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Original Article

Effects of Exercise Type on Hemodynamic Responses and Cardiac Events in ACS Patients

Chul Kim, MD, PhD[1)], Chul-Hyun Kim, PhD[2)], Haemi Jee, PhD[3)], Young-Joon Lim, MD[1)], Young-Joo Kim, PhD[1)*]

[1)] *Department of Rehabilitation Medicine, College of Medicine, Sanggye-Paik Hospital, Inje University: 761-7, Sanggye 7 dong Nowon-gu, Seoul 139-707, Republic of Korea*
[2)] *Department of Sports Medicine, Soonchunhyang University, Republic of Korea*
[3)] *Department of Health & Fitness Management, Namseoul University, Republic of Korea*

Abstract. [Purpose] This study investigated the effects of mid, and high exercise intensities on hemodynamic responses and cardiac events during two exercise types of treadmill exercise (TM) and cycle ergometer exercises (CE) in patients with acute coronary syndrome (ACS). [Subjects] Patients who had percutaneous coronary intervention (PCI) for ACS and were participating in cardiac rehabilitation program were included. [Methods] The patients were assessed for hemodynamic responses, cardiac events, and rate of perceived exertion (RPE) with target heart rates of 60% and 85% heart rate reserve (HRR) during TM and CE. [Results] Maximum systolic blood pressure (SBP), diastolic blood pressure (DBP), RPE, and rate pressure product (RPP) measured during CE were significantly higher than their values in TM at the same exercise intensities. The highest SBP was shown at 85% HRR during CE. SBP_{max} to SBP_{max} ratios obtained during the graded exercise test (GXT) showed that all $\%SBP_{max}$ were significantly greater in CE than in TM at the same exercise intensities. Out of 102 patients, cardiac events occurred in 8 at 85% HRR during CE, and 1 at 85% HRR during TM. Patients with cardiac events (CE-E) had significantly higher %SBP, %RPP, and RPE at 85% HRR than those without events (CE-NE) during CE. [Conclusion] Prescribing exercise based on the intensity obtained in a treadmill GXT may expose patients to cardiovascular complications such as higher RPP, higher exercise intensity, and cardiac events during CE.
Key words: Treadmill, Cycle ergometer, Rate pressure product

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INTRODUCTION

Cardiac rehabilitation has been known to play a key role in the enhancement of exercise ability, secondary prevention, and reduction in the mortality rate of patients with coronary syndrome through comprehensive programs including exercise prescription, nutrition counseling, drug therapy, and weight control[1, 2)]. However, an improper rehabilitation program may result in negative outcomes, especially in patients with cardiac problems. Therefore, the programs should be closely monitored and controlled to prevent undesirable side-effects. Establishing the proper exercise intensity unique to a patient is one of the major steps in designing an appropriate cardiac rehabilitation program.

An exercise stress test is conducted before initiating exercise intervention in cardiac rehabilitation[3)]. The exercise intensity is established based on the maximal heart rate or maximal oxygen consumption (VO_{2peak}) obtained during an exercise stress test[4)]. Although Karvonen's formula (220 − age), or the formula suggested by AHA (American Heart Association) {206.9 − (0.67 × age)}, are the most widely used formula for establishing exercise intensity[5, 6)], they are not recommended for patients with cardiovascular disorders. An exercise stress test is recommended to establish the maximal heart rate, since medications such as beta blockers taken by patients are known to considerably lower heart rates, not only at rest but also during exercise[7, 8)]. The exercise stress test is usually conducted on a treadmill or ergometer to establish the appropriate exercise intensity based on the percent heart rate reserve (%HRR)[4)]. The exercise intensities obtained from either treadmill or ergometer exercise have been interchangeably applied to prescribe exercise programs for patients with ACS.

