 | 7.5 ±7.4 | 7.3 ±8.9 | NS |
| Delay global extent [%] | 44.6 ±18.2 | 42.6 ±14.4 | 42.8 ±18.9 | 38.9 ±20.3 | NS |
| Delay global severity [%] | 10.3 ±8.6 | 7.4 ±6.0 | 10.2 ±9.3 | 7.9 ±9.7 | NS |

*Values are expressed as mean ± SD; 0M – 0 months, 6M – 6 months, LVEDV – left ventricular end-diastolic volume, LVESV – left ventricular end-systolic volume, LVEF – left ventricular ejection fraction. Other abbreviations were are the same as in Table I*

**Table III.** The changes of radionuclide parameters after 6 months of treatment

| Radionuclide study | rHR < 70 bpm ($n$ = 14) | rHR ≥ 70 bpm ($n$ = 15) | Value of $p$ |
|---|---|---|---|
| LVEDV [ml] | 5.7 ±23.2 | –2.0 ±25.5 | NS |
| LVESV [ml] | –0.93 ±20.3 | –7.79 ±19.1 | NS |
| LVEF [%] | 3.5 ±12.7 | 9.6 ±9.1 | NS |
| Regional washout [%] | –3.5 ±6.8 | –5.5 ±12.8 | NS |
| Global washout [%] | –1.2 ±7.9 | –4.1 ±10.2 | NS |
| Early global extent [%] | 3.3 ±20.0 | 1.9 ±15.6 | NS |
| Early global severity [%] | –0.5 ±3.8 | 0.07 ±4.1 | NS |
| Delay global extent [%] | –5.1 ±17.0 | –3.1 ±19.2 | NS |
| Delay global severity [%] | –3.6 ±4.6 | –1.7 ±3.3 | NS |

*Values are expressed as mean ± SD. Abbreviations were are the same as in Tables I and II*

$p < 0.05$), lower limb muscle volume (0.23 ±0.22 vs. –0.13 ±0.45, $p < 0.05$) and thigh muscle volume (0.19 ±0.22 vs. –0.13 ±0.45, $p < 0.05$) were found between the < 70 bpm group and the ≥70 bpm group (Table V).

### Associations between the improvements of $^{99m}$Tc-sestamibi global extent and severity scores versus decrease in the rHR after cardiac rehabilitation

Figure 1 shows the association between the $^{99m}$Tc-sestamibi SPECT parameters and the rHR after 6 months of cardiac rehabilitation. The changes in the global severity score calculated from the $^{99m}$Tc-sestamibi early SPECT images were significantly correlated with those of the rHR after rehabilitation ($r$ = 0.48, $p$ = 0.016). A significant correlation was also observed between the changes in the global severity score calculated from the $^{99m}$Tc-sestamibi delayed SPECT images and those of the rHR ($r$ = 0.62, $p$ = 0.0013). No correlation was found between the changes in the global extent score calculated from the $^{99m}$Tc-sestamibi early SPECT images and those of the rHR; however, a significant correlation was observed between the changes in the global extent score calculated from the $^{99m}$Tc-sestamibi delayed SPECT images and those of the rHR ($r$ = 0.48, $p$ = 0.017).

## Discussion

Cardiac rehabilitation for patients with acute myocardial infarction is well recognized to contribute to improvement of exercise tolerance [9, 23]. In the present study, however, cardiac rehabilitation improved neither the cardiac contractility nor the exercise tolerance. This result could be explained by: (1) the patients already having had favorable heart function prior to the rehabilitation; (2) maintenance of the heart function by successful reperfusion, etc. Some previous reports have also reported that while 2 months of physical training improved the exercise tolerance, it did not improve

**Table IV.** The results from cardiopulmonary exercise test and muscle volume before and after rehabilitation

| Variable | rHR < 70 bpm (*n* = 14) | | rHR ≥ 70 bpm (*n* = 15) | |
|---|---|---|---|---|
| | 0M | 6M | 0M | 6M |
| Cardiopulmonary Exercise Test: | | | | |
| Rest HR [bpm] | 67.4 ±7.4 | 61.4 ±7.3 | 76.9 ±8.9* | 77.9 ±9.0† |
| Rest SBP [mm Hg] | 111.9 ±15.2 | 118.8 ±19.3 | 118.5 ±28.0 | 127.9 ±22.5 |
| Peak HR [bpm] | 136.4 ±16.5 | 138.5 ±21.1 | 148.9 ±19.5** | 154.7 ±21.8†† |
| Peak SBP [mm Hg] | 187.6 ±30.1 | 189.4 ±21.6 | 169.9 ±32.9 | 183.1 ±27.7 |
| Peak DBP [mm Hg] | 83.4 ±19.2 | 88.7 ±18.7 | 86.0 ±16.5 | 85.6 ±14.0 |
| AT [ml/kg/min] | 19.2 ±2.7 | 23.0 ±3.3 | 21.1 ±3.2 | 21.8 ±5.3 |
| Peak $VO_2$ [ml/kg/min] | 25.8 ±3.4 | 28.7 ±4.6 | 27.1±5.6 | 28.1 ±7.2 |
| VE/$VCO_2$ | 28.4 ±3.8 | 27.0 ±3.1 | 29.3 ±5.4 | 28.2 ±6.2 |
| Muscle volume: | | | | |
| Whole body [kg] | 33.5 ±1.8 | 35.3 ±2.7 | 33.5 ±1.8 | 33.4 ±3.4 |
| Upper limbs [kg] | 1.3 ±0.2 | 1.3 ±0.2 | 1.3 ±0.3 | 1.2 ±0.2 |
| Humerus [kg] | 0.7 ±0.2 | 0.8 ±0.1 | 0.7 ±0.2 | 0.7 ±0.2 |
| Antebrachium [kg] | 0.6 ±0.08 | 0.6 ±0.08 | 0.6 ±0.2 | 0.5 ±0.09 |
| Lower limbs [kg] | 4.9 ±0.8 | 5.2 ±0.8 | 5.1 ±0.8 | 4.7 ±0.9 |
| Femurs [kg] | 2.9 ±0.5 | 3.2 ±0.6 | 3.1 ±0.6 | 2.8 ±0.6 |
| Crus [kg] | 2.0 ±0.4 | 2.0 ±0.3 | 2.0 ±0.4 | 1.9 ±0.4 |

*Values are expressed as mean ± SD; HR – heart rate, SBP – systolic blood pressure, DBP – diastolic blood pressure, AT – anaerobic threshold, $VO_2$ – oxygen uptake, VE – respiratory minute volume, $VCO_2$ – carbon dioxide output. Other abbreviations were are the same as in Table I; *$p < 0.01$ vs. 0M rHR < 70 bpm, **$p < 0.05$ vs. 0M rHR < 70 bpm, †$p < 0.001$ vs. 6M rHR < 70 bpm, ††$p < 0.001$ vs. 6M rHR < 70 bpm*

**Table V.** Changes of parameters obtained from cardiopulmonary exercise test after 6 months of rehabilitation

| Variable | rHR < 70 bpm (*n* = 14) | rHR ≥ 70 bpm (*n* = 15) | Value of *p* |
|---|---|---|---|
| Cardiopulmonary Exercise Test: | | | |
| Rest HR [bpm] | –7.1 ±7.1 | 0.1 ±8.3 | NS |
| Rest SBP [mm Hg] | 9.2 ±16.2 | 14.5 ±22.3 | NS |
| Rest DBP [mm Hg] | 3.6 ±10.5 | 8.8 ±14.5 | NS |
| Peak HR [bpm] | –0.08 ±19.3 | 7.3 ±21.6 | NS |
| Peak SBP [mm Hg] | 2.3 ±37.6 | 13.2 ±29.2 | NS |
| Peak DBP [mm Hg] | 8.1 ±30.6 | 1.3 ±12.8 | NS |
| AT [ml/kg/min] | 3.2 ±3.3 | 0.9 ±4.1 | NS |
| Peak $VO_2$ [ml/kg/min] | 2.4 ±3.6 | 1.2 ±4.1 | NS |
| VE/$VCO_2$ | –1.3 ±2.5 | –1.2 ±4.2 | NS |
| Muscle volume: | | | |
| Whole body [kg] | 1.7 ±2.0 | –1.1 ±2.9 | < 0.05 |
| Upper limbs [kg] | 0.03 ±0.11 | –0.06 ±0.18 | NS |
| Humerus [kg] | 0.02 ±0.09 | –0.01 ±0.16 | NS |
| Antebrachium [kg] | 0.01 ±0.04 | –0.05 ±0.20 | NS |
| Lower limbs [kg] | 0.23 ±0.22 | –0.07 ±0.26 | < 0.05 |
| Femurs [kg] | 0.19 ±0.22 | –0.13 ±0.45 | < 0.05 |
| Crus [kg] | 0.04 ±0.16 | 0.06 ±0.27 | NS |

*Values are expressed as mean ± SD. Other abbreviations were are the same as in Tables I and III*

