Cardiac Rehabilitation in Patients with Heart Failure

Tieh-Cheng Fu, 1,3,5 Shu-Chun Huang, 2 Chih-Chin Hsu, 1 Chao-Hung Wang 3 and Jong-Shyan Wang 4

Reduced exercise capacity negatively affects the ability of patients with heart failure (HF) to perform activities required for daily life, further decreasing their independence and quality of life (QoL). Cardiac rehabilitation (CR) can effectively improve aerobic fitness and overall health status in patients with HF. Low referral rate is an important limitation that may impede successful CR, whereas the automatic referral and liaison strategies performed by some healthcare providers manifestly increase the CR referral rate. However, there is still controversy regarding the most effective exercise strategy for improving hemodynamic efficiency during daily activities in the HF population. Aerobic interval training (AIT), that includes alternating high- and low-intensity exercise sessions, may be a more effective modality for improving functional capacity than traditional moderate continuous training (MCT) in patients with HF. A novel AIT regimen designed in our previous study may substantially enhance the ability of ventilation-perfusion matching during exercise, which effects are accompanied by an improved global and disease-specific QoL in HF patients. Conversely, the traditional MCT regimen may only maintain these physiologic responses to exercise at pre-interventional status. By elucidating the relationship between physical activity and hemodynamic property, this review attempts to provide a CR strategy for developing suitable exercise prescription that ameliorates hemodynamic disturbance, further retarding the disease progression and improving health-related QoL in patients with HF.

Key Words: Aerobic capacity • Heart failure • Hemodynamics • Rehabilitation

BENEFICIAL EFFECTS OF CARDIAC REHABILITATION (CR) IN HEART FAILURE (HF)

Cardiovascular disease is the second highest cause of mortality in the Taiwanese population, at approximately 11.1%. 1 As the end stage of cardiovascular disease nears, HF patients suffer a higher rate of morbidity and have a generally poor prognosis. 2 According to the report in 2009, the hospitalization cost of HF in the United States for those aged 65 years or older at $20.1 billion. 3 Hence, healthcare associated with HF subjects the medical system to a substantial burden.

CR is suitable for patients with acute myocardial infarction (AMI), post myocardial revascularization or cardiac transplantation, and also for those patients with stable chronic angina and chronic cardiac insufficiency. 4 By modifying health behavior, this medical strategy can effectively improve physical and psychological well-being, help patients recover productive participation and function in society, and further minimize disease progression in patients with cardiovascular disorders. 5 Additionally, CR also reduces the detrimental effects associated with cardiac events to prevent patients with HF from recurrent hospitalization, eventually reducing...
healthcare costs. As a multidisciplinary intervention, CR involves exercise therapeutics, medication, smoking cessation, nutritional counseling, and psychological aid. Moreover, the ability of CR to succeed in eventually controlling cardiovascular risk factors is mainly determined by the efficacy of physical exercise-based therapy. Compared to usual care without exercise, recent studies of meta-analyses demonstrated that CR with an emphasis on exercise therapeutics was associated with a decrease of 20%-30% in the mortality rate. Therefore, this review article focuses on current exercise strategies in HF healthcare according to the opinion of a physiatrist. Table 1 shows the overview of candidates and contraindication for cardiac rehabilitation.

**Table 1. Overview of cardiac rehabilitation**

<table>
<thead>
<tr>
<th>Candidate of cardiac rehabilitation</th>
<th>Effect of exercise training on cardiac risk factors</th>
<th>Contraindication of Cardiac Rehabilitation</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAD</td>
<td>Decrease in hemoglobin A1C of 0.8%</td>
<td>A recent significant change in the resting ECG suggesting significant ischemia, recent MI (within 2 days), or other acute cardiac event</td>
</tr>
<tr>
<td>MI</td>
<td>Increase in high-density lipoprotein of 2.5 mg/dL</td>
<td>Unstable angina</td>
</tr>
<tr>
<td>PTCA</td>
<td>Reduction in blood pressure of 3.4/2.4 mm Hg</td>
<td>Uncontrolled cardiac dysrhythmias causing symptoms or hemodynamic compromise</td>
</tr>
<tr>
<td>CABG</td>
<td>Higher levels of abstinence from smoking</td>
<td>Symptomatic severe aortic stenosis</td>
</tr>
<tr>
<td>HF</td>
<td>6.7-kg weight loss at 1 year</td>
<td>Uncontrolled symptomatic HF</td>
</tr>
<tr>
<td>Heart transplant</td>
<td>Decreases in depression, anxiety, hostility, somatization, and psychosocial stress</td>
<td>Acute pulmonary embolus or pulmonary infarction</td>
</tr>
<tr>
<td>Pacemaker, ICD, RCT</td>
<td></td>
<td>Acute myocarditis or pericarditis</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Suspected or known dissecting aneurysm</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Acute systemic infection, accompanied by fever, body aches, or swollen lymph glands</td>
</tr>
</tbody>
</table>

