EXERCISE TRAINING MODES IN REHABILITATION OF PATIENTS WITH CHRONIC HEART FAILURE

Jannis V. Papathanasiou1, Elena M. Ilieva1, Fedya P. Nikolov2
1Department of Physical and Rehabilitation Medicine, 2Department of Cardiology, Medical University Plovdiv, Bulgaria

ABSTRACT
Modern cardiac rehabilitation (CR) in chronic heart failure (CHF) is a multidisciplinary process with the patient being the centre of the focus. Various CR models (inpatient, outpatient and home based) have been used the last two decades in the pursuit of higher effectiveness and better results.

The aim of this review is to present different exercise training modes applied in rehabilitating patients with CHF and to highlight their clinical value, advantages and disadvantages and practical implication.

Key words: cardiac rehabilitation, chronic heart failure, interval training

CHRONIC HEART FAILURE
Chronic heart failure is one of the leading causes for increasing morbidity and mortality worldwide as well as exercise intolerance1-3 and diminished health-related quality of life4. Approximately, five million Americans suffer every year from CHF and 500,000 new patients are registered annually.5

Chronic heart failure also results in a higher rate of hospitalizations and major public expenditures which seriously burden the health care systems.6 In times of global world economic crisis, health care insurance systems face the serious challenge of efficient allocation of available resources for the treatment of CHF and other cardiovascular diseases.7

Current pharmacological treatments as well as exercise training models seem to reduce mortality, morbidity, and the number of hospitalizations while improving the quality of life of heart patients.8

CARDIAC REHABILITATION
WHO experts have defined CR as a set of interventions that are needed to provide the optimal physical, psychic and social state for patients with subacute or chronic cardiovascular diseases in a way that they are able to recover by themselves and to keep a decent status in society and life as a whole.9,10 Modern CR starts from the first day after the occurrence of a cardiac event and continues until the full possible recovery of the patient as a worthy member of society.

WHO has subdivided cardiac rehabilitation in three major phases (Table 1).

Two key issues should be addressed before patients are included in a CR program: the optimal training intensity level of the CR program, and the most appropriate CR model for patients.11 According to Wisloff et al., high-intensity aerobic interval training, achieving 95% of maximal heart rate (HRmax) significantly improves aerobic capacity, left ventricular remodelling and the quality of life in comparison with the moderately intensive continuous training models which achieve as high as 70% of HRmax.12 Rognmo et al. have demonstrated that high intensity aerobic interval exercise is superior to moderate exercise for increasing VO2peak in stable coronary artery disease (CAD) patients.13 The goal of all cardiac rehabilitation models remains the same - full recovery and re-socialization of the patient as a complete person in society and improved quality of life

Table 1. Duration of cardiac rehabilitation phases

<table>
<thead>
<tr>
<th>CR Phases</th>
<th>Duration</th>
</tr>
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<tbody>
<tr>
<td>Acute phase</td>
<td>7 days</td>
</tr>
<tr>
<td>Recovery phase</td>
<td>4-8 weeks</td>
</tr>
<tr>
<td>Maintenance phase</td>
<td>3 months</td>
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In the acute phase a multidisciplinary approach with the participation of different specialists is necessary; cardiologists, physical and rehabilitation medicine (PRM) specialists, physical therapists, psychologists, nurses, etc.

The second phase of cardiac rehabilitation is the most important for the physical and rehabilitation medicine specialist, as it is part of the multidisciplinary strategy requiring exercise training education and counselling of patients with cardiovascular diseases.

The maintenance phase (third phase) is an adjuvant therapy held primarily in specialized cardiac rehabilitation centers and sports dispensaries. It focuses on cardiac rehabilitation, exercise training and change of risk factors - smoking, inactive way of life and control of hypertension and hyperlipidemia.

Integration of patient family members in the recovery phase is a leading guideline for modern programs. Therefore, cardiac rehabilitation confirms its multidisciplinary character by integrating the Health promotion tools of Public Health.

The following issues are required in order to achieve and maintain the actual objectives and strategies of CR:

Elaboration of new training models optimally tailored to the achievements of exercise physiology, cardiology and physical rehabilitation medicine;

Application of various exercise training modes; individual and group-based, moderate and high intensive.

Providing maximum safety for patients during cardiac rehabilitation sessions.