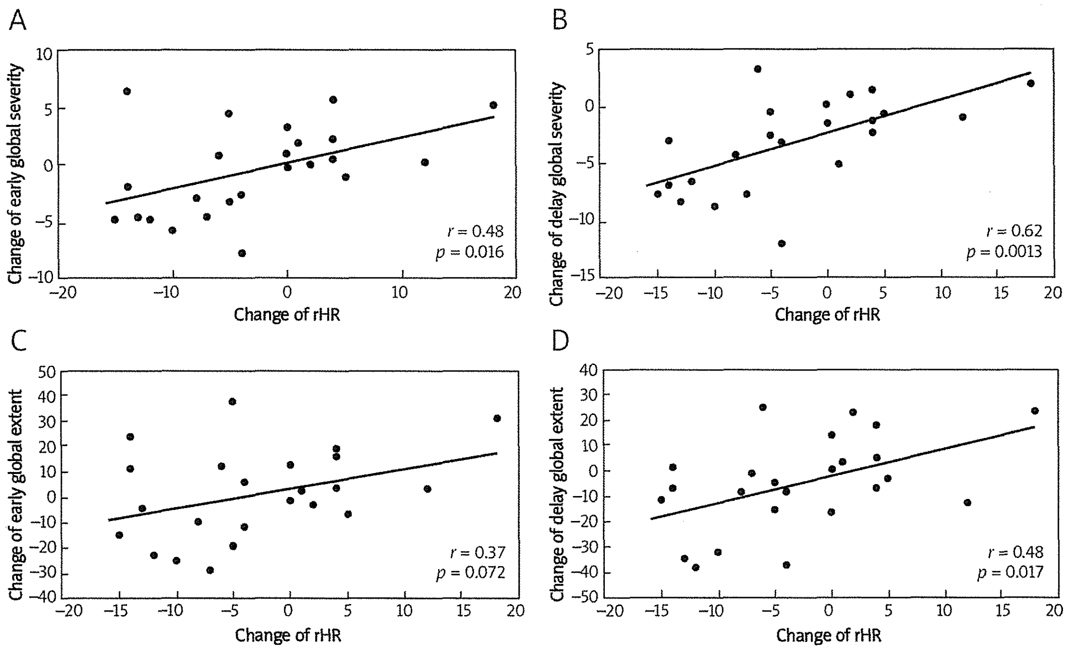


**Figure 1.** Associations between the changes in the extent of the 99mTc-sestamibi extent and severity scores and the changes of the rHR after cardiac rehabilitation: **A** – early global severity, **B** – delay global severity, **C** – early global extent, **D** – delay global extent

*There was a significant correlation between the changes of the global severity score obtained from $^{99}$mTc-sestamibi early SPECT images and the changes of the rHR after the rehabilitation (r = 0.48, p = 0.016). A significant correlation was also observed between the changes of the global severity score obtained from $^{99}$mTc-sestamibi delayed SPECT images and the changes of the rHR (r = 0.62, p = 0.0013). In regard to the global extent score, a significant correlation was observed between the changes of the global extent score obtained from $^{99}$mTc-sestamibi delayed SPECT images and the changes of the rHR (r = 0.48, p = 0.017).*

the LVEF [24, 25]. In the above-mentioned report on the effects of exercise, the patients performing regular exercises showed steady improvement of the exercise tolerance for one year, without developing left ventricular remodeling [26]. In the present study also, no changes potentially leading to left ventricular remodeling were noted during the first half-year period. The effects of rehabilitation in patients with myocardial infarction are probably unlikely to appear within a short period of time (e.g., 6 months), thus necessitating long-term follow-up to verify the effects. The prognosis of the patients may be improved after cardiac rehabilitation because of the efforts to improve the lifestyle and to prevent relapse of infarction through continuation of habitual exercises, etc.

When the patients were divided into the high heart rate at rest (≥ 70 bpm) group and low heart rate at rest (< 70 bpm) group, an inter-group difference was found in the lower limb muscle volume, particularly the thigh muscle volume after cardiac rehabilitation. In the low heart rate at rest group, the muscle volume was maintained in many patients during the first half-year period. In the high heart rate at rest group, on the other hand, reduced muscle volume was noted in many patients during the same period. Lower limb muscles serve as an important factor regulating the exercise tolerance in patients with heart diseases, and may serve as a factor determining exercise [27, 28]. One possible reason for the failure to maintain muscle volume in some patients despite continued rehabilitation was inadequate lower limb muscle training (advised before discharge from the hospital) under a non-supervised training program in these patients. The inadequate lower limb muscle training probably delayed the development of the peripheral skeletal muscles, leading to delay in peripheral artery/vein development. In these cases, it is estimated that although the effects of rehabilitation did not become obviously evident, the heart rate increased and the cardiac output was maintained, leading to maintained peripheral arterial/venous return and maintained exercise tolerance. In the > 70 bpm group, the LVEF in the acute stage after the onset of AMI was lower (although the difference was not statistically significant), suggesting the possibility that the compromised heart function affected the appearance of the effects of rehabilitation. However, considering that the LVEF became close to normal by 6 months after the onset of AMI, it seems unlikely that the baseline heart function affected the effects of rehabilitation in these cases. The results of the present study do not fully answer the question which of acute-stage angioplasty or rehabilitation contributed more to the heart rate in these patients. However, the finding of the differences in the systemic muscle volume and lower limb muscle volume between the ≥ 70 bpm group and < 70 bpm group despite the absence of significant differences in the 6-month SPECT data between the two groups suggests a greater impact of the changes of the systemic skeletal muscle volume than of the changes in the heart.

High rHR is consistently associated with an increased risk of in-hospital events and the long-term mortality in patients with AMI [29]. The recently conducted Beautiful Study has revealed that HR ≥ 70 bpm or < 70 bpm in patients with compromised heart function is a determinant of prognosis [30]. The Systolic Heart Failure Treatment with the If Inhibitor Ivabradine (SHIFT) study has also demonstrated that, among patients with compromised heart function, the prognosis is favorable in the subset of patients with low HR [31]. It is well known that 5 bpm reductions in HR with β-blockers lead to a decrease in the mortality by 18%. The recognition of this relationship has attracted close attention to HR [32]. In the present study, no significant reduction in rHR was observed, although the newly identified correlation indicated that post-reperfusion myocardial injury (as assessed with SPECT) was less severe in patients with lower HR. Since they were treated with β-blockers without any changes in the dosage regimen during the study period, the change over time rather than the influence of medication was closely associated with our study result.

The small number of subjects in the present study may mask a significant result. However, as Figure 1 shows, the patients who had successful reperfusion and a larger salvaged myocardium tended to have lower rHR, which is closely associated with the newly identified correlation. If this correlation can be observed in a larger study population, changes in rHR in AMI patients probably indicate the effect of PCI on the myocardium as well as that of cardiac rehabilitation on the whole body. Hence, the evaluation of diagnostic imaging and physical findings seems essential when the course of treatment for myocardial infarction is considered. These are the clinical implications of this study.

The main limitation of the study was connected with the small number of subjects included. Furthermore, it was not a controlled trial. Acute myocardial infarction patients not receiving PCI should be included as controls in future studies. The prognostic SPECT values in patients with ischemic cardiac disease remain unknown in this study. Further investigations on larger numbers of patients should be conducted to elucidate the potential usefulness of $^{99m}$Tc-sestamibi parameters as a prognostic incremental indicator.

In conclusion, AMI patients showing a decrease of the rHR after 6 months of cardiac rehabilitation also showed a significant increase of the leg muscle volumes. The results of this preliminary study demonstrated that improved myocardial perfusion was closely associated with the decrease of the rHR after cardiac rehabilitation.

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RESEARCH PAPER

# Relation between physical activity and exercise capacity of ≥5 metabolic equivalents in middle- and older-aged patients with chronic heart failure

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***Purpose*: Patients with exercise capacity of <5 metabolic equivalents (METs) are considered to have a high risk of death. The aim of this study was to determine age-related differences in physical activity associated with an exercise capacity of ≥5 METs in chronic heart failure (CHF) outpatients. *Methods*: We enrolled 157 stable CHF patients (79.6% men, age 60.3 ± 11.5 years). Patients were divided into two age-based groups (middle-aged, <65 years, $n$ = 97) and (older-aged, ≥65 years, $n$ = 60). Peak oxygen uptake (peak $\dot{V}O_2$) was assessed by cardiopulmonary exercise testing. We further divided patients into groups according to exercise capacity: ≥5 METs and <5 METs. Physical activity was assessed by measuring the average number of steps/day for 1 week with an electronic pedometer. *Results*: Receiver-operating characteristic curves were used to select cutoff values for steps associated with an exercise capacity of ≥5 METs in the middle- and older-aged patients. Cutoff values of 6045 steps in the middle-aged and 6070 steps in the older-aged patients were determined. *Conclusions*: Both middle- and older-aged CHF patients with exercise capacity of ≥5 METs completed approximately 6000 steps/day. This could become a target amount for minimal physical activity that could contribute to increased exercise capacity in CHF patients.**

**Keywords:** Cardiopulmonary exercise testing, cardiac, exercise, heart

**Implications for Rehabilitation**

- Middle-aged and older-aged chronic heart failure (CHF) patients with a measured exercise capacity of ≥5 METs completed approximately 6000 steps/day as measured by electronic pedometer.
- This amount of steps could become a target amount for minimal physical activity that could contribute to increased exercise capacity in CHF patients.

## Introduction

Exercise capacity is very important due to its relation with morbidity. Low exercise capacity is a leading cause of hospitalization in many countries and has a major adverse impact on health status including symptoms, functional incapacity, and impairment of health-related quality of life in cardiac patients [1–5]. Particularly, apparently normal subjects and those with cardiovascular disease whose exercise capacity is <5 metabolic equivalents (METs) are considered to be at high risk for death and to have low ability to perform activities of daily living [1,2]. In addition, a previous report suggested a relation between directly measured oxygen uptake ($\dot{V}O_2$) and self-reported physical function such as stooping, crouching, kneeling, lifting, or performing activities of daily living in older adults (161 community-dwelling adults aged 65–90 years [6]). This study suggested that peak $\dot{V}O_2$ was most strongly associated with physical function, and subjects with an exercise capacity of less than approximately 5 METs experienced significant difficulty in the performance of daily tasks [6].