CABG, coronary artery bypass graft; CAD, coronary artery disease; DM, diabetes mellitus; HF, heart failure; ICD, implantable cardiac defibrillator; MI, myocardial infarction; PTCA, percutaneous coronary angioplasty; RCT, cardiac resynchronization therapy.
On the other hand, the studies of Gravely-Witte et al. 20 and Grace et al. 21 indicated that the automatic referral and liaison strategies performed by healthcare providers and early outpatient education increased the CR referral rate by over 80%. These aforementioned investigations support the proposition that physicians and other healthcare providers including case managers and physical therapists play important roles as modulators in early CR access and a successful CR referral system. In Taiwan, the Heart Failure Center (HFC), Keelung Chang Gung Memorial Hospital (CGMH) effectively applied the automatic referral system to recruit core team members when patients were admitted, and then started consequent education course and liaison work during hospitalization. Afterwards, these eligible patients would refer to the rehabilitation department. Thereafter, the CR referral mechanism was able to achieve up to and even > 90% efficacy rate.

EXERCISE TESTING FOR HF

The cardiopulmonary exercise test (CPET) is a useful tool to evaluate patient exercise capacity and exertional symptoms using objective measures. 22-24 This test can offer numerous physiologic parameters including ventilatory, hemodynamic, and metabolic responses to exercise, which may reflect on underlying mechanisms of exertional dyspnea, angina pectoris, and fatigue in patients with cardiovascular disorders (Table 2). 22,25 Even in patients with arrhythmia or users of β-adrenergic blocker, the CPET can also provide highly reproducible results of exercise performance and limitation. 26 Furthermore, the ventilatory parameters obtained from CPET may contain information about disease prognosis. Peak oxygen consumption (VO2peak) and oxygen uptake efficiency slope (OUES) are the surrogates of exercise capacity and efficiency, respectively. 27 The Ve-VCO2 slope is a powerful predictor of survival in cardiac patients; namely, a slope number over 34 may represent a worse prognosis. 27 Besides, periodic breathing, an abnormal pattern of respiration that consists of alternating hyperpnea and hypopnea, has been recognized during exercise in chronic HF patients. 28 Notably, these indices of ventilatory efficiency may be correlated with exercise-induced central and peripheral hemodynamic changes. 29

Recently, the HFC in Keelung CGMH first integrated a novel bioelectance-based measurement (noninvasive continuous cardiac output monitoring system, NICOM), near-infrared spectroscopy, and automatic gas analysis to identify the involvement of ventilatory and cardiac-cerebral-muscle hemodynamic responses to exercise in functional impairment in patients with HF (Figure 1). 29 The results of this study clearly demonstrated that the suppression of cerebral and muscle hemodynamics during exercise were associated with ventilatory abnormality, which reduced functional capacity in patients with HF. 29 A subsequent investigation further found that less than 4.5 L/min/m² of peak cardiac index was a signifi-

Table 2. Parameters in CPET and its clinical implication

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Change in HF</th>
<th>Cut-off value</th>
<th>Clinical implication</th>
</tr>
</thead>
<tbody>
<tr>
<td>VO2max</td>
<td>↓</td>
<td>14 cc/min/kg</td>
<td>Aerobic capacity</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Functional fitness</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Prognosis prediction</td>
</tr>
<tr>
<td>OUES</td>
<td>↓</td>
<td>(not yet)</td>
<td>Surrogate of VO2max in submaximal exercise test</td>
</tr>
<tr>
<td>Ve-VCO2 slope</td>
<td>↑</td>
<td>34</td>
<td>Exertional hyperventilation</td>
</tr>
<tr>
<td>VO2 at AT</td>
<td>↑</td>
<td>-</td>
<td>Aerobic capacity</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Functional fitness</td>
</tr>
<tr>
<td>CI</td>
<td>↓</td>
<td>4.5 L/min/m²</td>
<td>Predictor on composite events of rehospitalization and death in HF</td>
</tr>
<tr>
<td>EPB</td>
<td>prevalence↑</td>
<td>-</td>
<td>Survival prediction</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Sleep apnea correlation</td>
</tr>
</tbody>
</table>

AT, anaerobic threshold; CI, cardiac index (cardiac output/body surface area); EPB, exercise periodic breathing; OUES, oxygen uptake efficiency slope; VeVCO2 slope, minute ventilation versus carbon dioxide production slope; VO2, oxygen consumption; VO2max, maximal oxygen consumption.
EXERCISE PRESCRIPTION FOR HF

Exercise prescription aims to enhance physical fitness, promote health by reducing risk factors for cardiovascular disease, and ensure safety during exercise. The principal components of a systematic, individual exercise prescription comprise an appropriate type, intensity, duration, frequency, and progression of exercise.4

Type of exercise

Aerobic endurance training that comprises isotonic and rhythmic exercise using large muscles has been proposed to be part of an effective rehabilitation strategy for HF patients. This exercise regimen in outpatient cardiac patients is typically performed at moderate intensity for at least 30 min,33 and has been associated with an increased VO₂peak of 11-36%32

