Evidence Based Guidelines for

Exercise and Chronic Heart Failure

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INTRODUCTION

Chronic heart failure (CHF) is characterized by an intolerance to exercise, with this group of patients often experiencing early fatigue and shortness of breath. Such symptoms impact upon one's ability to perform activities of daily living, thus significantly contributing to reduced participation and poor quality of life. In an attempt to both improve outcomes for this population and reduce the significant economic burden imposed upon the health care system, designated heart failure services have recently been established throughout Queensland.

Up until the late 1980s, exercise was considered unsafe for the patient with CHF. It was unclear whether any benefit could be gained from rehabilitation, and concern also existed regarding patient safety, with the belief that additional myocardial stress would cause further harm. Since this time, considerable research has been completed and the evidence resoundingly suggests that exercise for this patient group is not only safe but also provides substantial physiological and psychological benefits. As such, exercise is now considered an integral component of the non pharmacological management of these patients.

Whilst the potential benefits are clear, there are currently no guidelines or resources available to exercise specialists working in designated heart failure services in Queensland. This document provides a review of the current literature specific to various forms of exercise available for patients with CHF. The information is relevant for centre based rehabilitation programmes and also provides guidelines for exercise undertaken external to these environments. This information can be utilized by both those patients seeking additional opportunities to exercise, as well as those unable to access the formal rehabilitation programmes.

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Of the many studies relating to aerobic training and CHF, it has often been noted that functional capacity improves significantly. In comparison, little or no improvement in cardiac performance takes place. As such, the majority of the physiological changes that occur post training are thought to be secondary to peripheral, rather than central adaptations. The most commonly cited outcomes of aerobic training are listed below and will be discussed in more detail.

- Improved aerobic metabolism
- Improved autonomic regulation
- Improved peripheral perfusion
- Decreased local inflammation
- Improved ventilatory control
- Improved quality of life
- Decreased hospital readmissions and mortality

Aerobic metabolism

In keeping with the specificity of training principle, aerobic training has been shown to improve the physiological components of aerobic metabolism. In particular, studies have repeatedly demonstrated an improvement in $VO2_{peak.}$ [1,2,3,4,5,6,7,8] This improvement is usually cited as being between 15-25% though has been documented as high as 36%[7]. It has been reported that individuals with a lower baseline $VO2_{peak}$ respond more significantly to exercise training [9], though this has not been substantiated by other researchers[10]. As $VO2_{peak}$ has been shown to be good predictor of prognosis in the CHF patient population, this is a significant finding. The mechanisms responsible for this change in $VO2_{peak}$ remain unclear though one may presume it is related to either an improvement in oxygen extraction peripherally or an increase in cardiac output and thus oxygen delivery. It is likely that it is due to a combination of both mechanisms though the extent to which each contributes is unknown.

Another frequent measure of exercise capacity is the 6 minute walk test (6MWT) and this too has been shown to significantly improve in CHF patients post aerobic training [3,11,12,13,14,15]. A meta-analysis in 2006 reported an improvement of 46.2m for subjects post training compared to no significant improvement in controls[3]. Whilst the 6MWT is a submaximal test and thus not an ideal measure for exercise capacity, it more closely resembles functional activity, especially in this population and is easily reproduced in a clinical setting.

A common physiological feature of CHF contributing to early fatigue is a shift towards anaerobic metabolism and rapid lactate accumulation. This has been demonstrated by the following physiological changes [16,17,18,19] :

- decreased mitochondrial volume and density

- altered muscle fibre type distribution to fast twitch type II fibres
- decreased levels of oxidative enzymes
- decreased anaerobic threshold

Aerobic training for patients with CHF has been shown to consistently increase exercise time and increase the anaerobic threshold [5,18-26]. The effect on altering muscle fibre type, mitochondrial volume and density and levels of oxidative enzymes is inconsistently reported in the literature [18, 27] though it would appear that some degree of reversal of these changes does occur.