However, the two exercise types have distinctively different physiological hemodynamic responses. It was reported that VO_2max obtained during TM was 6% to 25% higher than VO_2max obtained during CE, along with increased maximal heart rate[9–14)]. The maximum exercise capacity could not be achieved due to comparatively lower cardiac outputs and early fatigue tendencies in the lower limbs during CE[11, 15)]. In addition, the maximal SBP measured during exercise stress tests was higher during CE than during TM[10, 16)]. When the exercise intensity established during a

*Corresponding author. Young-Joo Kim (E-mail: kyj1383@yahoo.com)

TM stress test is applied to CE, despite the physiological differences, the patients may exercise at a higher intensity with greater cardiovascular demands. Reed[17] reported a higher rate pressure production (RPP) during CE than during TM, due to higher blood pressure responses with targeted heart rates established at low- (40%) and mid-intensity exercise (60%). Angina pectoris was seen in patients with stable angina who experienced chest pain during exercise at certain values of RPP[18, 19]. Thus, when exercise is conducted on both a treadmill and an ergometer with identical target heart rates, a higher exercise intensity may be achieved during CE than during TM. Moreover, the cardiac burden may be significantly increased at higher exercise intensities, especially at 85% HRR or greater. In particular, RPP, which measures the hemodynamic stress of the heart, may significantly increase to detriment of the treatment effects and exercise performance, and further induce cardiovascular symptoms. Despite such significant differences in CE and TM, many guidelines for exercise prescription do not clearly distinguish the characteristics and risks involved in the two exercise types. Therefore, in order to elucidate the differences and risks involved in applying the established exercise intensity to two different exercise types, this study calculated two commonly used exercise intensities using a treadmill graded exercise test performed by patients with ACS. Then, we applied the treadmill graded exercise test-derived exercise intensities of 60% and 85% HRR to both TM and CE to assess the differences in the hemodynamic responses, rate of perceived exertion (RPE), and the number of cardiac events between the two exercise types. The results may be used to improve exercise prescription guidelines for patients with ACS.

SUBJECTS AND METHODS

The subjects of this study were patients who were hospitalized for ACS, who received percutaneous transluminal coronary angioplasty (PTCA) and drug therapy, and participated in a hospital-based cardiac rehabilitation program from May 2009 to April 2011. The subjects were recruited on a voluntary basis. After explaining the purpose and procedure of the study, the subjects volunteered and gave their written consent before participating in the study. The study design and procedures were approved by the Institutional Review Board (IRB) of Inje University Sanggae Baik Hospital. The study was performed according to the guidelines set by the Ethics Committee[20]. The patients with severe arrhythmia, heart failure with 40% or less ejection fraction in the left ventricle, exercise-induced high blood pressure, an interrupted exercise stress test due to abnormal cardiovascular response, changes in administered drugs during the study period, or chronic obstructive pulmonary or musculoskeletal disease contraindications to the exercise stress test were excluded from this study. Although no premature termination was observed during the exercise stress test, 16 out of 118 patients were excluded from the study due to reasons such as difficulty adapting to CE or the prescribed exercise loads. Of the 102 patients who completed this study, 38 patients were diagnosed as having unstable angina (37.3%) and 64 were diagnosed as having acute myocardial infarction (62.7%). The patient characteristics such as age, sex, height, weight, body mass index (BMI), complications, administered drugs, heart rate (HR), blood pressure (BP), RPP, and VO_2max are described in Table 1.

Table 1. Demographic characteristics of the subjects (n=102)

Variables	Mean±SD / Frequency
Age (y)	56.6±9.7 (M) / 57.8±3.6 (F)
Sex (Male/Female)	93 (91.2%) / 9 (8.8%)
Height (cm)	167.0.±6.0 (M) / 154.6±9.3 (F)
Weight (kg)	69.6±8.9 (M) / 61.7±11.3 (F)
BMI (kg/m^2)	25.0±3.1 (M) / 25.7±3.1 (F)
Disease	
UA	38 (37.3%)
MI	64 (62.7%)
Complications	
Hypertension	56 (54.9%)
Diabetes Mellitus	24 (23.5%)
Dyslipidemia	24 (24.5%)
Drugs	
Aspirin	102 (100%)
Plavix	98 (96.1%)
Beta-blocker	37 (36.3%)
CCB	9 (8.8%)
Carvedilol	26 (25.5%)
ACEI	51 (50%)
ARB	10 (9.8%)
Nitrate	63 (61.8%)
Diuretics	10 (9.8%)
Statin	95 (93.1%)
HR_{rest} (beat/min)	72.5±12.6
SBP_{rest} (mm Hg)	117.3±16.9
DBP_{rest} (mm Hg)	78.5±10.0
RPP_{rest}	8486.8±1784.7
VO_{2max} (O_2 ml/kg/min)	28.3±6.9
HR_{max} (beat/min)	138.2±18.4
SBP_{max} (mm Hg)	174.9±28.4
DBP_{max} (mm Hg)	78.5±10.0
RPP_{max}	24359.4± 5771.5