Patients with chronic heart failure (CHF) also have lowered exercise capacity [5,7,8]. CHF leads to frequent

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hospitalization and is associated with mortality [7]. One of the important objectives of cardiac rehabilitation (CR) in CHF patients is improvement in exercise capacity, which is associated with mortality, morbidity, and measured health-related quality of life [3]. Previous studies have shown that CR improves peak $\dot{V}O_2$, muscle strength, and endothelial function in patients with CHF [3,8]. In regard to age-related difference in physiological outcomes such as peak $\dot{V}O_2$ in a phase II CR program, we previously reported that baseline peak $\dot{V}O_2$ in older-aged subjects at entry into a phase II CR outpatient program was lower than that of middle-aged subjects, and their recovery process was also different from baseline to the post-phase II CR program [9].

However, for CR patients and sedentary individuals, higher physical activity and total energy expenditure are also associated with lower mortality, lower number of cardiac relapses, and reduced symptoms [10]. Although individual perceptions may differ regarding the value of exercise considered important in the design of strategies to improve exercise in CHF patients, only a few studies have reported on physical activity in CHF patients. However, little is known about the relation between physical activity and peak $\dot{V}O_2$ and age-related differences in physical activity based on exercise capacity, and the baseline target value of physical activity necessary to achieve an exercise capacity of ≥5 METs is unknown.

Therefore, the purpose of the present study was to determine 1) the relation between physical activity and peak $\dot{V}O_2$, 2) age-related differences in the amount of physical activity performed by patients with an exercise capacity of ≥5 METs, and 3) levels of physical activity associated with an exercise capacity of ≥5 METs in middle- and older-aged patients with CHF.

## Methods

### Patients

This was a cross-sectional study in which 246 consecutive outpatients with CHF were selected from 1009 cardiac patients with conditions such as myocardial infarction, coronary artery bypass grafting, valve replacement, and CHF who visited St. Marianna University School of Medicine Hospital, Kawasaki, Japan, from October 2004 to September 2009 for evaluation of exercise capacity by cardiopulmonary exercise testing. From these 246 CHF outpatients, 172 with stable CHF were included in the present study.

Inclusion criteria were first-time cardiopulmonary exercise testing (specified so as to reduce selection bias and unify this condition among all study patients) and left ventricular ejection fraction of <45% as measured by standard M-mode echocardiography (Aplio, Toshiba, Tokyo, Japan). New York Heart Association (NYHA) functional class IV patients were excluded as were those who had neurological, peripheral vascular, orthopedic, or pulmonary disease. NYHA classification was determined in all patients by an independent investigator. The patients were initially divided into two groups defined by age: middle-aged (<65 years, $n$ = 104) and older-aged (≥65 years, $n$ = 68). The present study was approved by the St. Marianna University School of Medicine Institutional Committee on Human Research (Approval no. 1480). Informed consent was obtained from each patient.

### Clinical characteristics of the patients

We evaluated several patient characteristics, including age, sex, etiology of heart failure, and medications. A cardiologist assessed cardiac function by left ventricular ejection fraction and disease severity by brain natriuretic peptide (BNP) concentration. A blood sample for measurement of BNP was drawn from each patient after 15 min of rest in the supine position before cardiopulmonary exercise testing via a catheter inserted into a cubital vein. Blood samples were immediately immersed in ice and centrifuged at 3000 rpm for 10 min at 4°C. The plasma was stored at −70°C and used to measure BNP by radioimmunoassay within 1 week of sampling [5].

### Exercise capacity

The 172 outpatients with stable CHF underwent cardiopulmonary exercise testing via a ramp cycle ergometer protocol. Symptom-limited exercise testing was performed on a CORIVAL 400 ergometer (Lode Co., Groningen, Holland). Testing consisted of an initial 3 minutes of rest on the cycle ergometer, 3 min of warm-up (20 watts load), and full exercise with a linear increase in load by 1 watt every 6 sec. Measurements made from expired gasses were used as indices of cardiovascular dynamics during exercise. A 12-lead ECG was continuously monitored throughout the test, and heart rate was determined from the R-R interval of the ECG (ML-5000, Fukuda Denshi Co., Tokyo, Japan). $\dot{V}O_2$ was measured throughout the exercise period with an AE-300S aero monitor (Minato Ikagaku Co., Tokyo, Japan [5]). Exercise capacity was calculated following measurement of peak $\dot{V}O_2$. The endpoint of cardiopulmonary exercise testing was determined according to the criteria of the American College of Sports Medicine [11] and included leg fatigue, shortness of breath, or respiratory exchange ratio (RER) >1.15. We calculated the METs for each patient as follows: METs = peak $\dot{V}O_2$ ml/kg/min/3.5 ml/kg/min. After cardiopulmonary exercise testing, we divided the patients into two groups according to exercise capacity attained: ≥5 METs group and <5 METs group. At one outpatient visit prior to performing cardiopulmonary exercise testing, NYHA class was determined by a physician, and BNP and left ventricular ejection fraction were assessed.

### Physical activity

Pedometers are widely used to evaluate physical activity in CHF patients [12–14]. We measured the number of steps/day for 1 week as the index of physical activity in the present study. This index was estimated by use of an electronic pedometer (Kenz Lifecorder, Suzuken Co., Ltd., Nagoya, Japan) chosen for its reliability and the validity of the data it outputs [13,14]. The Lifecorder records number of steps taken on the basis of physical characteristics (age, sex, height, and weight) entered by the patient. All patients were taught to put on the Lifecorder themselves and were instructed to use the Lifecorder 24 h a day for 1 week, except while bathing, from the time they received it. At the end of the 1-week measurement period, the patients were asked to return the Lifecorder to us by mail. We calculated the mean number of steps taken daily over 1 week for each patient as mean daily step count = total step count over 7 days/7 [15].

### Statistical analysis

Results are expressed as mean ± SD. Parametric and chi-square tests were used to analyze differences between the ≥5 METs and <5 METs groups in the middle-aged and older-aged patients. Because comparisons between the ≥5 METs and <5 METs groups in both age groups were performed for the CHF sample across the subscales, the unpaired *t*-test was used to test for differences such as clinical characteristics and physical activity in the middle-aged and older-aged patients. The relation between peak $\dot{V}O_2$ and physical activity for each patient was analyzed by Pearson's correlation methods. The sensitivity of step counts associated with an exercise capacity of ≥5 METs was calculated to determine the best cutoff value for each age group. Receiver-operating characteristic (ROC) curves were then constructed by means of plotting true-positive rates (sensitivity) against false-positive rates (1-specificity). The area under the curve (AUC) was also calculated and is shown with 95% confidence interval (CI). A p value of <0.05 was considered significant. Statistical analyses were performed with SPSS 12.0 J statistical software (SPSS Japan, Inc., Tokyo, Japan).

## Results

### Clinical characteristics of the patients

Of the 172 patients, 15 patients were excluded due to their failure to comply with the instructions for wearing the pedometer and measuring physical activity. Therefore, the study sample comprised 157 patients, of whom 97 patients were middle-aged and 60 were older-aged. Of the 97 middle-aged patients, 67 were included in the ≥5 METs group and 30 were included in the <5 METs group. Of the 60 older-aged patients, 25 were included in the ≥5 METs group and 35 were included in the <5 METs group.

Patient characteristics, including age, sex, body mass index, left ventricular ejection fraction, etiology, and medications, were not significantly different between the ≥5 METs and <5 METs groups in both the middle-aged and older-aged patients. However, BNP did differ significantly between the ≥5 METs and <5 METs groups in both the middle-aged (p <0.001) and older-aged (p = 0.031) patients. NYHA class also differed significantly between the ≥5 METs and <5 METs groups in middle-aged (p < 0.001) and older-aged (p < 0.001) patients. Patient characteristics and functional variables in all patients are summarized in Table I.

### Relation between physical activity and peak $\dot{V}O_2$

No patient showed ischemic ST changes or experienced chest pain or serious arrhythmia during cardiopulmonary exercise testing. The relation between physical activity and peak $\dot{V}O_2$ in the middle-aged and older-aged patients is shown in Figure 1. A significant positive correlation of physical activity with peak $\dot{V}O_2$ was found in both the middle-aged ($r = 0.46$, $p < 0.001$) and older-aged patients ($r = 0.49$, $p < 0.001$).

### Age-related differences in physical activity

Age-related differences in physical activity according to exercise capacity in the middle-aged and older-aged patients are shown in Figure 2. Physical activity outcome as assessed by electronic pedometer in the middle-aged patients was significantly lower in the <5 METs group than that in the ≥5 METs

Table I. Clinical characteristics of the middle- and older-aged chronic heart failure patients.

| | Middle-aged (n = 97) | | | Older-aged (n = 60) | | |
|---|---|---|---|---|---|---|
| Group | ≥5 METs | <5 METs | p Value | ≥5 METs | <5 METs | p Value |
| n | 67 | 30 | | 25 | 35 | |
| Age (yrs) | 55.3 ± 6.7 | 52.1 ± 8.3 | 0.084 | 70.5 ± 3.9 | 72.1 ± 4.7 | 0.092 |
| Sex, male (%) | 78.1 | 69.6 | 0.723 | 84.0 | 88.5 | 0.263 |
| BMI (kg/m²) | 23.3 ± 4.5 | 22.9 ± 4.6 | 0.703 | 22.0 ± 1.7 | 23.2 ± 2.7 | 0.081 |
| LVEF (%) | 36.1 ± 13.7 | 31.2 ± 12.0 | 0.692 | 35.4 ± 11.8 | 31.3 ± 9.9 | 0.263 |
| BNP | 93.1 ± 78.7 | 419.3 ± 401.5 | 0.001 | 203.8 ± 169.5 | 343.5 ± 299.0 | 0.031 |
| NYHA (I/II/III) | 45/22/0 | 1/14/15 | 0.001 | 17/8/0 | 3/21/11 | 0.001 |
| Etiology (%) | | | | | | |
| Cardiomyopathy | 53.7 | 43.3 | 0.101 | 48.0 | 31.4 | 0.102 |
| Previous MI | 16.4 | 33.3 | | 24.0 | 37.2 | |
| Arrhythmia | 19.4 | 10.0 | | 28.0 | 22.8 | |
| CABG/VR | 10.5 | 13.4 | | 0.0 | 8.6 | |
| Medications (%) | | | | | | |
| β-Blockers | 80 | 80.5 | 0.773 | 68.0 | 68.5 | 0.761 |
| ARB | 43.3 | 40.2 | 0.521 | 52.0 | 57.1 | 0.592 |
| ACEI | 66.6 | 47.7 | 0.092 | 32.0 | 31.4 | 0.443 |
| Diuretic | 86.6 | 82.1 | 0.534 | 88.0 | 85.7 | 0.581 |

METs, metabolic equivalents; BMI, body mass index; LVEF, left ventricular ejection fraction; BNP, brain natriuretic peptide; NYHA, New York Heart Association; MI, myocardial infarction; CABG, coronary artery bypass grafting; VR, valve replacement; ARB, angiotensin receptor blocker; ACEI, angiotensin converting enzyme inhibitor.