Effects on autonomic function and endothelial function

Autonomic dysfunction is a trademark feature of CHF and is associated with poor clinical prognosis. Amongst other significant physiological changes it causes chronic vasoconstriction and poor vascular compliance. Growing evidence suggests that a skeletal muscle myopathy occurs as a result of this autonomic dysfunction, and is one of the main causes of exercise intolerance in this population. Changes in muscle function are known to commence early in the disease process and are the result of multiple factors.

When a healthy individual exercises, arteriolar dilation occurs and additional capillary beds are recruited to enable the energy demands of the working muscle to be met. In CHF however, normal mechanisms for vasodilation are blunted leading to chronic peripheral hypoperfusion. This in turn contributes to local areas of muscle ischaemia. This impaired neurovascular response becomes more prominent as the severity of cardiac dysfunction increases.

Recent studies have provided convincing evidence that aerobic training may significantly improve total peripheral vascular resistance (TPR) and peripheral perfusion in patients with CHF [21]. This may in part be mediated by a reduction in sympathetic overdrive as a consequence of improved arterial and chemoreflex controls [10,28]. One particular study found this to be more significant in those patients with CHF from non ischaemic causes[22]. Whilst exercise has been shown to cause a reduction in plasma catecholamines, this change has not consistently correlated with changes in TPR, leading one to suspect that other mechanisms may be contributing [10,21,28,29].

One likely possibility is the effect of aerobic training on endothelial function. The endothelium plays an integral role in peripheral perfusion during exercise through the release of vasodilatory substances. In patients with CHF, endothelial dysfunction leads to an impaired response and consequently chronic vasoconstriction and peripheral hypoperfusion. Recent studies have shown that aerobic training corrects endothelial dysfunction in trained extremities, possibly through an upregulation of nitric oxide (NO) synthase locally. [8, 14, 19]

Inflammatory cytokines also appear to play a significant role in the development of skeletal muscle myopathy. It is believed that oxidative stress secondary to hypoperfusion initiates an inflammatory response, further contributing to skeletal muscle catabolism and cardiac cachexia [18]. Findings from recent studies have shown the following:

- Tumour necrosing factor (TNFα), IL-1-β and IL-6 and C-Reactive Protein (CRP) are elevated in muscle biopsies from patients with stable CHF [30, 31].

- Cytokines induce muscular expression of inducible nitric oxide synthase (iNOS) which in turn produces intracellular concentrations of NO high enough to interfere with aerobic metabolism [6, 30]

- Aerobic training of 6 months duration significantly reduces local cytokine expression. This occurs in association with a reduction in iNOS expression and intracellular accumulation of NO [30].

- Aerobic training does not increase pro-inflammatory cytokines and thus provoke further endothelial damage [4]

- Serum cytokine levels respond independently to those expressed locally and have not been shown to significantly alter with aerobic training [4, 30].

Whilst the exact mechanisms are not yet understood, aerobic training of significant duration has beneficial effects on local cytokine expression. This may serve to decrease skeletal muscle catabolism, reverse the inhibition of aerobic metabolism and in turn improve functional capacity [6, 30].

More recent studies have also shown that the cardiac cachexia seen in CHF may be influenced not only by the pro-catabolic mechanisms listed above, but also by a deficiency in local anabolic hormones. One such anabolic hormone is insulin-like growth factor 1 (IGF-1). Local expression of IGF-1 has been found to be significantly reduced in patients with stable CHF though with aerobic training significantly improves and correlates with changes in $VO2_{peak}$ [32]. This has not been a consistent finding however [33]. Similarly, a deficiency of vitamin D, which is common in patients with CHF, has been found to be associated with poor exercise capacity in these patients [31]. As yet it is unknown whether interventions to improve vitamin D would impact upon the inflammatory response and thus physical performance. This remains an area for future study.

