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Exercise and Chronic Heart Failure: A review on Exercise Recommendation, Mechanism of Action, Exercise-Related Risk and Innovative Exercise Approach

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Abstract

Heart failure (HF) is a complex clinical syndrome that can occur due to various structural or functional cardiac disorders, leading to impaired ventricular function in terms of blood filling or ejection. It represents the advanced stage of cardiovascular diseases. HF is associated with a decrease in the proliferation rate of cardiac muscles and the occurrence of cardio-myocyte apoptosis (cell death). This progressive pathological process of cardio-myocyte apoptosis is linked to age-related reduction in cardiomyocyte renewal, resulting in the accumulation of intracellular waste products. Consequently, this further contributes to cardiomyocyte apoptosis, leading to increased metabolic demand and subsequent cardiac dysfunction. Unfortunately, this condition is irreversible, and there is currently no known medical intervention that can cure HF. However, individuals with chronic heart failure have several strategies and options available to them to actively manage their condition. Engaging in physical activity is considered one of the most effective non-pharmacological approaches. Thus, this review presents an extensive and thorough examination of the exercise guidelines recommended for individuals with chronic heart failure. It provides a comprehensive analysis of the effects of exercise on heart functions, offering detailed explanations of the underlying mechanisms. Furthermore, the review briefly discusses the potential risks associated with exercise in individuals with heart failure and explores innovative exercise approaches that could be advantageous for this specific population.

Keywords: Chronic Heart Failure, Exercise, Physical Activity, Exercise-Related Risk, Innovative Exercise Approach.

Introduction

Heart failure has emerged as a global epidemic over the past few decades (Lesyuk et al., 2018). This epidemic has seen an increase in both morbidity and mortality rates among older men and women worldwide (Sakata & Shimokawa, 2013). In the United States alone, there were approximately 6.2 million newly diagnosed cases of heart failure reported between 2013 and 2016. Additionally, in 2018, there were 3,994 Americans waiting for heart transplants, with about 55 of them awaiting both heart and lung transplants (Benjamin et al., 2019).

In Malaysia, heart failure accounts for 6 to 10% of total acute medical admissions to hospitals and incurs around 1.8% of total healthcare expenses (Ministry of Health (MOH) Malaysia, 2019). Given Malaysia's diverse population, the epidemiology of heart failure varies among different genders and ethnicities, taking into account important factors such as risk factors, lifestyle, physical activity levels, and environmental influences. The Indian ethnicity, in particular, has the highest prevalence of cardiovascular diseases and faces a higher risk of developing hypertension, diabetes, and ischemic heart disease (Butler et al., 2013).

Heart failure (HF) can be classified into two main types: systolic HF and diastolic HF, as well as left-sided or right-sided HF (MOH, 2019). These categories of HF are interconnected, meaning that left-sided HF can progress to right-sided HF, and vice versa (Wright & Thomas, 2018). HF is often considered a chronic condition but can also be characterized by worsening chronic heart failure, new onset heart failure, and advanced heart failure (Roger, 2013). In this review, the focus will primarily be on diastolic heart failure rather than systolic heart failure. The severity of HF is typically classified based on the patient's functional abilities, following the New York Heart Association (NYHA) classification system, as shown in Table 1.0 below.

Table 1.0
Heart Failure Classification by New York Heart Association

Stage	Interpretation
Class Ⅰ (Mild)	No limit on physical activities. Common physical activity does not cause undue shortness of breath, palpitations, chest pain or fatigue.
Class Ⅱ (Mild)	Minor limitation on physical activity. Feel comfortable during rest, but common physical activity results in undue shortness of breath, palpitations, chest pain or fatigue.
Class Ⅲ (Moderate)	Marked limitation of physical activity. Comfortable at rest, but less than ordinary physical activity results in undue breathlessness, palpitations, chest pain or fatigue.
Class Ⅳ (Severe)	Patient unable to carry out any physical activity deprived of discomfort. Symptoms at rest can be present. If any physical activity is undertaken, discomfort is increased.