Values are mean±SD, BMI: body mass index, MI: myocardial infarction, CCB: calcium channel blocker, ACEI: angiotensin converting enzyme inhibitor, ARB: angiotensin II receptor blocker, HR: heart rate, SBP: systolic blood pressure, DBP: diastolic blood pressure, RPP: rate pressure product

Symptom-limited graded exercise tests (GXT) were conducted with a modified Bruce protocol within a week of discharge. The tests were conducted to determine the appropriate exercise intensities prior to cardiac rehabilitation exercise on a treadmill and cycle ergometer. Peak oxygen consumption (VO_{2peak}) and the highest value of VO_2 were measured during the GXT. All tests were terminated according to the ACSM termination criteria[21]. A 12-channel real-time electrocardiograph (Q4500, Quinton Instrument Co., Boston, USA), a gas analyzer (QMC (Quinton metabolic cart), Quinton Instrument Co., Boston, USA), an automated blood pressure and pulsation measurement device (Model 412, Quinton Instrument Co., Boston, USA), and a treadmill (Medtrack ST 55, Quinton Instrument Co., Boston, USA) were used for the exercise stress tests. Heart rate (HR), blood pressure (BP), and VO_2 at rest and during maximal exercise were recorded. The Borg scale (6–20) was also used to measure the rate of perceived exertion (RPE).

The patients participated in a cardiac rehabilitation program within one week of discharge. The exercise intensities of 60% and 85% HRR were first calculated using Karvonen's formula,{(maximal heart rate − resting heart rate × % intensity) + resting heart rate} based on the results obtained during the exercise stress test[6].

The cardiac rehabilitation program was composed of 10 minutes warm up (stretching), 24 minutes of main exercise (treadmill or cycle ergometer), and 10 minutes of cool down (3 minutes of slow walking and stretching)[22]. The main exercise was divided into two 12-minute exercise bouts either on a treadmill (Quinton MED-TRACK SR 60, Quinton Instrument Co., Boston, USA) or a fixed cycle ergometer (Quinton CORIVAL 400, Quinton Instrument Co., Boston, USA). The participants took a three-minute rest by calmly walking on a flat floor between the two 12-minute exercise bouts. The exercise sessions were conducted every other day for two weeks, in a total of six sessions.

The cardiac rehabilitation exercise program was conducted alternatively on a treadmill and a cycle ergometer with a gradual increase in the exercise intensity. On the first, third, and fifth sessions, the treadmill exercise intensity was gradually increased to 60% HRR, 70% HRR, and 85% HRR, respectively. On the second, fourth, and sixth sessions, the cycle ergometer intensity was gradually increased to 60% HRR, 70% HRR, and 85% HRR, respectively.

HR, SBP, DBP, RPP, RPE, and cardiac events were assessed two minutes prior to the end of all the first exercise bouts. An ECG telemetry system (Quinton Instrument Co., Boston, USA) and a mercury blood pressure unit with a stethoscope were used to measure HR and BP at the chest height of the patients. The devices were also used to monitor for clinical signs of myocardial ischemia, or arrhythmia. RPP was calculated by multiplying HR by SBP. RPE was measured on the Borg scale[23], and possible chest pain was expressed using an angina pectoris scale[24]. The measurements obtained during TM and CE at 60% and 85% HRR were used for comparison. The measurements were performed by the same investigators to maintain the measurement accuracy and impartiality. The study procedure is shown as a flow chart in Fig. 1.