Effect on Pulmonary Function

CHF is associated with an excessive ventilatory response to exercise. Aerobic training has been shown to consistently improve minute volume in this population [26, 34,35]. The ventilation to carbon dioxide production slope (VE/CO2) is a marker of CHF severity and has also been shown to consistently improve with exercise training [2,23,26,34,36]. Together, these factors may contribute to a reduced perception of breathlessness.

A recent study also reported that aerobic training may have a positive benefit on central sleep apnoea though this was in a particularly small, nonrandomized population and thus requires further investigation [37].

Whilst ventilatory improvements are most likely the result of improved oxidative capacity and decreased pulmonary vascular resistance [21], the impact upon ventilation perfusion matching is yet to be confirmed.

Effect on Central Haemodynamics

As mentioned previously, the change in $VO2_{peak}$ seen post aerobic training in patients with CHF is considered to be predominantly due to peripheral adaptations. Few studies have investigated central haemodynamic and structural changes in this population, possibly due to methodological limitations. Clinical trials in this area have been inconsistent in their outcomes however a meta-analysis investigating the effect of exercise training on left ventricular remodelling has recently been published [38].

Changes in cardiac output (CO) at peak effort may be the result of a change in stroke volume (SV), heart rate (HR), or both. Significant improvement has been noted in the majority of studies [3,26,34] though not all [21]. It is possible that the type of training is significant, as one study [39] found a significant improvement in those who did interval training compared to no improvement in controls or those who used a steady state approach. It must also be noted that the majority of studies showing significant change in CO, were performed before a time when the use of beta blockers became common practice.

The table below demonstrates that the response of other central cardiac parameters to aerobic exercise training is similarly inconsistently reported in the literature.

Parameter	Outcome post training	Comment
Stroke volume (SV)	significant improvement [21, 34] no significant improvement [26]	Poor correlation between SV at rest and response to aerobic training may account for some discrepancies
Heart rate (HR)	significant reduction at rest though not at peak [21,29,35,40] significant change at peak though not at rest [41,42] changes at both rest and peak [22] no significant change [20,26,43,44]	Most studies conducted before use of beta blockers became common practice
HR variability	Significant improvement [34]	HR variability reflects autonomic dysfunction and is of prognostic significance not only for identification of all cause cardiac mortality but also sudden cardiac death [45]. Shown also to correlate well with

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		improvements in exercise capacity [10,34].
Left ventricular ejection fraction (EF)	significant improvement [21,35,44,] no significant change [20,26,46]	A recent meta-analysis reported significant improvement in EF with aerobic training though not with combined aerobic + resistance training [38].
Left ventricular measurements	significant improvement [21,33] no significant change [20,26,43,44,46]	Meta-analysis in 2006 demonstrated small though significant reduction in end diastolic volume [3]
Myocardial collateral circulation	Significant improvement [35]	Patients with greater myocardial perfusion at baseline showed greatest improvement post programme[35,46]. Changes occur within 2mths of training.

Brain natriuretic peptide (BNP) is released by cardiomyocytes following ventricular wall stress and has been cited as an independent predictor of mortality in patients with CHF. It might be expected that improvements in central haemodynamics and a subsequent decrease in ventricular stress, would be associated with a reduction in BNP. Literature investigating the effect of aerobic training on BNP is particularly sparse and remains controversial, with some studies reporting a significant change [28,29,33,37] and others not [14]. The study by Passino *et al*, reported changes in BNP and N-terminal pro BNP (NT-proBNP) significantly correlated with changes in VO2peak. It was also suggested that longer duration exercise programmes accounted for a more significant reduction in these peptides. Since multiple factors influence BNP, interpretation of results is difficult and there are too few clinical trials in the exercise literature to draw strong conclusions.

Quality of Life and Symptoms

As previously discussed, exercise intolerance and early fatigue are key features of CHF. These symptoms often lead to a decline in function and for some patients, social isolation. Together with depression and anxiety which is not uncommon in this population, these features may contribute to a significant decline in quality of life (QoL).