The treatment of heart failure (HF) can be physically demanding and exhausting. It is common for HF patients to experience mental distress, including depression, anxiety, hostility, phobia, paranoid ideation, somatisation, and obsession-compulsion. Compared to other cardiovascular diseases and chronic illnesses, the quality of life (QoL) for HF patients is significantly lower. QoL tends to decrease as the severity of heart failure increases. HF patients often present with persistent coughing or wheezing, shortness of breath, swelling in the limbs (edema), and fatigue. In some cases, patients may exhibit pulmonary crackles during auscultation, elevated jugular venous pressure, and increased heart rates (Wright & Thomas, 2018; Moradi et al., 2020; Thomson et al., 2020).

Furthermore, HF patients typically have limited functional capacities and exercise tolerance. This is concerning as low mobility is associated with poor health-related quality of life (HRQoL), which can further worsen their prognosis (Taylor et al., 2019). In addition to medical management, exercise-based cardiac rehabilitation and exercise training are considered the best approaches to improve HRQoL in HF patients. Numerous research studies have demonstrated that exercise can enhance functional and exercise capacity, improve blood flow, reduce symptoms, enhance metabolism, alleviate fatigue, and promote psychosocial well-being in HF patients (Taylor et al., 2019; Autunes-Correa et al., 2020; Shuvalova et al., 2020).

Discussion

Exercise Recommendations for Heart Failure

After heart failure (HF), functional working capacities decline, and patients with chronic heart failure often rely on caregivers due to poor self-care (Thomson et al., 2020). The accumulation of coronary artery pathology, which contributes to HF, leads to reduced cardiac output (CO), stroke volume (SV) and arterial and mixed venous blood differences. Peak oxygen consumption (VO_{2peak}) and functional capacities are dependent on CO, SV, and arterial and mixed venous blood differences. As blood flow and oxygen supply decrease, HF patients also experience skeletal muscle disturbances, resulting in sarcopenia, skeletal myopathy, reduced muscle contraction force and exercise intolerance (Wright & Thomas, 2018; Antunes-Correa et al., 2020; Curcio et al., 2020).

Research indicates that exercise training does not reverse cardiac remodeling but does improve arterial function and aerobic exercise capacities (Carvalho et al., 2009). Antunes-Correa et al (2020) compared the effectiveness of aerobic exercises and inspiratory muscle training in improving quality of life (QoL). They found that aerobic exercise directly enhances skeletal muscle strength, VO_{2peak} and functional capacity, while inspiratory muscle training improves peripheral vascular function and strengthens inspiratory muscles. Improved blood circulation by skeletal muscles leads to enhanced vascular endothelial function and sympathetic nervous system function. However, inspiratory muscle training specifically targets strengthening the diaphragm muscles. Both exercises focus on muscle improvement, but aerobic exercise training provides more benefits for HF patients, although the benefits of inspiratory muscle training should not be overlooked (Antunes-Correa et al., 2020).

According to American College of Sport Medicine (ACSM) (2018), it is recommended for HF patient to perform aerobic, resistance and stretching exercise. The details of the exercise are as of table 2.0 below.

Table 2.0
Exercise recommendation for heart failure patient

	Aerobic	Resistance	Flexibility
Frequency	Should be performed 3 to 5 days per week	Should be performed 1 to 2 nonconsecutive day per week	Should be performed 2 to 3 days per weeks with daily being more effective. It is preferably performed after warm-up or during cool down period
Intensity	If the HR data are available from graded exercise testing, intensity is set between 60-80% of heart rate reserve (HRR). If not, use Rating Perceive Exertion (RPE) scale of 11-14.	Begin at 40% of 1 Repetition Maximum (RM) for upper body and 50% of lower body. Increase gradually to 70% of 1RM over several weeks to months.	Stretch to the point of feeling tightness or slight discomfort.
Time	Progressively increase to 30 minutes per day and then up to 60 minutes per day.	2 sets of 10-15 repetitions focusing on major muscle groups.	10 to 30 seconds hold for static stretching with 2 to 4 repetitions of each exercise
Type	Treadmill or free-walking and stationary bicycle.	Machine weights should be best tolerable to HF patients.	Static, dynamic and/or Proprioceptive Neuromuscular Facilitation stretching.