Descriptive statistics were used to calculate the patients' characteristics. The measurements were evaluated using one-way repeated-measures ANOVA with the exercise intensities of 60% HRR, and 85% HRR during CE and TM as the independent variables. Pair-wise comparisons between the intensities were performed using a contrast test. The measurement differences between patients without cardiac event during CE (CE-NE) and TM (TM-NE) and in patients with cardiac events during CE (CE-E) were analyzed using

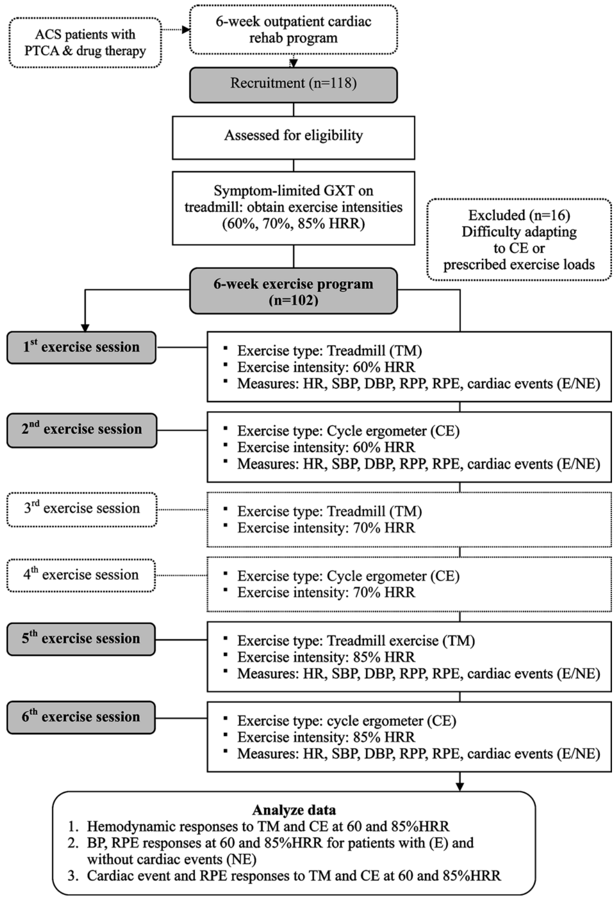

Fig. 1. Flow chart of the study procedure

one-way ANOVA. After determining the significance of the difference by ANOVA, a post-hoc multiple comparison was performed using the Scheffe test. Fisher's exact test was performed to assess the significance of differences between the proportions of the two exercise types. All data are presented as the mean±SD unless otherwise stated. All statistical analyses were performed using SPSS for windows, version 14 (SPSS Inc., Chicago, Illinois).

RESULTS

Medium and high exercise intensities of 60% and 85% HRR were calculated for the cardiac rehabilitation exercise based on the results obtained during GXT using Karvonen's formula. The calculated intensities were used for the types of exercises, TM and CE. The hemodynamic responses, RPE, and cardiac events were measured to determine the differences between the exercise types and to evaluate the significance of the differences in patients with ACS.

Table 2 shows the maximal hemodynamic responses of HR, SBP, DBP, as well as RPP and RPE at the 60% and 85% exercise intensities during TM and CE. The maximal SBP, DBP, and RPP values were divided by the maximal SBP, DBP, and RPP values obtained during treadmill GXT and multiplied by 100% to obtain percentages for comparison. HR at the exercise intensities of 60% and 85% were identi-

Table 2. Hemodynamic responses (n=102) to treadmill and cycle ergometer exercise at 60%HRR and 85%HRR

	60%HRR-TM	60%HRR-CE	85%HRR-TM	85%HRR-CE
HR (beats/min)	111.9±13.0	110.7±13.8	127.4±16.4*	128.2±14.4*
SBP_{max} (mm Hg)	135.2±18.8	155.8±22.6*	151.6±20.0*	177.1±23.6*
$\%SBP_{max}$	78.2±10.0%	89.9±11.3%	87.7±10.9%	102.2±12.0%
DBP_{max} (mm Hg)	77.1±8.9	83.7±11.5*	79.2±8.9	88.7±11.3*
$\%DBP_{max}$	101.7±16.3%	110.1±18.1%	104.4±15.8%	116.8±17.8%
RPP_{max}	15227±3187	17516±3641*	19574±4014*	22853±4782*
$\%RPP_{max}$	63.4±8.6%	73.0±9.5%	81.4±10.1%	95.0±11.1%
RPE_{max}	11.1±1.5	12.4±1.3*	13.0±1.2*	15.3±1.2*