Numerous studies have investigated the impact of aerobic training on QoL with favourable results. Whilst a number of studies have shown no significant improvement post training [47,48,49,50] numerous studies have reported the contrary [3,5,7,24,34,38, 39, 46,51,52]. Difficulties arise in interpreting this information however, as the instruments used to measure QoL have not been consistent and studies have been conducted over variable timeframes. The Minnesota Living with Heart Failure Questionnaire (MLWHF) is the most commonly employed disease specific QoL tool whilst the SF-36 and dyspnoea-fatigue index (DFI) have also been frequently utilized. Changes in QoL have not consistently parallelled changes in $VO2_{peak}$, [7,24,46,51], leading one to suspect that perception of health is influenced by more than physical function alone.

Very few studies have investigated the effect of aerobic training on depression and anxiety specifically. One such study published in 2004 [7] reported a significant reduction in both parameters following a 6 month training programme. These results occurred in association with an improvement in general well being, mood and social interaction though again, were not related to changes in exercise capacity.

Improvements in the various aspects of QoL appear to be related to initial gains in physical and psychological status though there appears to be a ceiling effect. Some evidence supports that those patients more depressed initially may show a greater improvement post exercise training [7]. Improvements gained are not sustained 6 months post cessation of training however, suggesting that exercise needs to be long term for sustained QoL benefits[48].

Safety, Morbidity and Mortality Benefits

As previously discussed, the majority of clinical trials investigating exercise training and CHF have been in small patient populations with little long term follow up. Impact upon mortality and morbidity has therefore been difficult to discern. One of the earliest trials to show a significant impact upon hospital admissions and mortality was published in 1999 [46]. This study of 14 months duration led to significant change in the non pharmacological management of patients with CHF as it reported not only safety of exercise in this population but also a significant reduction in mortality and hospital readmissions in those who participated in a long term exercise programme. This was the first study of its kind and its results have been supported by a recent meta-analysis [53] and systematic review on this topic [54]. The recent large scale HF ACTION trial also demonstrated exercise to be associated with a significant reduction in all cause mortality and hospital admissions as well as cardiovascular mortality and admissions once adjustment was made for highly prognostic predictors of end point [55]. Additionally, a recent Cochrane review demonstrated a significant reduction in heart failure specific admissions though only a non significant trend toward mortality reduction [56].

Initial concerns regarding safety of exercise in the CHF population have now been dispelled. Importantly, a review of the literature revealed that in over 60 000 patient hours of exercise training, no exercise related deaths were reported [54]. All exercise related systematic reviews and meta-analyses published to date concur, and recommend that exercise be considered a standard component of the management of patients with CHF [3,11,53,54].

Training Principles

Prior to commencing an exercise programme, patients with CHF require a comprehensive assessment to stratify risk. These patients cannot be considered in the same manner as other patient populations for the following reasons:

- normal physiological responses to exercise are blunted and abnormal as described previously
- multiple medications specific to this population impact upon exercise responses
- risk of sudden cardiac death and frequency of other arrhythmias requires specific attention regarding safety procedures and level of supervision
- influence of permanent pacemakers (PPM) or implantable cardioversion devices/ defibrillators (ICD) requires specific attention when exercising
- patients commonly have multiple medical co-morbidities that impact upon exercise capabilities

Relative and absolute contraindications to exercise are listed below [57]:

Relative Contraindications
>1.8kg increase in body mass over previous 1-3 days
Concurrent or continuous inotropic therapy
Decrease in SBP with exercise
NYHA class IV
Complex ventricular arrhythmias at rest or appearing with exertion
Supine resting HR >100bpm
Pre-existing significant co-morbidities
Absolute Contraindications
Progressive worsening of exercise tolerance or dyspnoea at rest or on exertion over previous 3-5days
Significant ischaemia at low work rates (<2 METS)
Uncontrolled diabetes
Acute systemic illness or fever
Recent embolism
Thrombophlebitis
Acute pericarditis or myocarditis
Moderate to severe aortic stenosis
Regurgitant valvular heart disease requiring surgery
Myocardial infarction within previous 3 wks
New onset atrial fibrillation

The F.I.T.T Principle

The general principles for exercise training are summarized by the FITT principle – frequency, intensity, time and type. Guidelines for each of these parameters remain relatively vague as the trials to date have adopted such variable study designs and no correlation has been found to exist between any individual parameter and functional outcome [54].