Another study by Shuvalova et al (2020) suggests that low to moderate intensity aerobic exercise and resistance exercise yield significant results in improving aerobic capacity, muscle strength and QoL. The study subjects showed improvements over 12 weeks, with 60-minute sessions conducted three times per week. The training regimen included a combination of aerobic and resistance exercises into third week of training with 30-60% of one repetition maximum and gradually increasing the intensity by 10% each week. Each exercise should be performed five times for three sets (Shuvalova et al., 2020).

Furthermore, Smart et al (2012) conducted an interesting study suggesting that high-intensity or resistance activities can be prescribed for tolerable HF patients. Since many HF patients are obese, high-intensity training promotes greater energy expenditure and aids in weight loss, reducing the risk of complications. High-intensity interval training (HIIT) has been shown to be more effective than moderate continuous training for HF patients. Continuous exercise can produce oxidative stress, while HIIT combines aerobic exercise training with high-intensity intervals to improve cardiovascular fitness (Smart et al., 2011). In a pilot study by Hornikx et al (2020), patients who underwent resistance training supplemented with HIIT saw improvements in their VO_{2peak} by 25% to 29%.

Aerobic exercise training is considered the first-line treatment strategy for reducing cardiovascular symptoms, improving QoL and managing HF severity (Rebelo et al., 2012). However, the exercise regimen should be carefully modified to provide the maximum benefits to HF patients. HIIT can be implemented for stable HF patients who can tolerate it. The optimal intensity range for HF exercise training is typically 40% to 75% of VO_{2peak}, 70% to 80% of peak capacity, 50% to 85% of maximum heart rate (HRmax), 60% of HRR, or a rating of perceived exertion of 12 to 14. Using heart rate to calculate exercise intensity may not be reliable for HF patients taking beta-blockers, so the VO_2 method should be considered (Dun et al., 2019).

On the other hand, resistance training is crucial for enhancing muscular strength. It brings about beneficial adaptations in the musculoskeletal system, reduces circulatory pro-inflammatory markers, decreases dyspnea, enhances oxidative capacity and promotes capillarization in the muscles (Sadek et al., 2019). Moderate resistance training has been reported to improve endothelial vascular function (Selig et al., 2004). Palevo et al (2009) found that isotonic strength training improves left ventricular function, muscle strength, and functional capacity in patients with HF class II and III. They recommended a protocol of three sessions per week for eight weeks, using 60% of the one-repetition maximum (1 RM) and incorporating 12 exercises with free weights.

Mechanism of exercise in improving heart failure

The root cause of various cardiovascular diseases lies in oxidative stress. However, regular exercise can significantly improve the body's redox state by enhancing its antioxidant capacity, a vital mechanism that boosts cardiovascular health. Physical activity leads to increased generation of reactive oxygen species (ROS) during muscle contraction, mainly through the mitochondrial electron transfer pathway (Powers et al., 2020). Although ROS can be harmful by causing cellular oxidative stress and damaging biological molecules, their controlled production during exercise serves a physiological purpose. It stimulates mitochondrial synthesis, activates insulin signaling, promotes muscle development and protein synthesis, regulates gene expression, and strengthens the body's antioxidant defense. Long-term exercise has positive effects on mitochondrial function, antioxidant capacity, and oxidative balance, thus benefiting overall cardiovascular health (Taherkhani et al., 2020).