HR: heart rate, SBP: systolic blood pressure (mmHg), DBP: diastolic blood pressure (mmHg), RPP: rate pressure product, RPE: Rate of perceived exertion. The values in parenthesis are ratios expressed in percent. These values were obtained by dividing the maximal SBP, DBP, and RPP values obtained at 60% HRR and 85% HRR during CE and TM by SBP_{max} (175±28 mmHg), DBP_{max} (77±13 mmHg), and RPP_{max} (24359±5771) obtained during treadmill GXT, respectively, and multiplying each result by 100%.
*=significantly different from the previous trial, $p < 0.001$

Table 3. Blood pressure and RPE responses of the patients with and without cardiac-events at the two different exercise intensities cycle ergometer and treadmill exercise

	60%HRR			85%HRR		
	TM-NE (N=101)	CE-NE (N=72)	CE-E (N=29)	TM (N=101)	CE-NE (N=72)	CE-E (N=29)
$\%SBP_{max}$	78.0±9.8	88.3±10.7†	93.4±11.5†	87.6±10.9	99.2±9.9§	110.4±13.7§*
$\%RPP_{max}$	63.3±8.4	71.4±8.8†	76.1±9.9†	81.4±10.1	92.1±9.1§	101.9±12.7§*
RPE_{max}	11.0±1.4	12.3±1.2†	12.7±1.6†	13.0±1.1	14.6±0.8§	16.9±0.5§*

TM-NE = Patients without cardiac event during treadmill exercise, CE-NE = Patients without cardiac event during cycle ergometer exercise, CE-E = Patients with cardiac events during cycle ergometer exercise. The TM-E group was omitted from the comparison since only one patient showed a cardiac event during treadmill exercise. SBP: systolic blood pressure, RPP: rate pressure product, RPE: rate of perceived exertion. $\%SBP_{max}$ and $\%RPP_{max}$ were calculated by dividing the maximal SBP and RPP obtained at 60%HRR and 85%HRR during CE and TM by SBP_{max} (175±28 mmHg) and RPP_{max} (24359±5771) obtained during treadmill GXT, respectively, and multiplying each result by 100%. † = significantly different from 60%HRR-TM, $p < 0.05$, § = significantly different from 85%HRR-TM, $p < 0.05$, * = significantly different from 85%HRR-CE-NE, $p < 0.05$.

cal (TM vs. CE = 111.9±13.0 bpm vs. 110.7±13.8 bpm at 60% HRR; TM vs. CE = 127.4±16.4 bpm vs. 128.2±14.4 bpm at 85% HRR.

For SBP expressed as a percentage of maximal SBP, $\%SBP_{max}$ (89.9±11.3%) of 60% HRR during CE was significantly higher than %SBPmax (78.2±10.0%) of 60% HRR during TM. %SBPmax (102.2±12.0%) of 85% HRR during CE was also significantly higher than %SBPmax (87.7±10.9%) of 85% HRR during TM ($p < 0.001$), and $\%SBP_{max}$ of 85% HRR during CE showed the highest value. A similar trend was identified for RPP. $\%RPP_{max}$ (73.0±9.5%) of 60% HRR during CE was significantly higher than %RPPmax (63.4±8.6%) of 60% HRR during TM, and %RPPmax (95.0±11.1%) of 85% HRR during CE was also significantly higher than %RPPmax (81.4±10.1%) of 85% HRR during TM ($p < 0.001$).

In addition, all measurements of DBP and RPE at the exercise intensities of 60% HRR and 85% HRR were significantly higher during CE than during TM ($p < 0.001$).