Frequency and Duration

Exercise outcomes are often considered to be dose dependent, meaning that the total volume of exercise performed over a period of time is of greater significance than specific parameters alone. This has been shown to be the case for patients with CHF [11,54]. The frequency and duration of exercise prescribed for each individual should be tailored to their functional ability. Those more debilitated patients for example should exercise for a shorter duration though do so more frequently. This allows for greater recovery time whilst performing the same or greater total volume of exercise. Current recommendations suggest a minimum frequency of 3-5 days per week though evidence supports that twice weekly exercise may be sufficient to maintain functional improvement gained following a centre based training programme [46]. Patients should start at short durations (eg 10-20 minutes) and progress to longer session times (eg 30-40 minutes).

Duration of the rehabilitation programme has also been shown to be an important factor. Greater functional gains have been achieved with longer duration training programmes [10,15,52]. Once training ceases however, there appears to be a general trend towards decreased physical activity and a loss of the positive benefits achieved with formal exercise training [1,15,48]. Such functional decline occurs within 3 weeks post cessation of activity [36]. Because of this and due to the chronic nature of the condition, programmes of longer duration than traditional cardiac rehabilitation programmes are recommended in this population. This is deemed necessary in order to effect significant change and to slow the rate decline[52].

Intensity

No clear relationship has been found between exercise intensity and functional capacity[54]. Training benefits have been demonstrated to occur with intensities ranging from 40-85% $VO2_{peak}$ though some researchers hypothesize myocardial wall stress is more likely to be minimized at the lower intensities. As such, 50-70% $VO2_{peak}$ or 60-80% heart rate reserve (HRR) is the intensity usually recommended for rehabilitation programmes [58]. Patients should also exercise at a rating of perceived exertion between 9-14 on the 6-20 RPE scale[58].

Type

Study designs have varied significantly with respect to the type of exercise performed. Some have included individual activities such as cycle ergometer or treadmill alone, whilst others have investigated combination therapies such as cycle ergometer plus additional activities such as rowing machines, step aerobics [59] or calisthenics. There is some evidence that more comprehensive programmes including a combination of activities may be more beneficial than one activity alone[10].

Aerobic training for patients with CHF may be delivered in either a steady state or intermittent manner. Steady state protocols aim to keep the HR elevated for prolonged periods of time. In comparison, intermittent or interval training refers to exercise that allows rest periods in order to decrease the total cardiac stress. The exercise is usually performed at a higher intensity than would be possible with a continuous protocol and thus has the intention of inducing more significant aerobic benefits. Both intermittent and continuous protocols have been shown to be of significant benefit to the patient with CHF [2,39], though only one study has cited more prominent outcomes with interval training [33]. The sample size in this latter trial was particularly small however justifying further research in this area.

In recent times, studies have investigated the benefits of combining aerobic training with other modes of exercise. One such example is strength training. This and other forms of exercise will be presented later in this document.

Other considerations

As previously discussed, the majority of studies to date have been in small populations of patients with stable CHF. Women and the frail elderly have been underrepresented. In addition to this, the majority of studies have not separated aetiologies and have thus included both ischaemic and dilated cardiomyopathies. Whilst there is some suggestion that those patients with ischaemic aetiology may have a higher mortality[46] and may respond less significantly than those with CHF from other causes[10,41], there is currently insufficient evidence to support this.