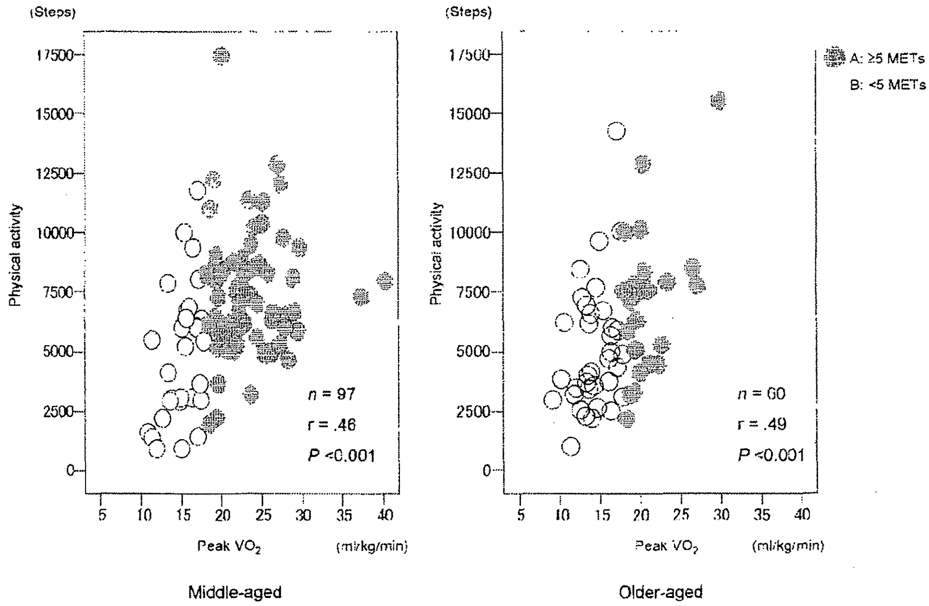


Figure 1. Plots of physical activity and peak $\dot{V}O_2$ in middle-aged and older-aged patients. Closed circles indicate patients in the ≥5 METs group, and open circles indicate patients in the <5 METs group. There were significant positive correlations between physical activity and peak $\dot{V}O_2$ in middle-aged ($r = 0.46$, $p < 0.001$) and older-aged patients ($r = 0.49$, $p < 0.001$).

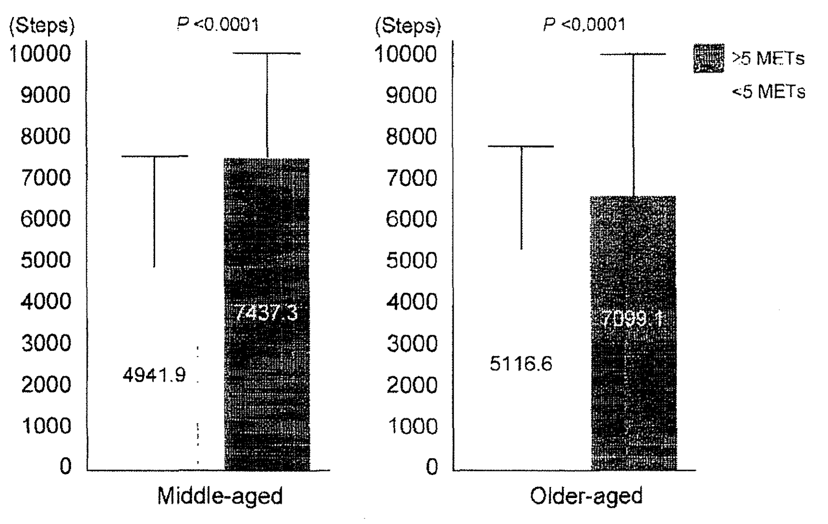


Figure 2. Graphs of physical activity according to exercise capacity in middle-aged and older-aged patients. Gray bars indicate patients in the ≥5 METs group, and white bars indicate patients in the <5 METs group. Physical activity outcome as assessed by electronic pedometer in middle-aged patients in the <5 METs group was lower than that in the ≥5 METs group, and the difference was significant between the ≥5 METs and <5 METs groups (7437.3 ± 2575.2 vs. 4941.9 ± 2795.8 steps/day for 1 week, $p < 0.001$). Moreover, physical activity in older-aged patients in the <5 METs group was lower than that in the ≥5 METs group, and the difference was also significant between the ≥5 METs and <5 METs groups (7099.1 ± 2988.7 vs. 5116.6 ± 2678.3 steps/day for 1 week, $p < 0.001$).

group (4941.9 ± 2795.8 vs. 7437.3 ± 2575.2 steps/day for 1 week, $p < 0.001$). In the older-aged patients, physical activity in the <5 METs group was also significantly lower than that in the ≥5 METs group (5116.6 ± 2678.3 vs. 7099.1 ± 2988.7 steps/day for 1 week, $p < 0.001$).

## Cutoff values associated with exercise capacity of ≥5 METs

The sensitivities of each cutoff value for the ≥5 METs group and the <5 METs group were calculated for both age groups and used to construct the ROC curves for the middle-aged and older-aged patients (Figure 3). Using ROC analysis of exercise capacity of ≥5 METs, we identified a cutoff value of 6045.2 steps/day for 1 week for physical activity in middle-aged patients, with a sensitivity of 0.71, 1-specificity of 0.33, and AUC value of 0.75 (95% CI: 0.634–0.857, $p<0.001$). However, in older-aged patients, ROC analysis of exercise capacity of ≥5 METs identified a cutoff value of 6070.1 steps/day for 1 week for physical activity, with a sensitivity of 0.64, 1-specificity of 0.31, and AUC value of 0.72 (95% CI: 0.589–0.855, $p<0.001$).

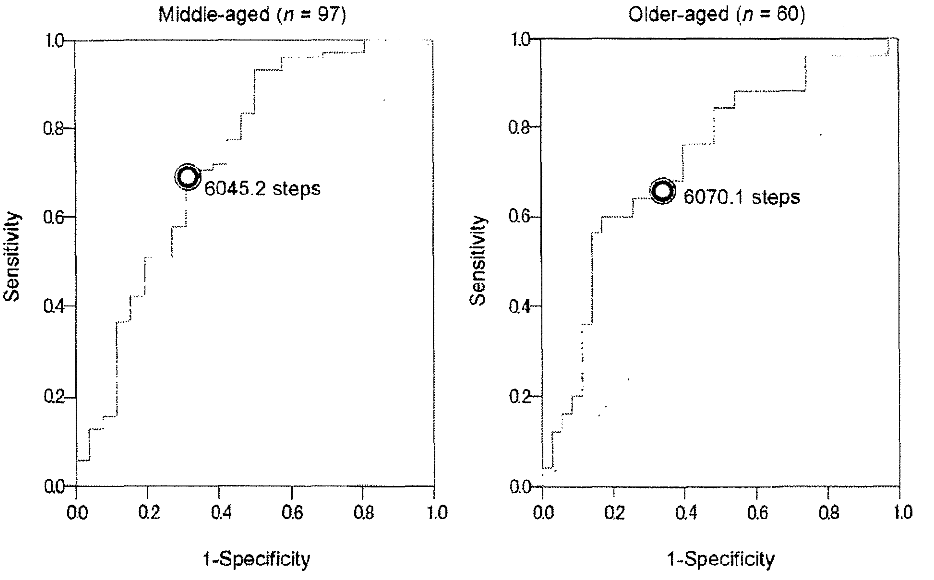


Figure 3. ROC curves. Sensitivities for the ≥5 METs group and the <5 METs group for each cutoff value were calculated for both patient age groups and used to construct ROC curves for middle- and older-aged patients. ROC analysis of exercise capacity of ≥5 METs identified a cutoff value (circle) of 6045.2 steps/day for 1 week for physical activity in middle-aged patients, with a sensitivity of 0.71, 1-specificity of 0.33,and AUC value of 0.75 (95% CI: 0.634–0.857, $p < 0.001$). However, in older-aged patients, ROC analysis of exercise capacity of ≥5 METs identified a cutoff value (circle) of 6070.1 steps/day for 1 week for physical activity, with sensitivity of 0.64, 1-specificity of 0.31, and AUC value of 0.72 (95% CI: 0.589–0.855, $p < 0.001$).