**FUNCTIONAL CAPACITY EVALUATION/CARDIOPULMONARY EXERCISE TESTS (CPET)**

Different kinds of exercise training protocols are used; they vary for individual patients.

The Bruce protocol is one of the most common and most applicable cardiopulmonary exercise test. The beginning of this protocol is more progressive while providing the folding of hemodynamic and respiratory response to fatigue. The advantage of the Bruce protocol as mentioned in many published studies is the value of 3-minute stages to acquire submaximal data. Its disadvantages are large interstage increments in work that can make estimation of VO₂max less accurate and a fourth stage that can be either run or walked, resulting in different oxygen costs. There are other protocols (Naughton’s and Balke protocols), and there is also the modified Bruce protocol in which one more stage is added.

It is estimated that the cardiopulmonary exercise test (CPET) protocols such as Bruce protocol make it possible to achieve high levels of VO₂/kg (range 45.9 - 61.3 mL·min⁻¹·kg⁻¹) which hardly ever occurs in patients with CHF. Frequently, Naughton’s protocol is used, consisting of 2-minute MET steps, which are achieved by simultaneously increasing the speed and inclination of the treadmill.

The optimal duration of the CPET is considered to be 8-12 minutes, while in the protocols of Naughton and Balke it usually extends to 15 minutes. Ramp protocols start at low treadmill speed, which is gradually increased until the patient has a good stride. The ramp angle of inclination is progressively increased at fixed intervals (i.e., 10 to 60 seconds) starting at 0 grade, with the increase in grade calculated on the patient’s estimated functional capacity. In this type of protocol, the rate of work increases continuously, and steady states are not reached. A limitation of ramp protocols is the requirement to estimate functional capacity from an activity scale and adjust the ramp accordingly. This type of protocol is completed in 6 to 12 minutes. Bader et al. found no differences between peak VO₂, heart rate, rate pressure product and anaerobic threshold for the ramp and step protocols, respectively. Peak cardiopulmonary responses in the elderly are similar during individualized ramp and step protocols when appropriately selected based on a pretest activity questionnaire. Both protocols appear to provide clinically reasonable estimates of VO₂ when gas exchange analysis is not used.

**SIX MINUTE WALK TEST**

The six minute walk test (6MWT) is described by Guyatt et al. as an effective tool for assessing the functional capacity in patients with cardiovascular and pulmonary diseases.

Six minute walk test (6MWT) is a validated, inexpensive, non-invasive cardiopulmonary test for functional assessment, used in patients with cardiovascular and pulmonary diseases. In addition to being the functional capacity equivalent, it is also a powerful prognostic marker for the severity of cardiac and pulmonary diseases.

It is well tolerated by patients because it mimics daily submaximal energy consumption required for activities of daily living (ADL). Primarily, during the 6MWT, the distance is measured in meters. Furthermore, additional information is obtained on the response of hemodynamic parameters: blood pressure, heart rate and also on the self-esteem of
patients for the effort and the dyspnea during the test using the Borg scale.\textsuperscript{33} The increase in blood pressure, heart rate and plasma catecholamines during the 6MWT is mild, making it suitable for patients with significantly reduced functional capacity. The minimal clinically significant difference, according to the guidelines of the American Thoracic Society (ATS), reported in patients with CHF through the 6MWT, is 43 m.\textsuperscript{34}

**OXYGEN CONSUMPTION VO\textsubscript{2}**

\(\text{VO}_{2\text{max}}\) has been defined by Hill in 1925\textsuperscript{23,24} as the main criterion for cardiopulmonary capacity and is regarded as one of the “golden standards” for risk stratification in CHF. Its prognostic value is characterized by short-term reproducibility even in severe forms of heart disease and decompensation.\textsuperscript{35}

Weber was the first to use \(\text{VO}_{2\text{max}}\) to determine functional capacity in patients with CHF; he categorizes it into five classes, from A to E, considering that \(\text{VO}_{2\text{max}}\) and anaerobic threshold (AT) provide the best measurement of the degree of impairment of cardiovascular function.\textsuperscript{36}

Fifty percent of the patients with CHF do not reach a plateau but it does not necessarily mean that they do not reach their proper \(\text{VO}_{2\text{max}}\) - in this case, the latter is called peak oxygen consumption \(\text{VO}_{2\text{peak}}\).