Despite the recent surge of evidence in the area of exercise and CHF, numerous questions remain unanswered. Further research is particularly warranted in the following subgroups:

- women
- the frail elderly
- ischaemic versus non ischaemic aetiology
- CHF with preserved LV systolic function
- NYHA class IV patients
- those with less stable disease such as in the immediate post hospitalization phase.

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2. Resistance Training and Chronic Heart Failure

Prior to the late 1980's, resistance training was not recommended for patients with CHF due to its perceived association with undesirable haemodynamic responses. It was believed that such training would unfavourably increase afterload and thus accelerate left ventricular remodelling. Recent studies however have demonstrated that resistance training is not only safe but the haemodynamic responses evoked do not exceed those levels attained during standard treadmill testing[1].

As previously described in this document, the skeletal muscle changes that occur in patients with CHF play a significant role in the exercise intolerance seen in this population. The peripheral adaptations associated with this myopathy differ from those related to aging or disuse syndromes alone [2,3].

Resistance training aims to delay the onset and in part, counteract a number of the peripheral adaptations previously described. Muscle strength (in particular leg strength) and total muscle cross sectional area are independent predictors of exercise tolerance, clinical prognosis and long term survival in patients with CHF [4]. For these reasons, the inclusion of resistance training is now accepted practice when designing a rehabilitation programme for patients with CHF.

Physiological Benefits of Resistance Training

Until recently, studies investigating the impact of resistance training were difficult to interpret. This was due to small sample sizes, poor patient selection and methodology, which included both aerobic and resistance training in the study design. More recently however, a number of studies have emerged which have addressed these issues by evaluating the physiological benefits of resistance training alone. These studies are summarized in Table 2.

It is proposed that the physiological improvements noted with resistance training are likely the result of improvement in skeletal muscle abnormalities +/- neuromuscular function, rather than the result of increasing muscle mass alone[4]. The most common benefits that occur following resistance training include the following:

- increased muscle strength [2,5,6, 7]
- increased muscle endurance [2,5]
- increased forearm blood flow [8,9,10]
- increased mitochondrial ATP production rate [11]
- increased oxidative capacity [2]
- relative increase in area of type I fibre type distribution [2]
- increased 6 minute walk distance [2,7, 12]
- increased $VO2_{peak}$ in some studies [5,6,11], (decreased $VO2^{peak}$ at submaximal levels [9] or no change [2,7] in others)
- increased quality of life[7]
- no adverse events, no deterioration in left ventricular function [13,14]

It should be noted that a number of these benefits also occur with aerobic training. Local improvements in muscle strength and endurance however, occur only following resistance type exercise protocols and are not seen post aerobic training. Reversal of these physiological benefits occurs within 8 weeks of training cessation [10], thus emphasizing the need for long term programmes. It is also known that the strength gains that occur are not inhibited by beta blocker therapy [15].

Resistance Training versus Aerobic Training

As previously described, the effect of aerobic training on $VO2_{peak}$ is well documented. Whilst the impact of resistance training on this parameter remains uncertain, there is some suggestion that it may significantly improve $VO2_{peak}$ as much as 16%[6]. Some studies report that improvements in $VO2_{peak}$ are significantly greater when resistance and aerobic training are combined, however, a recent systematic review did not support this[12]. Greater strength benefits also appear to be gained when both forms of exercise are incorporated into the exercise programme [16,17]. Current recommendations therefore support the inclusion of both aerobic and resistance training in CHF rehabilitation programmes rather than either one in isolation [18,19].

Type of Exercise

Isometric exercise is not recommended for patients with CHF due to the pressure load that it places upon the heart. During this form of exercise, the increased intramuscular pressure compromises blood flow and oxygen delivery and thus energy requirements are met by anaerobic metabolism. During isometric exercise, systolic blood pressure increases to maintain perfusion and may have a negative influence upon central haemodynamics. When combined with a valsalva manoeuvre, these haemodynamic changes become increasingly dangerous [20].