## Discussion

The present study shows that for both middle- and older-aged CHF patients, there was a positive correlation between physical activity and peak $\dot{V}O_2$ and an age-related difference in physical activity in relation to an exercise capacity threshold of 5 METs. We determined the cutoff value for physical activity associated with an exercise capacity of ≥5 METs to be approximately 6000 steps/day for 1 week.

Evaluation of patient clinical characteristics showed a significant difference only in BNP concentration, which was significantly lower in the ≥5 METs group than in the <5 METs group in both the middle-aged and older-aged patients. BNP concentration increases as CHF becomes more severe, and BNP is a known, independent factor of mortality of CHF that correlates negatively with exercise capacity [16,17]. NYHA functional class also differed significantly between the ≥5 METs and <5 METs groups in both age groups. Peak $\dot{V}O_2$ has been reported to relate to symptom scores and prognosis [16]. Itoh *et al.* [18] also reported that percentage of peak $\dot{V}O_2$ decreases significantly as disease severity increases; in other words, peak $\dot{V}O_2$ decreases as NYHA functional class increases. Thus, because BNP concentration and NYHA functional class in our study were significantly different between the ≥5 METs and <5 METs groups in both the middle- and older-aged patients, an exercise capacity threshold of 5 METs might also reflect the degree of seriousness of CHF similarly to that of BNP concentration or NYHA functional class.

With regard to the relation between physical activity and exercise capacity, there is a relation between average daily step counts and peak $\dot{V}O_2$ on non-CR days in patients attending phase II CR. Savage *et al.* [19] reported that peak $\dot{V}O_2$ positively correlated with average daily step counts on non-CR days in 107 phase II cardiac patients following myocardial infarction and such procedures as percutaneous coronary intervention and coronary artery bypass grafting. Although clinical characteristics of the patients in their study differed from those in the present study, peak $\dot{V}O_2$ in the present study was also found to correlate positively with steps/day in both the middle- and older-aged CHF patients, consistent with the findings of the Savage *et al.* study [19]. In addition, physical activity outcome as assessed by pedometer in the <5 METs group was significantly lower than that of the ≥5 METs group for both age groups (Figure 2), suggesting that an exercise capacity threshold of 5 METs does have some influence on the amount of physical activity that can be performed.

Using ROC analysis of exercise capacity of ≥5 METs, we identified a cutoff value for physical activity of 6045.2 steps/day for 1 week in middle-aged patients and 6070.1 steps/day for 1 week in older-aged patients (Figure 3). Our previous study [5] suggested that physiological outcomes such as grip strength and knee extensor and flexor muscle strength correlate positively with peak $\dot{V}O_2$, and these outcomes were higher in middle-aged than older-aged subjects participating in phase II CR [9]. Interestingly, however, at the exercise capacity threshold of 5 METs, physical activity in the present study, as measured by steps per day, was similar in both age groups. Savage *et al.* [19] previously reported that the average step count measured by pedometer on non-CR days was 5315 steps at the beginning of a phase II CR program. Jones *et al.* [20] also reported an average step count of 5287 steps on days that the subjects did not participant in phase III CR.

To our knowledge, this is the first study to evaluate physical activity with pedometer-measured steps per day in middle- and older-aged CHF patients beginning a phase II CR program. Because all of our patients were at the beginning of phase II CR and had never participated in such rehabilitation, study conditions were similar to those of the previous reports. However, in terms of physical activity in the present study, the step counts associated with an exercise capacity threshold of 5 METs were greater than those reported by Savage *et al.* [19] for patients on non-phase II CR days or by Jones *et al.* [20] for a phase III CR program. The average number of steps taken per day in these two previous studies was approximately 5300 steps, whereas that value was approximately 6000 steps in the present study. However, the patient populations in these two studies are not directly comparable with the population of the present study.

Savage *et al.* [19] also reported an average number of steps per day for coronary heart disease patients in the first week of phase II CR of 7387 steps, and our previous report [21] suggested that physical activity in patients with myocardial infarction was at 9252.5 steps after phase II CR. Because the etiology of steps in these two previous studies differed from that in the present study, we did not directly compare our study with these two previous studies. However, the average number of steps per day taken by the middle- and older-aged CHF patients in our study was less than that of these previous studies. Subjectively, however, the patients achieving a step count of 6000 steps/day appeared to successfully perform activities of daily living and to have an adequate health-related quality of life. Because we do not have objective data on this, further study is needed to determine if achievement of a target amount of 6000 steps/day can contribute to an adequate health-related quality of life in middle- and older-aged CHF outpatients.

In a previous review of pedometer use to measure physical activity, Tudor-Locke and Myers reported that the expected number of steps per day for individuals living with disabilities and chronic illnesses was in the range of 3500 to 5500 steps [22]. Another recent systematic review [23] and that of our previous study [15] suggested that a self-monitoring approach to pedometer use may be an effective intervention to increase physical activity by 2491 more steps per day than those in control participants and decrease blood pressure and body mass index among patients with diabetes, sedentary hypertension, chronic obstructive pulmonary disease, and myocardial infarction. Therefore, further study is required to evaluate the usefulness of pedometers as a method to encourage physical activity resulting in an exercise capacity of ≥5 METs in a phase II CR program for middle- and older-aged CHF outpatients.

It is important to objectively measure physical activity of CHF patients because several investigators have shown that limitations to self-reporting methods include social desirability bias (over-reporting of good behavior), poor sensitivity, subjectivity, and dependence on recall [24,25]. Of note, analysis of self-reported physical activity data from the 2003 to 2004 National Health and Nutrition Examination Survey in the United States revealed that subjects significantly overestimated physical activity count, duration, and adherence [26].

There were several limitations in the present study. First, the sample size was small, and it was thus not possible to determine exercise intensity, nor did we reflect non-walking-related activities such as swimming, for example, that may also result in improved exercise capacity. Further studies are needed to investigate relations to other factors.

The second limitation might be the cross-sectional design of the study. The main purpose of the present study was to assess the differences in age in relation to physical activity and peak $\dot{V}O_2$ assessed at a particular time. Nevertheless, it would be highly desirable to document longitudinal changes in peak $\dot{V}O_2$ and physical activity in patients with CHF.

Third, although differences in physical activity associated with exercise capacity in relation to activities of daily living and risk factors were determined in the present study, we did not directly measure these, nor did we measure mortality or morbidity. Therefore, future trials are needed to evaluate the relation between physical activity and these factors in middle- and older-aged CHF patients.

Finally, the results of this study should be interpreted to indicate only a dose-dependent association between physical activity and exercise capacity and not a direct cause-and-effect relation. Many factors are involved in improving exercise capacity, and clinicians cannot base their assessment of a patient's exercise capacity and ability to perform activities of daily living solely on the achievement of a target step count.

## Conclusions

In middle-aged and older-aged CHF outpatients, we found positive correlations between physical activity and exercise capacity and an age-related difference in physical activity as related to an exercise capacity threshold of 5 METs. In addition, cutoff values of 6045.2 steps/day in middle-aged and 6070.1 steps/day in older-aged patients were determined to be associated with an exercise capacity threshold of ≥5 METs. These findings suggest that an exercise capacity threshold of 5 METs was associated with the completion of approximately 6000 steps/day and was similar for both age groups. This amount could become a target amount for minimal physical activity that could contribute to increased exercise capacity in middle- and older-aged CHF patients. Further study is needed to evaluate the usefulness of the pedometer to encourage physical activity in middle- and older-aged CHF patients in CR that will produce an exercise capacity of ≥5 METs.

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ORIGINAL ARTICLE

# Determination of the Effectiveness of Accelerometer Use in the Promotion of Physical Activity in Cardiac Patients: A Randomized Controlled Trial

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ABSTRACT. Izawa KP, Watanabe S, Hiraki K, Morio Y, Kasahara Y, Takeichi N, Oka K, Osada N, Omiya K. Determination of the effectiveness of accelerometer use in the promotion of physical activity in cardiac patients: a randomized controlled trial. Arch Phys Med Rehabil 2012;93:1896-1902.

**Objective:** To investigate the effect of the self-monitoring of physical activity by hospitalized cardiac patients attending phase I cardiac rehabilitation (CR).

**Design:** Randomized controlled trial.

**Setting:** University hospital CR program.

**Participants:** CR patients (N=126) with a mean age of 59.1 years.

**Interventions:** Patients were randomly assigned to the self-monitoring group (group A, n=63) or the control group (group B, n=63). Along with CR, group A patients performed self-monitoring of their physical activity at the beginning of a phase I CR program (acute in-hospital phase for inpatients) and ending just before they began a phase II CR program (postdischarge recovery phase for outpatients).

**Main Outcome Measures:** Physical activity (averages of daily number of steps taken and daily energy expenditure for 1wk) as measured by accelerometer was assessed in both groups at baseline (t1) and before the beginning of phase II CR (t2).

**Results:** Although there were no significant differences in physical activity values between groups A and B at t1, values of group A at t2 were significantly higher than those of group B (8609.6 vs 5512.9 steps, $P<.001$; 242.6 vs 155.9kcal, $P<.001$).

**Conclusions:** Self-monitoring of patient physical activity from phase I CR might effectively increase the physical activity level in preparation for entering a phase II CR program. Results of the present study could contribute to the development of new strategies for the promotion of physical activity in cardiac patients.