Chronic diseases, especially metabolic cardiovascular disorders, often trigger low-grade chronic inflammation, a driving factor for non-communicable diseases and accelerated aging. Yet, engaging in regular aerobic exercise effectively combats chronic inflammation and disrupts this harmful cycle. Studies indicate that aerobic exercise can reduce high-sensitivity C-reactive protein which is an inflammatory marker, by 40% in patients with coronary heart disease (Milani et al., 2004). Furthermore, exercise enhances interleukin-6 (IL-6) synthesis in skeletal muscle, while reducing the production of proinflammatory molecules such as tumor necrosis factor-α (TNF-α) and interleukin-1 (IL-1), resulting in an overall anti-inflammatory effect (Wang et al., 2022). Additionally, exercise influences fat metabolism, reduces visceral fat, and activates the hypothalamic-pituitary-adrenal axis and sympathetic nervous system, leading to the production of anti-inflammatory cytokines like cortisol (Marthur & Pedersen, 2008). Long-term exercise has systemic impacts on the body's redox balance and inflammatory state, contributing significantly to improved cardiovascular health.

Moreover, even moderate exercise has the potential to mitigate pathological ventricular hypertrophy, which is commonly associated with heart failure, leading to enhanced cardiac shape and function in such conditions. Exercise-induced vascular remodeling encompasses an increase in arterial vessel diameter and arterial wall thickness, including coronary arteries (Thijssen et al., 2012). Correspondingly, exercise elevates the collagen and elastin content within atherosclerotic plaques, resulting in reduced adverse outcomes related to atherosclerosis (Shimada et al., 2011). This favorable impact is believed to be one of the mechanisms through which physical activity safeguards vital organ function and retards the aging process (Seals et al., 2008).

Additionally, exercise exerts notable effects on blood vessels, promoting the development of new blood vessels. Capillary formation and angiogenesis are enhanced by exercise, while arterial lumen widening, termed arteriogenesis, occurs in existing blood vessels, including coronary arteries, showcasing the remarkable adaptability of the vascular system. A significant regulator of angiogenesis, vascular endothelial growth factor (VEGF), experiences increased expression in skeletal and cardiac muscle in response to exercise (Schuttler et al., 2019). These vascular adaptations contribute to the overall cardiovascular benefits of exercise and underscore its role in promoting vascular health (Wang et al., 2022).

Limitations and exercise-related risk for chronic heart failure patients

While exercise regimens can be beneficial for chronic HF patients, it is important to consider contraindications and risks associated with exercise. HF can be characterized as chronic, worsening chronic heart failure, new onset heart failure, or advanced heart failure (Roger, 2013; Selig et al., 2004).

Firstly, medical clearance should be obtained before HF patients engage in any exercise program. This helps identify underlying medical conditions such as hypertension, ischemia, chronic obstructive pulmonary disease (COPD), renal dysfunction, arrhythmias, iron deficiency, diabetes mellitus, or valvular lesions that may be exacerbated during exercise (Palevo et al., 2009; Lewis et al., 2017). Low levels of iron can contribute to exercise intolerance and breathlessness (Okonko et al., 2011). Early mobilization should start gradually without weights or equipment until the patient feels better and achieves a VO_2 peak increase of more than 18ml/kg/min or walks more than 450 meters in the 6-minute walking test (Chung & Schulze, 2011).

Exercise should be avoided in HF patients who have experienced a myocardial infarction within the past four months, have moderate to severe aortic stenosis, unstable angina, uncontrolled hypertension, or uncontrolled ventricular or atrial dysrhythmias (Evans, 2011). Exercise professionals should be vigilant and discontinue exercise immediately if the HF patient presents with diastolic blood pressure above 110 mmHg, a decline in systolic blood pressure exceeding 10 mmHg, second or third-degree heart atrioventricular block, significant ventricular or atrial dysrhythmias, exercise intolerance, dyspnea, chest pain, or abnormal signs on the electrocardiogram (ECG) such as ischemia (Evans, 2011). Healthcare professionals should also be trained in advanced life support in exercise settings, with defibrillation equipment readily available. Maximal exercise testing, such as the incremental shuttle walk test (ISWT) with telemetry, is recommended before initiating exercise treatment to establish baseline measurements for patients (Evans, 2011). High-intensity training is not suitable for home-based maintenance programs to ensure safety and compliance considerations (Selig et al., 2004). HF patients should avoid the Valsalva maneuver, especially during resistance training, to prevent rises in blood pressure (Palevo et al., 2009).