Alternatively, dynamic resistance training has been established as safe in this population. The majority of studies have investigated the effects of concentric exercise. There is only one known study that has specifically reviewed the impact of eccentric exercise in a cardiac population [21]. Results were positive and showed that eccentric exercise induces similar cardiovascular and metabolic stress when compared to concentric exercise, though is able to generate significantly greater muscle torque. Unfortunately this study was limited to patients with normal left ventricular function and as such, information cannot be extrapolated to the heart failure population. Further research in this area is thus warranted.

Isokinetic resistance training, which requires specific equipment, has been utilized in some studies with positive physiological benefits. There is currently no literature however to support this type of training over isotonic exercise for patients with CHF.

Training Specifics

Caution should always be taken to avoid pressure and/or volume overload of the left ventricle when prescribing resistance exercises. It is therefore recommended that short duration exercise be performed to provide the peripheral muscular stimulation with sufficient rest intervals to avoid high cardiovascular stress [22].

In the majority of studies, the training workload is assessed utilizing the 1RM method (ie maximum weight lifted in one full range of motion). Whilst considered safe [23], significant caution should be taken when using this method. An alternative approach is to calculate 10 or 15 RM [24]. Intensity of training significantly varies in the literature with some researchers advocating as high as 80% 1RM. The intensity and duration of exercise prescribed however, should always reflect the severity of disease, clinical status and the size of the working muscle mass. Authors therefore recommend small hand weights (eg 0.5, 1 or 3 kg) for patients with limited cardiovascular reserve [4,17]. In addition, patients with exertional angina should be advised to exercise at an intensity below that at which the onset of angina occurs.

Very little literature exists with respect to resistance training for NYHA class IV patients. Current recommendations suggest that these patients avoid traditional resistance training programmes but should be encouraged to maintain strength, range of movement and balance through participation in modified programmes [4].

Based on current research, recommendations for resistance training for patients with CHF are listed in Table 1.

Table 1. Resistance Training Recommendations for Patients with CHF

Parameter	Recommendation
Warm up and warm down	10 mins duration each
Intensity	Light weights only Commence at workload of 40% 1RM progress to 60% 1RM [18]. 9-13 on RPE (6-20 scale)
Reps and sets	8-15 reps, 2-4 sets
Recovery	Work : recovery >1:2 [25]
Frequency	1-2 days/ week (NYHA II, III) and days/week (NYHA I) [4]
Duration of exercise	Short duration - <60secs
Duration of session	20- 30 mins duration [18]
Type of training	Programmes should incorporate both aer and resistance training

Clinical Implications

CHF is a progressive illness characterized by multiple physiological changes that impair exercise capacity and evoke functional decline over the course of time. The aim of resistance training in this population is not to significantly increase muscle strength but instead to maintain a more normal skeletal muscle mass and reverse or delay those physiological changes that take place with the myopathy that occurs in this population. Heavy weights should therefore be avoided. Physiological improvements within the skeletal muscle are considered to positively influence long term outcomes.

Resistance exercise is considered safe, and in combination with aerobic training, is recommended for all rehabilitation programmes for patients with CHF. Despite a number of recent studies, the majority of trials to date have been performed in small populations, most of whom are males with a disease classification of NYHA II and III. Further research would thus be recommended in larger populations for the following groups:

- the frail elderly
- NYHA I and IV
- Ischaemic versus CHF secondary to other aetiologies
- CHF with preserved left ventricular systolic function

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3. Swimming and Chronic Heart Failure

Many people with CHF enquire about the benefits of water based exercise. Understanding the effects of immersion is integral to providing accurate and sound advice.