In order to confirm the increased risk of CE, the patients were continuously monitored and recorded for cardiac events during all the exercise sessions (Table 3). Of the 102 patients, 29 patients (28.4% of the patients; CE-E: patients with cardiac events during cycle ergometer exercise) showed cardiac events at 85% HRR during CE. $\%SBP_{max}$ and $\%RPP_{max}$ of 60% HRR and 85% HRR during TM for the 29 patients with cardiac events and the 72 patients without cardiac events were calculated for comparison (Table 3). Significantly higher maximal %SBP, %RPP, and RPE were shown at 60% HRR and 85% HRR during CE than during TM in the patients with (CE-E) compared to those without (CE-NE) cardiac events. $\%SBP_{max}$ and $\%RPP_{max}$ showed non-significant differences in both CE-E and CE-NE at 60% HRR during CE. However, the patients without cardiac event (CE-NE) at 85% HRR during CE had significantly higher $\%SBP_{max}$ and $\%RPP_{max}$ ($p<0.001$). Furthermore, $\%SBP_{max}$ and $\%RPP_{max}$ of CE-E were 110.4±13.7%, and 101.9±12.7%, respectively, exceeding the maximal SBP and RPP obtained in the treadmill GXT. Although RPE_{max} for CE-NE (14.6±0.8) was significantly greater than RPE_{max} of TM (13.0±1.1), RPE_{max} for CE-E was much greater (16.9±0.5) with a difficulty level of "very very difficult" ($p<0.001$).

Finally, Table 4 shows the number of patients who were

Table 4. Total cardiac events and RPE responses (n=102) at the different exercise intensities of the different exercise types

	60% HRR	60% HRR	85% HRR	85% HRR
	TM	CE	TM	CE
Cardiac Events				
Chest pain (2) + RPE (17)	0	0	1	1
Chest pain (2) + RPE (15)	0	0	0	3
Intermittent PVC + RPE (17)	0	0	0	1
Bigeminy PVC + RPE (17)	0	0	0	1
AF + RPE (17)	0	0	0	1
ST depression without chest pain	0	0	0	1
Total Cardiac Events	0	0	1	8*
RPE Response				
RPE 17	0	0	0	21*

Chest pain scale (2): mild chest pain. RPE: Rate of perceived exertion, PVC: premature ventricle contraction, AF: atrial fibrillation, ST segment depression: ≥1 mm (horizontal), * = significantly different, $p < 0.01$

interrupted during exercise due to the occurrence of cardiac events. One patient at 85% HRR during TM and one patient at 85% HRR during CE complained of RPE of 17 (very hard) with some chest pain. Three patients at 85% HRR during CE complained of RPE of 15 (hard) with some chest pain. At 85% HRR during CE, one patient complained of RPE of 17 with intermittent PVCs (premature ventricular contractions), one patient complained of RPE of 17 with bigeminy PVC, one patient complained of RPE of 17 with atrial fibrillation, and one patient showed ST segment depression (≥1 mm, horizontal). Chest pain or arrhythmia occurred between 8 to 12 minutes after the initiation of the first exercise session. Twenty-one patients complained of RPE of 17 without an event at the 85% HRR during CE. All the relative hemodynamic values of the two exercise types at 85%HRR showed significant differences ($p<0.01$). Cardiac events were not observed at 70% HRR during TM, but 4 patients terminated the exercise sessions during CE. These events occurring at 70% HRR are not included in Table 4.

DISCUSSION

The hemodynamic responses, RPE, and cardiac events during two common exercise types conducted at 60% and 85% HRR were assessed in patients with ACS. Patients with surgical interventions are more vulnerable to recurrence of heart conditions. Although early rehabilitation exercise is helpful for improving health status, the exercise mode should be carefully monitored. Exercise intensity is one of the most critical factors. Patient-specific exercise intensity has been traditionally obtained through a treadmill exercise graded test for both treadmill and cycle ergometer exercises.

RPP was significantly higher during CE than during TM at intensities of 60% HRR and 85% HRR due to higher blood pressure. RPP measured during 60% HRR-CE was close to 90% of the maximal RPP, and RPP during 85% HRR-CE exceeded the maximal RPP (102.2±12.0%). Various cardiac events were induced when RPP exceeded the maximal RPP during 85% HRR-CE. There have been many studies of the physiological characteristics of the exercise stress test done on a treadmill and cycle ergometer. The major differences in characteristics of CE, compared to TM, have been reported to be increased maximal heart rate and VO_2max[9–14]. Moreover, higher blood pressures were also induced during CE than during TM[6, 16]. Because of these physiological differences, application of exercise intensity based on the maximal heart rates obtained from either exercise type may expose cardiac patients to risk of various clinical problems.