**Key Words:** Exercise; Physical activity; Rehabilitation.



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REGULAR PHYSICAL ACTIVITY produces significant improvements in many risk factors for cardiovascular disease, increases functional capacity and reduces the risk of rehospitalization of cardiac patients, and improves the prognosis of patients with coronary artery disease.[1] However, physical activity levels decline significantly after hospitalization, regardless of attendance in cardiac rehabilitation (CR) programs.[2,3] Savage and Ades[4] reported that daily steps taken by cardiac patients during the first week of phase II CR (postdischarge recovery phase for outpatients) are quite low: 78% took <7500 steps per day, 57% took <5000 steps per day, and 21% took 5000 to 7499 steps per day, indicating that physical activity levels in cardiac patients are not adequate after hospital discharge.

A recent systematic review[5] suggested that promotion of physical activity using pedometers is associated with a significant increase in physical activity and significant decreases in body mass index (BMI) and blood pressure. Izawa et al[6] previously reported that a self-monitoring approach, in which cardiac patients record such variables as physical activity based on accelerometer use, body weight, and blood pressure by themselves during phase II CR, effectively increases exercise maintenance and physical activity at 12 months after the onset of myocardial infarction. Other reports[7,8] also suggested that the self-monitoring approach improves short-term physical activity levels and maintains physical activity behavior in sedentary people with diabetes when compared with a standard exercise approach. Thus, improvement of physical activity with the use of an accelerometer appears effective not only for cardiac outpatients but also for those with other diseases.

The Japanese Ministry of Health, Labour and Welfare presented data from 1996 to 2008 showing that the average hospital stay in cardiac patients including those with heart failure decreased from 37.6 to 23.1 days, and particularly in patients with ischemic heart disease, it decreased from 30.4 to 12.8 days.[9] With regard to discharge education, Koelling et al[10] previously reported that the addition of a 1-hour teaching session delivered by a nurse educator at the time of hospital discharge resulted in improved clinical outcomes, increased adherence to self-care measures, and reduced cost of care in patients with systolic heart failure. In the future, the length of hospital stay in Japan will become shorter and shorter, leaving little time to educate patients. Thus, strategies for discharge

**List of Abbreviations**

| | |
|---|---|
| BMI | body mass index |
| CR | cardiac rehabilitation |
| LVEF | left ventricular ejection fraction |

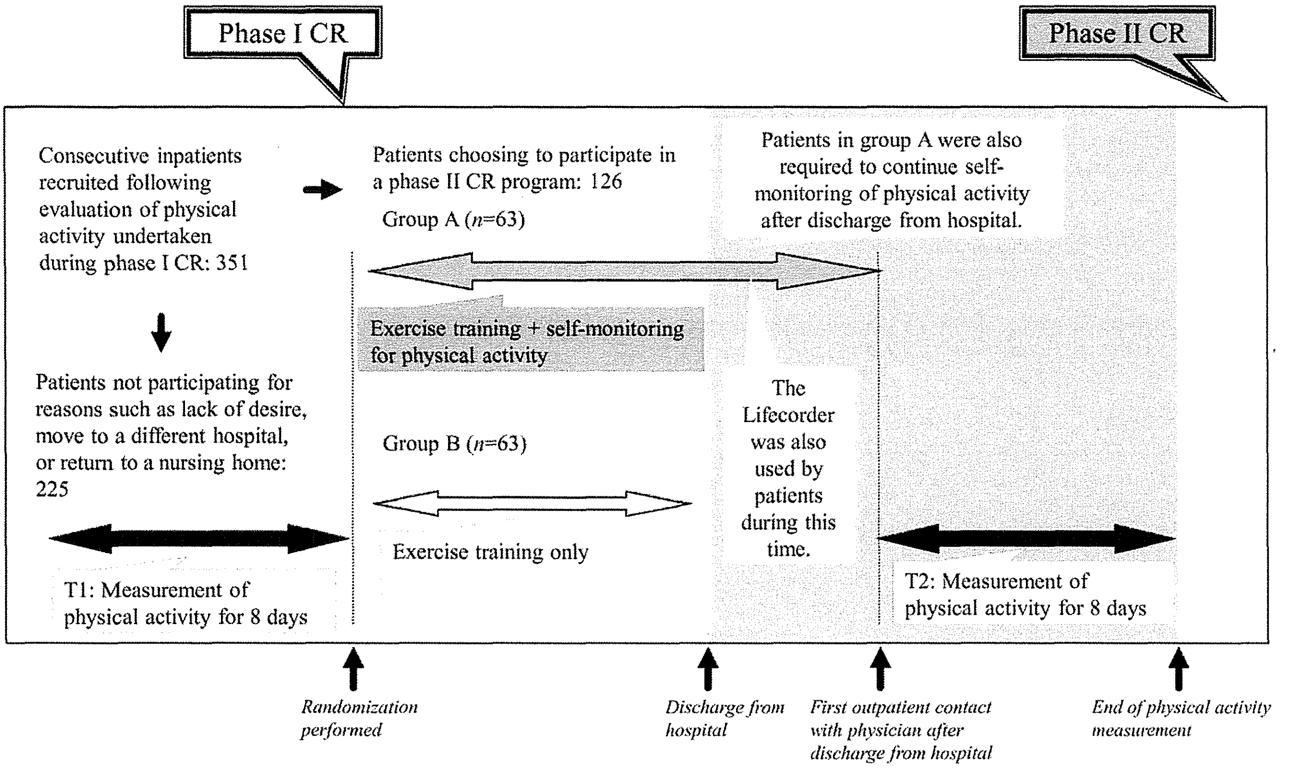


**Fig 1. Patient flow through the study.**

education that strongly promote physical activity for cardiac patients must be considered. However, there is little evidence that the promotion of in-hospital physical activity for cardiac outpatients is effective after discharge.[11]

We hypothesized that exercise training combined with self-monitoring of physical activity begun during phase I CR (acute in-hospital phase for inpatients) and continued until phase II CR would increase the physical activity level in cardiac patients. Therefore, we conducted a randomized controlled trial to evaluate the effect of a self-monitoring approach on physical activity begun during an acute phase I CR program and continued until the beginning of a phase II CR program.

## METHODS

### Study Population

This study was a randomized controlled trial using systematic sampling with subjects selected from among 1061 consecutive cardiovascular patients admitted to St. Marianna University School of Medicine Hospital between April 2008 and August 2010. Of these patients, 351 were recruited after evaluation of physical activity undertaken during an acute phase I CR program and were initially included in the present study. Excluded were 710 patients because of younger age (<30y), refusal to evaluate physical activity, cerebrovascular disease, orthopedic disorder, severe heart failure, pulmonary disease, or because they had experienced an uncontrolled arrhythmia. Of these 351 patients, 126 agreed to participate in phase II CR; the other 225 patients did not participate for reasons such as lack of desire, move to a different hospital, or return to a nursing home. Thus, 126 patients (80.5% men; mean age, 59.1y) were randomly assigned to either the self-monitoring approach group (group A, n=63) or the control group (group B, n=63). In the present study, t1 was defined as 8 days of measurement for baseline assessment of physical activity during phase I CR for inpatients, and t2 was defined as 8 days of measurement for reassessment of physical activity before the beginning of phase II CR for outpatients. Patient flow through the study is shown in figure 1.

### Sample Size

Before creating the study design, we estimated the necessary sample size required for both groups in the present study according to methods described elsewhere.[12] Type 1 error ($\alpha$ error = 5% by 2-sided test) and power ($1-\beta$, 80%) were also defined. Sample size was calculated for each group: standard effect size was calculated as effect size/SD = 2500 steps/3100 steps = .806, where the number of steps was estimated based on previous studies.[5,6] As a result, the sample size was estimated to be at least 26 patients for each group, and the total number of patients required to populate the present study was estimated to be at least >52 patients.

### Ethics

Approval for this study was granted by the ethics committee of St. Marianna University School of Medicine institutional committee on human research (approval no. 1480). All patients gave their written informed consent to participate in this study.

### Clinical Characteristics of the Patients

We evaluated patient characteristics that included age, sex, BMI, left ventricular ejection fraction (LVEF), employment status, marital status, disease etiology, and medications.

### Readiness for Exercise Before Admission to Phase I CR

We used the transtheoretical model of exercise behavior change to evaluate patient readiness for exercise before admission to the phase I CR.[13,14] This model suggests that changes in an individual's exercise behavior progress through 5 stages: (1) precontemplation, (2) contemplation, (3) preparation, (4) action, and (5) maintenance.[13,14] Patients in the preparation, action, or maintenance stage were defined as exercising, and patients in the precontemplation or contemplation stage were defined as not exercising.

### Physical Activity

All patients in groups A and B were taught to use the accelerometer, and from the time of reception, they used it during both t1 and t2 for 8 days, 24h/d, except when bathing or during nighttime sleeping. Averages of daily number of steps taken and daily energy expenditure for 1 week were used as the indices of physical activity. These indices were estimated with the Kenz Lifecorder EX[a] 1-axial accelerometer, which provides reliable and validated output data[15,16] and which can store 100Kb of data onboard, enough for 200 days of continuous use. All subjects wore the accelerometer on a belt at waist level just above either leg. The Kenz Lifecorder EX records number of steps taken and energy expenditure, which is based on pre-entered physical characteristics data (age, sex, height, weight). After 8 days of continuous wear, the device was retrieved, and the data were downloaded into a computer with Microsoft Excel[b] software. Daily energy expenditure on physical activity is calculated and counted by the accelerometer every 4 seconds, using body weight (W) and a factor Ka (exercise index), which depends on the exercise intensity level:

$$\text{Daily energy expenditure (kcal)} = \text{Ka (kcal/kg/4s)} \times \text{W (kg)}.^{17}$$

However, the value of factor Ka cannot be provided here because it is proprietary information of the manufacturer and is therefore confidential.[17]

To assess the patient's usual daily physical activity, this study used the final 7 days of continuous data from the 8-day collection period. The average of the daily number of steps taken was calculated as the total step count over 7 days divided by 7, and the average of the daily energy expenditure as kilocalories expended over 7 days divided by 7.[6]

### Phase I CR Program

The supervised phase I CR program involved an interdisciplinary team approach to CR. A physical therapist supervised exercise training that combined exercise at 40% to 60% of maximum predicted heart rate with treadmill walking at an intensity of 11 to 13 (according to the Borg 6–20 scale)[18] and own-weight resistance exercises along with pre- and postexercise upper and lower extremity and body stretches. Patients participated 5 times a week for 1 hour each. The exercise session comprised a warmup period, own-weight resistance exercises, aerobic exercise, and a cooldown period. Own-weight resistance training comprised 4 sets of a series of 2 own-weight upper extremity exercises (shoulder flexion and abduction from anatomic position performed with handgrip resistance provided by a clenched fist) that allowed completion of 5 repetitions[19] at a perceived exertion rating of 11 to 13. Lower extremity exercises comprised a series of 4 sets of squats and calf raises maintained at a perceived exertion rating of 11 to 13. At discharge, a dietician and pharmacist provided diet and medication instructions, respectively, to each patient, and a nurse instructed each patient on cardiovascular risk factors and smoking cessation. Both groups A and B received these interventions.