Additionally, a study by Balmain et al (2018) demonstrated that HF patients have impaired heat regulation due to hyper-reactivity of the sympathetic nervous and humoral systems. They found that chronic HF patients exhibit poor cutaneous vasodilatory response (skin blood flow) and reduced thermosensitivity during exercise, likely due to endothelial dysfunction and decreased reaction to nitric oxide. This results in uneven heat distribution in the body, with higher core temperature compared to peripheral temperature. Sweat gland function may be preserved in HF, but the disruption of thermoregulation in HF is not solely caused by hyper-reactivity of the sympathetic nervous system, as the use of beta blockers has also been found to reduce skin blood flow. In summary, it is advisable for HF patients to exercise in climate-controlled indoor facilities. Mild HF patients in NYHA class Ⅰ and Ⅱ may have more flexibility to exercise outdoors in hot ambient conditions or engage in high-intensity workouts (Balmain et al., 2018).

Innovative exercise approaches for chronic heart failure populations

Yoga has been identified as a potential option for chronic heart failure patients. Studies by Pullen et al (2010) have shown that yoga promotes relaxation, improves psychological status, and reduces blood pressure. By inducing relaxation, yoga effectively reduces the activity of the sympathetic nervous system and inflammatory markers. HF patients who engage in yoga twice weekly have shown improvements in peak VO2, exercise capacity, and flexibility. Yoga has been found to address dyspnea by enhancing aerobic capacity and stimulating oxygen extraction, which can alleviate inspiratory muscle weakness and improve arterial oxygen levels (Pullen et al., 2010).

Another beneficial exercise option for HF patients is Tai Chi. Although Tai Chi is a low-intensity activity, it offers similar benefits to low-intensity aerobic exercise, such as improving neuromuscular function, aerobic capacity, depression scores, coordination, fine motor movements, limb muscle strength (especially in the legs and hand grip), and circulation. Compared to aerobic exercise, Tai Chi poses fewer cardiovascular risks and is considered safer, making it suitable for individuals with arthritis and the elderly population (Pullen et al., 2010).

Next, pilates can also be considered as an exercise option for HF patients who prefer a different form of exercise. Pilates provides similar functional benefits to aerobic exercise, but it is more complex and challenging. It is an excellent choice for those looking to improve kinesthetic sense and flexibility (Guimarães et al., 2012).

Moreover, aquatic exercise is recommended for HF patients, as studied by (Asa et al., 2012). The water temperature is typically set between 33 to 34°C, and patients are advised to perform low to moderate-intensity exercise, ranging from 40% to 75% of maximal heart rate reserve (HRR). Aquatic exercise is conducted three times weekly over eight weeks, with each session lasting 45 minutes. This form of exercise has been shown to improve peak oxygen consumption (VO_{2peak}), cardiac function, peripheral vasodilation, neural adaptation, muscle strength, and endurance, ultimately improving prognosis and survival rates in chronic HF patients. Isokinetic movements are performed throughout the aquatic exercise sessions.

Conclusion

Exercise training plays a crucial role in improving the well-being and prognosis of chronic heart failure patients. Personalized exercise regimens that take into account an individual's baseline health status, severity of HF, and comfort level are essential. It is important to ensure that the exercise program produces an anti-inflammatory effect, as this can provide significant benefits.

Regular exercise not only helps reduce cardiac symptoms but also improves muscle strength, functional capacity, and overall quality of life for chronic heart failure patients. As a clinical exercise physiologist, your role in helping patients adhere to their exercise program is vital. By promoting physical activity and regular exercise, individuals can contribute to higher survival rates and better outcomes for these patients. Keep encouraging and supporting them on their fitness journey.

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