**CELL ADHESION MOLECULES (CAMs) AND CYTOKINES**

There is no consensus in literature as to the influence of different exercise training programs on serum levels of cell adhesion molecules (intracellular CAM and vascular CAM) in heart patients. Usually, serum levels of iCAM and vCAM in CHF patients are elevated.\textsuperscript{37}

Unlike the \textit{C-reactive protein}, iCAM and vCAM have specific biological functions and play a crucial role in early immune response. There has been an increased interest in the last decade in researching the soluble CAMs in participants of CR programs. Adamopoulos et al. have reported a significant reduction of iCAM and vCAM in the participants of a 12 week high intensive cardiac rehabilitation program.\textsuperscript{38,39}

It has been proven that interval training results in reduction of the elevated plasma levels of cardiac markers - brain uretic peptide\textsuperscript{40} and peripheral markers of inflammation.\textsuperscript{41}

There is also a significant reduction of local expression of the cytokine tumor necrosis factor alpha (TNF \(\alpha\)), IL\(\beta\), IL6 and the induced production of nitric oxide in the muscles of CHF patients.\textsuperscript{39}

The methods evaluating the effects of different CR interventions are objective by measuring \(\text{VO}_{2}\), HR, RER, LVEF, and through study of cytokines and soluble adhesion molecules iCAM & vCAM.\textsuperscript{37,38,41}

Also the effects of CR interventions can be optimal assessed by health related questioners Minnesota Living with Hearth Failure MLHFQ\textsuperscript{42} and McNew questionnaire\textsuperscript{43}.

**INTERVAL TRAINING**

There has been extensive research into the benefits of exercise training in patients with cardiovascular disease, particularly after acute cardiac events. Physical and functional outcome measures have been well defined and it is clear that exercise training produces definite physical, quality of life and secondary prevention benefits.\textsuperscript{18,44} Available evidence confirms that exercise training brings definite improvements in physical performance (exercise tolerance, muscle strength and symptoms, increase the production of nitric oxide (NO), psychological functioning (anxiety, depression, well-being), and social adaptation and functioning.\textsuperscript{15}

Interval training is defined as the application of repeated high-intensity work stimuli in combination with different time varying breaks.\textsuperscript{45} In interval models, CHF patients relatively quickly reach the anaerobic threshold. This makes it possible to perform short bursts of high intensity intervals that would be impossible for continuous training models.

Low training capacity of CHF patients allows the implementation of interval training models with different combinations of training and cool down intervals. Through interval training models, patients achieve a significantly higher training capacity in comparison to those reached in continuous models.\textsuperscript{12,13}

For CHF patients, the application of three different types of exercises (aerobic, endurance and breathing exercises) is evaluated (Fig. 1).\textsuperscript{15,46}

\textbf{Figure 1.} Aerobic training modalities.
GROUP BASED MODELS

There are now available detailed descriptions of group-based aerobic interval training models relating to CHF patients, such as those described by Nilsson et al. The major advantage of group-based CR models is that they enable the PRM specialists to offer treatment to a group of patients that can have the same clinical outcomes achieved through individual therapy.45

Group based models eliminate the phenomena of anxiety, depression and social isolation, which are characteristic of these patients.47 The long term effects of group based CR models are presented in Table 2.

Table 2. Long-term effects of group based CR models are achieved through

| • increase of the training capacity of the patients |
| • maximal limitation of disability after acute cardiac event |
| • integration of the patient into society by providing greater PATIENT independence |
| • improvement of the quality of life44 |

ULLEVAAAL CARDIAC REHABILITATION MODEL

The Ullevaal CR model is based on the exercise training principles created by the Swedish athlete Johan Holmsater.48,49 This model matches closely modern exercise training trends and guidelines, and integrates high efficiency, low cost and group approach with individual character. The Ullevaal CR model is designed to improve physical capacity, body awareness, and emotional well-being; to promote a return to work and ADL, and to improve prognosis.

In essence, this model is group-based interval aerobic training tailored for patients with CHF based on ischemic heart disease.