In this study, both RPP and RPE were significantly higher during CE than during TM at 60%HRR and 85%HRR due to elevation of blood pressure. In addition, RPP during 60% HRR-CE was close to 90% of the maximal RPP, and RPP during 85%HRR-CE exceeded the maximal RPP. This significant increase in RPP was also caused by elevated blood pressure during CE. Although CE is mostly aerobic exercise, it is a combined form of exercise with some anaerobic factors in it[19].

The SBP of professional cyclists may increase to 200 mmHg during a maximal CE stress test[19], and their heart rates can be maintained close to the maximal HR for the duration of a race[24]. The average BP of endurance runners has been reported to be around 175/69 mmHg during exercise[25], while the average heart rate of resistance exercise athletes has been reported to be between 102 and 170 bpm, with maximal BP of 480/350 mmHg[26]. It was reported that the athletes specializing in cycling or rowing not only have bigger internal cardiac chambers, but have thicker myocardial walls due to the differences in hemodynamic responses compared to other athletes[19]. Moreover, endurance runners generally have larger internal cardiac diameters, and resistance exercise athletes have thicker cardiac chamber walls.

Generally, CE requires active performance in resistive pedaling with a greater range of motion and higher angle, while TM is performed under a condition which is relatively less active, and has a fixed grade and speed. For these reasons, increase in blood pressure during CE may be caused by greater resistance to blood flow in the exercising muscles[27], and larger tension within the lower limb muscles due to the increase in exercise intensity[28].

Reed reported that both the systolic and diastolic phases of females with sedentary lifestyles were higher during CE than during TM at exercise intensities of 40% HRR and 60% HRR[17]. These results indicate that RPP can be increase more during CE than during TM at identical exercise intensities.

RPP can be easily measured by multiplying the mean heart rate by the systolic blood pressure obtained during an exercise stress test[29, 30]. RPP is a reliable indicator of myocardial perfusion demand not only for patients with coronary arterial diseases, but also for healthy individuals[18]. Many patients with chronic stable angina tend to experience chest pain at a certain RPP[18, 31]. The changes in ischemic ST segments occur at a certain RPP as well[32].

Furthermore, an exercise which increases RPP in patients with aortic aneurysm may lead to aneurysm rupture[33]. The beta blockers used to decrease the ischemic threshold, or prevent arrhythmia or aortic aneurysm rupture are also used to reduce RPP[32, 33].

In this study, the 102 subjects who completed the cardiac rehabilitation exercise program on the cycle ergometer exceeded maximal RPP during 85% HRR-CE. In terms of cardiac events, CE induced 8 cases of cardiac events which included light chest pain (4 cases), arrhythmia (3 cases) compared to just one case of chest pain during TM. Twenty-one patients complained of strenuous exertion with PRE 17 or over during cycle ergometer exercise at 85%HRR (Table 4). All cardiac events occurred during increased RPP. A number of patients complained during performance of CE and terminated exercise (70% HRR exercise was excluded). Although cardiac events were not observed, 16 out of 118 patients who were excluded from the study groups complained of leg pain or interrupted exercise sessions due to excessive fatigue during CE[11, 15]. Therefore, additional recommendations for cardiac rehabilitation guidelines may be needed, explaining the differences in exercise intensity between TM and CE along with selective guidelines for patients with cardiovascular diseases, aneurysm, or exercise-induced high blood pressure.

This study had several limitations. First, it was difficult to reach target heart rates within the given time of 12 minutes by control of the exercise intensity. The pedaling speed as well as the power (watts) was adjusted for each patient in consideration of his/her physical condition. In addition, it was difficult to balance or adjust the angle of incline as well as the speed on the treadmill during TM. Differences in adjustments may have resulted in minor differences in exercise intensities among patients.

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