Aerobic interval training (AIT), that includes alternating high- and low-intensity exercise sessions, is a more effective modality for improving functional capacity than traditional endurance training in patients with HF.33-35 Use of an animal model of post-infarction HF has shown that AIT rescued impaired contractility, attenuated hypertrophy, and reduced expression of atrial natriuretic peptide in cardiac myocytes.36,37 The authors’ recent investigation also demonstrated that AIT was superior to moderate continuous training (MCT) for enhancing ventilatory and central/peripheral hemodynamic responses to exercise in patients with HF.38

In a recent development in HF rehabilitation, strength training has been recommended to counter cachexia-related disability.39 This training may increase muscle mass and strength, subsequently improving functional mobility in patients with HF. However, isometric or eccentric resistance exercise should be avoided (or performed with great care) because of the resultant increase in cardiac afterload.40

Evidence to date strongly suggests that poor inspiratory muscle performance is associated with dyspnea, exercise intolerance, and functional impairment in patients with HF.41 Inspiratory muscle training may be beneficial for increasing inspiratory muscular strength and endurance, alleviating dyspnea, and improving functional status in HF patients.42

Intensity, duration, and frequency of exercise

According to recommendations by the Center for Disease Control and Prevention and the American College of Sports Medicine (ACSM), exercise intensity is the primary factor when prescribing an exercise regimen to protect individuals against cardiovascular disease.4 The optimal exercise prescription for an individual is based on an objective evaluation of the individual’s response to exercise, including heart rate (HR), rating of perceived exertion (RPE), VO₂, and metabolic equivalents during a graded exercise test.4 Cardiac patients can use a HR/EKG monitor to obtain the assigned intensity of exercise. Additionally, the Borg 6-to-20 scale is used to assess the RPE during each exercise session. However, patients should be instructed to immediately stop exercise training if they have chest pain or other cardiac symptom/sign.

In general, the intensity of exercise has a diversity of setting ranged from 40% to 80% VO₂peak.4 In the HFC in Keelung CGMH, the HF patients performed two supervised hospital-based training programs on a bicycle ergometer (Figure 2), completing three weekly sessions for 12 weeks. The exercise protocol in traditional MCT comprised a warm-up at 30% of VO₂peak = 30% heart rate reserve (HRR); = 30%·(HRpeak-HRrest)+HRrest for 3 min, followed by continuous 60% of VO₂peak (≈ 60% HRR) for 30 min, then a cool-down at 30% of VO₂peak for...
3 min. From 2011 to date, a novel AIT regimen has been successfully applied to HF patients, which comprised a warm-up of 3 min at 30% of VO\textsubscript{peak} before exercise, and five 3-minute intervals at 80% of VO\textsubscript{peak} (\approx 80% HRR). Each interval was separated by 3-minute exercise at 40% of VO\textsubscript{peak} (\approx 40% HRR). The exercise session was terminated by a 3-minute cool-down period at 30% of VO\textsubscript{peak}. Although the two protocols were isocaloric at the same exercise duration, AIT rather than MCT effectively improved oxygen uptake efficiency by enhancing hemodynamics and suppressed oxidative stress/inflammation associated with cardiac dysfunction in patients with HF.\textsuperscript{38}

**HEALTH-RELATED QUALITY OF LIFE IMPROVED BY CR**

According to the authors’ investigations, both AIT and MCT decreased patient scores on the Minnesota Living with Heart Failure questionnaire, whereas only AIT significantly increased patient scores on the Short Form-36 Health Survey questionnaire of physical and mental dimensions.\textsuperscript{38,43} These findings imply that AIT rather than MCT simultaneously improves generic and disease-specific quality of life (QoL) in patients with HF. A possible explanation of the superior effects of AIT on these health-related QoL issues is that AIT effectively enhances aerobic capacity and efficiency and relieves exercise intolerance. This increases the ability of patients to cope with the physical demands of daily activity, and subsequently improves psychosocial status in HF patients. Furthermore, an improved health-related QoL could exhibit a reduced potential for mortality in HF patients,\textsuperscript{44} and simultaneously reduce the financial burden to the Taiwanese health care system.

CONCLUSIONS

HF is a major cardiovascular syndrome with an increasing incidence and prevalence, which may accelerate physical deconditioning and the consequent vicious cycle of numerous associated disorders.\textsuperscript{2} However, HF patients on optimal cardiovascular pharmacologic therapy frequently remain burdened by dyspnea and exercise intolerance.\textsuperscript{2} Successful CR is a valuable non-pharmacologic intervention for improving aerobic fitness and overall health status in patients with HF.\textsuperscript{46} The automatic referral and liaison strategies performed by healthcare providers and early outpatient education can significantly increase the referral rate of CR.\textsuperscript{20} However, controversy persists regarding the type and volume of CR that optimally promotes beneficial adaptations in ventilatory and hemodynamic functions. A novel AIT regimen noted in our previous study may effectively improve ventilatory and hemodynamic efficiencies during exercise, which effects are accompanied by improved global and disease-specific QoL in patients with HF.\textsuperscript{38} Conversely, the traditional MCT regimen may only maintain these physiologic responses to a level of exercise similar to pre-interventional status. These findings provide a new insight into the larger effect of AIT on ventilation-perfusion matching during exercise, and may have important implications for exercise training in HF rehabilitation.
ACKNOWLEDGMENTS

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