The Norwegian Ullevaal model45,47 consisted of a high-intensity 16-week aerobic interval training (2-days/week), with each session lasting 50 minutes (including warm-up and cool-down), followed by a 15 to 30 minutes counselling regarding how to cope with CHF under supervision of a physical therapist. Exercise training consisted of group-based simple aerobic dance movements (with music) and involved the use of both upper and lower extremities, including endurance, strength, and stretching exercises. The accompanying musical pieces are melodic and varied. They are specifically selected and tailored to the ability and music preferences of the groups.

The various intervals are optimally arranged with a smooth increase and decrease in physical exertion. High-intensity intervals include strength training exercises, exercises which increase the extent of movements of large joints, and exercises for flexibility and coordination. The intensity of workload and the ways of involvement of oxygen-transport systems are under double control by:

• The design of the exercises in the intervals and between them;
• The pace of the music.

The design of this CR model is based on the physiological principle of the gradual yet dynamic amplification and decelerating drive of Wasserman’s cogwheels 50, binding oxygen transport with muscle oxygen uptake during exercise.

The Norwegian Ullevaal model starts off with simple aerobic dance movements involving upper and lower limbs to achieve postural control and consecutively power and relaxation exercises are included.45

Workload and fatigue assessment is constantly monitored using the Borg scale30, a self-assessment scale of the physical effort made by a patients for a specific workload; it is more useful when reporting the intensity of the isolated monitoring of heart rate only.

In turn, the perception of effort is determined mainly by the functional capacity refracted through the psychological condition of the patient. The scale is in the range of 15-18 points for 90-95% of maximum heart rate during high-intensity intervals and respectively 11-13 points (50-60%) of maximum heart rate during moderate-intensity exercise. Unlike other previously described group-based models, the Norwegian Ullevaal Model allows repetitions of the exercises depending on the skills and the progress of the patients.

The Ullevaal cardiac rehabilitation model is approved and applied for outpatients with CHF and stage II - III NYHA class in the Sports Dispensary in Plovdiv, Bulgaria.51

The selection of patients that meet the strict inclusion criteria (Table 3) is of utmost importance.

Functional capacity (using the 6MWT), HRmax, VO2peak/max, VO2ATF are measured for all enrolled patients before and during the Ullevaal CR model. These parameters provide a clear picture of the patient’s functional status and the effects of the different CR interventions.

Different exercise training modes applied in patients with CHF, their clinical values, the benefits and disadvantages have been presented in this
review. A novel highly effective Norwegian group-based CR model which is applied for the first time in Bulgaria, particularly in the Sports Dispensary in Plovdiv has been highlighted in detail. This CR model is very promising and offers a number of advantages. It significantly improves functional capacity and quality of life of CHF patients.

CONCLUSIONS

This review presents in detail current CR training models applied to patients with CHF. Interval training has a substantial share in modern CR as it is more friendly to the cardiovascular system, providing adequate work stimulus through which patients reach higher levels of training.

The benefits of group-based models such as the described model Ullevaal are numerous. In addition to using the latest to develop collective relationships among the trained persons, the occurrence of depression and social isolation, characteristic of this group of patients, are removed and they are more economically efficient.

REFERENCES

10. Wenger NK, Gilbert CA. Rehabilitation of the
Exercise Training Modes in Rehabilitation of Patients with Chronic Heart Failure


51. Papathanasiou J. Research the effects of group-based high intensive interval training versus moderate continuous training in patients with CHF. [Dissertation]. Medical University of Plovdiv; 2012 (Bulgarian).

ТРЕНИРОВОЧНЫЕ МОДЕЛИ У ПАЦИЕНТОВ С ХРОНИЧЕСКОЙ СЕРДЕЧНОЙ НЕДОСТАТОЧНОСТЬЮ

Я. Папатанасиу, Е. Илиева, Ф. Николов

РЕЗЮМЕ

Современная кардиореабилитация при хронической сердечной недостаточности (XCH) представляет собой мультидисциплинарный процесс, при чем пациент занимает центральное место. В последние 20 лет применяемые различные кардиореабилитационные методы (внутрибольничные, амбулаторные, как и таковы, проведенные в домашних условиях) убедительно показывают высокую эффективность и лучшие результаты. Настоящая работа ставит себе целью представить различные тренировочные модели, применяемые на пациентах с XCH, как и подчеркнуть их клиническую стоимость, преимущества, недостатки и практические применения.