### Self-Monitoring Approach

This study was not blinded as to which patients were in groups A or B. A physical therapist on the phase I CR staff provided instruction on the self-monitoring approach. All patients were asked by the physical therapist to record physical activity derived from the accelerometer during the phase I CR program. In addition, patients in group A were then asked by the physical therapist to continue to wear the accelerometer and to continue this self-monitoring after the completion of the phase I CR program, through hospital discharge, and up to the beginning of t2. In contrast, patients in group B were not asked to continue wearing the accelerometer except during t1 and t2 for evaluation of physical activity in the present study. The duration of phase I CR in each group and the mean time from hospital discharge to completion of the evaluation of physical activity at t2 were also assessed.

Our goal for the self-monitoring approach group was to promote physical activity by the physical therapist on the phase I CR staff to greater than that currently performed at baseline. The patients used an exercise calendar on which to record step counts and energy expenditure, as well as weekly and long-term goals. We based the self-monitoring approach used in the present study on the self-efficacy theory of Bandura[20] and Oka,[21] which was designed to enhance confidence for the promotion of physical activity. This theory addresses the 4 components of self-efficacy: verbal persuasion, physiologic states, vicarious learning, and performance accomplishments.[20] Verbal persuasion promotes the motivation of regular exercise and other health behaviors. For example, the physical therapist praised the patients if they attained the target of physical activity. Thus, this target was initially set at a low level by the therapist for each patient. Vicarious learning encourages the patient through discussion, breaking of barriers that prevent patients from exercising, and adoption of other positive health behaviors. Performance accomplishments were addressed with written feedback after discussion of items such as physical activity entered in the patient's self-monitoring log. Physiologic states were addressed by reviewing normal and abnormal physiologic responses to exercise during phase I CR. Although group B patients also participated in the phase I CR program, they did not use the self-monitoring methods promoted in this study.

### Statistical Methods

Results are expressed as mean ± SD. Differences between the 2 groups relating to readiness for exercise and durations of phase I CR were analyzed with parametric (paired *t* test) and chi-square tests. Regarding factorial design with 2 factors in the 2-way analysis of variance repeated measures, the within-participants factor for physical activity was term (t1 vs t2), and the between-participants factor was group (group A vs group B). Effect sizes were also calculated as $\gamma$.[22,23] We used Cohen's guidelines for small ($r$=.10), medium ($r$=.30), and large ($r$=.50) effects to evaluate the magnitude of this effect size.[24] We considered a $P$ value of <.05 to indicate statistical significance. Statistical analyses were performed with IBM SPSS 17.0J[c] statistical software.

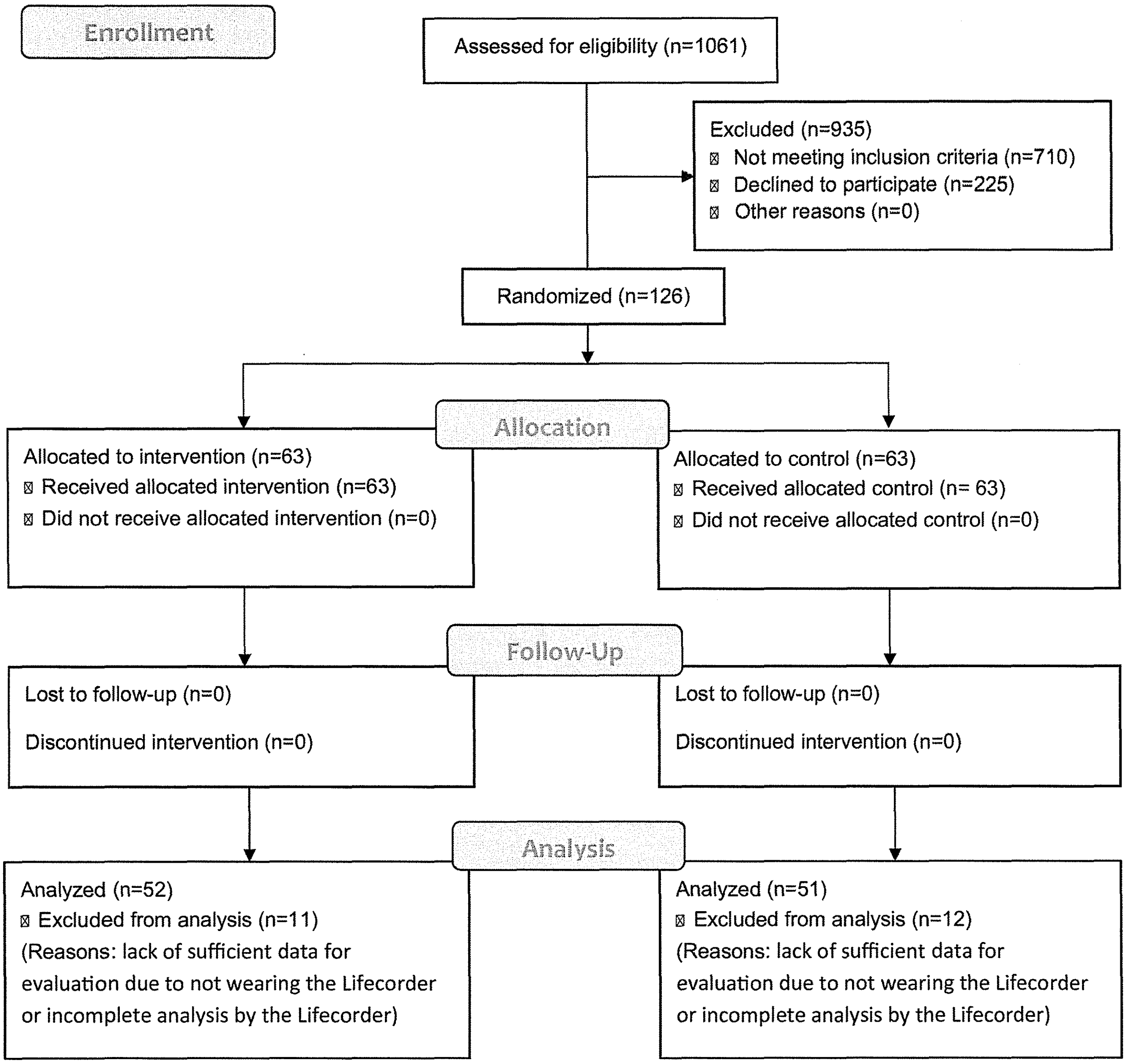


**Fig 2. Consolidated Standards of Reporting Trials flow diagram.**

## RESULTS

### Patients

Of the 126 study patients, 11 of the 63 patients in group A and 12 of the 63 patients in group B were excluded because of lack of sufficient data for evaluation resulting from problems such as not wearing the accelerometer or incomplete analysis by the accelerometer (possibly because of defective equipment). Therefore, the study sample included 103 patients, of which 52 patients comprised group A and 51 patients comprised group B. The Consolidated Standards of Reporting Trials flow diagram for the present study is shown in figure 2.

### Clinical Characteristics of the Patients

Patient characteristics at baseline, including age, sex, BMI, LVEF, employment and marital status, disease etiology, and medications, were not significantly different between the 2 groups (table 1).

### Readiness for Exercise and Other Factors

Readiness for exercise at baseline, duration of phase I CR, and mean term from discharge to end of physical activity measurement in both groups are shown in table 2. There were no statistically significant differences in these values between groups A and B.

Table 1: Patient Clinical Characteristics

| Characteristic | Group A (n=52) | Group B (n=51) | $t^*$ or $\chi^2$ | P |
|---|---|---|---|---|
| Mean age (y) | 59.2±8.2 | 59.1±12.8 | 0.05* | .95 |
| Men | 78.8 | 82.3 | 0.98 | .32 |
| BMI (kg/m$^2$) | 23.2±4.1 | 23.0±2.9 | 0.16* | .87 |
| LVEF | 46.8±16.9 | 41.3±16.8 | 1.62* | .10 |
| Employed | 60.4 | 56.5 | 0.14 | .70 |
| Married | 87.7 | 78.2 | 1.52 | .21 |
| Etiology | | | | |
| Heart failure | 21.1 | 39.2 | 4.82 | .09 |
| CABG/VR | 26.9 | 19.6 | | |
| MI | 52.0 | 41.2 | | |
| Medication | | | | |
| β-blocker | 76.9 | 84.3 | 0.89 | .34 |
| ARB | 26.9 | 31.3 | 0.24 | .61 |
| ACEI | 63.4 | 66.6 | 0.11 | .73 |
| Diuretic | 53.8 | 58.8 | 0.25 | .61 |

NOTE. Values are mean ± SD, percentages, or as otherwise indicated. There were no significant differences between groups ($P$>.05).
Abbreviations: ACEI, angiotensin-converting enzyme inhibitor; ARB, angiotensin receptor blocker; CABG, coronary artery bypass grafting; MI, myocardial infarction; VR, valve replacement.
*$t$ value.

### Differences in Physical Activity Between t1 and t2

Differences in physical activity between t1 and t2 in groups A and B are shown in table 3. Although there were no significant differences in physical activity values postulated from the averages of daily number of steps taken and energy expenditure between the 2 groups at t1, the values in group A at t2 were significantly higher than those in group B. Further, although these values were not significantly different for terms t1 and t2 in group B, these values in group A were significantly higher in t2 than in t1. Significant term by group interactions for step count and energy expenditure were also detected. Although the effect sizes of the daily number of steps taken ($\gamma$=.48) and energy expenditure ($\gamma$=.33) were medium between groups A and B at t2, the effect sizes of daily number of steps taken ($\gamma$=.83) and energy expenditure ($\gamma$=.80) were large for terms t1 and t2 in group A, whereas in group B they were small ($\gamma$=.16 and .13, respectively).

## DISCUSSION

To our knowledge, this study is the first randomized controlled trial to investigate the effect of the self-monitoring approach on physical activity of cardiac patients from the time of participation in phase I CR to the beginning of a phase II CR program. The main finding was that at the beginning of the phase II CR program, physical activity levels of patients using the self-monitoring approach were greater than those of the control group patients, as indicated by the higher averages of daily number of steps taken and energy expended in the group A versus group B patients, despite almost identical clinical characteristics, readiness for exercise before admission to the phase I CR program, and physical activity levels measured at t1 in both groups. The large effect size for physical activity within both t1 and t2 in group A and the medium effect size between the 2 groups suggest that the self-monitoring approach used in the present study merits further investigation.

Readiness for exercise has been reported to result in effective adherence to exercise maintenance in healthy people.[25] Prior readiness for exercise in the present study was not different between the 2 groups, and therefore, it may not be the essence of better exercise maintenance. Moreover, the duration of phase I CR and the mean term from hospital discharge to the end of measurement of physical activity at t2 were also similar between the 2 groups. Thus, these factors appeared to have no influence on the promotion of physical activity with the self-monitoring approach in the present study.

The present study suggests that an intervention such as self-monitoring may be applied to the CR setting to assist with exercise behavior. One reason we chose to investigate the self-monitoring approach used in this study was based on the self-efficacy theory of Bandura,[20] which posits that the performance of a specific behavior is strongly influenced by the confidence of individuals in their ability to perform that behavior.[21] The patients were encouraged to self-monitor their physical activity from the beginning of the phase I CR program after measurement of physical activity at t1 to the beginning of the phase II CR program and also to continue it thereafter. However, because the index of self-efficacy was not evaluated in the present study, we could not show evidence of a relation between the self-efficacy index and physical activity. Izawa[6] previously suggested that promotion of self-efficacy with the self-monitoring approach to physical activity correlated positively with improvement in both self-efficacy and physical activity in a phase II CR program. Therefore, the effectiveness of the self-monitoring approach on physical activity and self-efficacy performed from phase I CR to the beginning of a phase II CR program will require additional evaluation in a future trial.

Savage and Ades[4] previously reported that the average step count measured by a pedometer on non-CR days was 5315 steps at the beginning of a phase II CR program. Because the average step count in our patients in group B (5512.9 steps) was measured at t2, before the beginning of phase II CR, and these patients had never before participated in such rehabilitation, conditions in the present study were similar to those of previous reports. Moreover, with regard to steps and energy expenditure in cardiac patients, Ayabe et al[26] previously suggested that when using the same accelerometer as used in the present study, to achieve the total mean step counts and energy expenditure for physical activity recommended for the secondary prevention of cardiovascular disease, patients should be encouraged to accumulate between 6500 and 8500 steps (200–300kcal) per day. Although the physical activity of the patients in group A at t2 was 8609.6 steps (242.6kcal) and was higher

Table 2: Duration of Phase I CR, Mean Term From Discharge to End of Physical Activity Measurement, and Readiness for Exercise

| Variable | Group A (n=52) | Group B (n=51) | $t^*$ or $\chi^2$ | P |
|---|---|---|---|---|
| Duration of phase I CR (d) | 21.6±4.4 | 22.8±5.3 | 0.65 | .51 |
| Mean term from hospital discharge to end of physical activity measurement (d) | 28.0±18.5 | 26.2±22.1 | 0.14* | .43 |
| Readiness for exercise before admission to phase I CR | | | | |
| Not exercising | 18 (34.6) | 23 (45.1) | 1.18 | .31 |
| Exercising | 34 (65.4) | 28 (54.9) | | |

NOTE. Values are mean ± SD, n (%), or as otherwise indicated.
*$t$ value.

Table 3: Physical Activity Between Groups

| Variable | Group A (n=52) | | Group B (n=51) | | Interaction | |
|---|---|---|---|---|---|---|
| | t1 | t2 | t1 | t2 | F | P |
| Average daily number of steps | 4588.0±2056.3 | 8609.6±3064.5* | 5155.2±2424.5 | 5512.9±2571.8† | 54.5 | <.0001 |
| Average daily energy expenditure (kcal) | 128.6±77.8 | 242.6±111.5* | 140.0±86.2 | 155.9±135.4† | 23.6 | <.0001 |

*$P<.05$ within terms (t1 vs t2); †$P<.05$ between groups (group A vs group B).

than that reported in these previous studies, the step counts indicated in these previous studies might also be appropriate target values to achieve the necessary energy expenditure recommended for secondary prevention in cardiac patients.

However, a previous report[27] suggested that the physical activity level in patients with myocardial infarction who are beginning chronic phase III CR was at 9252.5 steps after the end of a recovery phase II CR program (>18mo after acute myocardial infarction onset), and the health-related quality of life of these patients as assessed by the Short Form-36 was similar to Japanese national norms. The average daily number of steps in group A in the present study was approximately 650 steps less than that in this previous study (9252.5 – 8609.6 = 642.9 steps),[27] indicating the need to further promote physical activity in recovery phase II CR programs.

With regard to pedometer use, a systematic review[5] and a previous study[6] in a phase II CR program suggested that a self-monitoring approach to pedometer use might be an effective intervention to increase physical activity by 2491 steps more per day than those in control participants[6] and decrease blood pressure and BMI among patients with diabetes, sedentary hypertension, chronic obstructive pulmonary disease, and myocardial infarction.[5] Therefore, additional study is required to evaluate the usefulness of pedometers as a method to encourage physical activity in phase II CR programs.

### Study Limitations

This study was not blinded as to which patients were in groups A or B, and a physical therapist on the phase I CR staff provided instruction on the self-monitoring approach. This factor may be associated with the improvement of physical activity in group A.

Although medications did not influence the rate of perceived exertion for exercise prescription in the present study, medications such as β-blockers can influence the percentage of maximal heart rate for exercise prescription,[28] indicating that this measure may be of limited accuracy for exercise prescription in patients taking β-blockers. We did not evaluate medication use or its exact influence on exercise prescription using percentage of maximum heart rate. However, there were no significant differences between the 2 groups in medications used, and we used both maximum predicted heart rate and a rate of perceived exertion of 11 to 13 in prescribing exercise intensity. Thus, we believe there was no difference in, and no influence on, exercise prescription for both groups in the present study. We did not ascertain all the reasons related to the promotion of physical activity. A recent report[29] suggested that self-efficacy is apparently related to 1 predictor of physical activity in 2000 Japanese adults aged 20 to 79 years, and Izawa[6] also previously suggested a relation between self-efficacy and physical activity in patients undergoing phase II CR. Therefore, self-efficacy may be 1 factor that affects the promotion of physical activity.

We did not assess physiologic differences in exercise capacity such as peak oxygen uptake from the phase I to phase II CR program. This index also relates to physical activity in cardiac patients.[30] Therefore, we could not precisely assess differences in exercise capacity between the 2 groups. Further study would be required to evaluate an association between exercise capacity and the self-monitoring approach over the long term in a phase II CR program.

We did not evaluate lipid cholesterol level or other coronary risk factor indicators. Additional study would also be necessary to validate the long-term effect of these factors on outcomes after completion of a supervised phase II CR program.

In the present study, the efficiency of the self-monitoring approach was shown by the higher number of steps attained in group A versus group B. However, because no additional functional tests (eg, 6-min or 10-m walk) were conducted, the results cannot imply the functional or medical benefits achieved by this behavior. Further study is needed using other functional tests to confirm our findings. Despite these limitations, we believe that the present data support the beneficial differential effect of the self-monitoring approach on physical activity of cardiac inpatients in phase I CR, and that the sample size was adequate to yield significant results from the test instrument scores.

## CONCLUSIONS

At the beginning of a phase II CR program, physical activity indices assessed by accelerometer use in the self-monitoring approach group were significantly higher than those in the control group, and the self-monitoring approach practiced during supervised phase I CR and during the time after hospital discharge appeared to be effective in increasing the physical activity level of cardiac patients before beginning a phase II CR program. We concluded that patient self-monitoring of physical activity during phase I CR and during the time after hospital discharge might effectively increase their physical activity level in preparation to entering a phase II CR program. The present results could contribute to the development of new strategies of physical activity promotion in cardiac patients. Longer trials should be undertaken in the future that include long-term follow-up to determine whether the benefits of the self-monitoring approach continue over time.

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