Effects of immersion

When a body is immersed in water, hydrostatic pressure causes a shift in blood volume centrally. This change is relatively insignificant when immersed in less than waist deep water. Immersion in water above the diaphragm however, may cause a rise in central venous pressure (CVP) as much as 10-15mmHg. Immersion to the sternal notch redistributes as much as 700mls of blood from the periphery to the thoracic cavity.[1] This position has also been found to increase mean pulmonary artery pressures to abnormally high levels (53mmHg). [2]

The increase in venous return that occurs following immersion, also impacts on the renal system. Some of the changes that occur include decreased plasma concentration of renin, angiotensin II, aldosterone, adrenaline and nor adrenaline as well as an increase in diuresis. [3]

In addition to depth of immersion and consequent hydrostatic pressure, the haemodynamic impact of immersion is influenced by water temperature and body position. Immersion in warm or thermoneutral water (33-34 degrees) is associated with peripheral vasodilation and a subsequent reduction in afterload. Similarly, it has been shown to cause a reduction in heart rate (HR) [4] whereas significantly higher temperatures tend to cause the opposite[5]. Cold water immersion (22 degrees) has been associated with safety concerns in patients with CHF as well as those patients with CAD alone. In both patient groups, the rate pressure product (RPP) has been shown to increase significantly representing an increase in oxygen demand, and in the CHF patients, the cold water has also been shown to significantly increase the frequency of premature ventricular contractions (PVCs) on ECG [6]. With respect to body position, a standing position will subject the individual to greater hydrostatic pressure effects than a sitting position. [2]

Haemodynamic Effects of Immersion in Patients with CHF

Until recently, exercise in water was considered unsafe for patients with CHF due to the increase in preload and consequent myocardial stress. More recent studies have suggested that whilst safety issues exist, they may not be as significant as first thought. Below is a summary of physiological responses from clinical trials investigating the effect of water immersion on patients with CHF.

Queensland Government

Haemodynamic Parameter	Effect of immersion
Heart rate	Increased in temperatures above thermoneutral, decreased in lower temperatures [4,5]
Blood pressure	No significant change at rest though increased with exercise [3,4,5,7]
Stroke volume	Increased [3,4,5, 8] No change or decreased [2]
Cardiac output/ cardiac index	Increased during immersion and returned to baseline during recovery. [3,4,8, 9] Increased during immersion though less significantly than patients with CAD [9] Remained elevated post immersion in warmer temperatures. [5]
Pulmonary vascular resistance and systemic vascular resistance	Decreased during immersion, returned to baseline during recovery though remained decreased post immersion in warmer temps [3,5, 10] Increased plasma nitrate indicating significant effect upon endothelial dysfunction. [11] Decreased SVR [9]
Cardiac dimensions	Decreased left atrial dimensions [5] Increased left atrial dimensions [3,4] Patients with severe CHF, systolic diameter increases more than diastolic with no increase in SV indicating possible ventricular dyskinesia [10]
Ejection fraction	Increased [4,5,8]
Arrhythmias	Unlikely to impact [5] More likely to occur in cold water [6,12,]
Renal changes	Decreased arginine vasopressin, renin and nor adrenaline. No change in adrenaline. This effect is the same for CHF patients and healthy subjects [3,5]
$VO2_{peak}$	No increase with exercise in water [4] Increased with swimming [9] Increased post training programme [7,13]

As noted above, immersion in thermoneutral water appears to have a positive impact upon stroke volume, cardiac output, ejection fraction, afterload and diuresis, resembling the goals of pharmacological therapy used in the management of CHF today. The impact upon preload however, varies in the literature and this is where the disparity arises regarding safety of immersion/ swimming in this population. Some studies suggest that the increase in venous return that occurs is outweighed by the reduction in afterload, causing a net effect of left ventricular unloading. Venous vasodilation and/or increased diastolic filling time are considered to enhance this process.[4,5] On the contrary however, other studies report that the impact of increased venous return on central pressures is too great for patients with severe CHF.

Whilst the majority of studies to date have focused on the haemodynamic effects of immersion, very few studies have been published with respect to exercise in water or horizontal swimming. Of those that have been published, 3 have compared exercise in water to a control group who did not exercise. Of these, no adverse events were experienced and in 2 of the studies, a significant improvement in quality of life and reduction of symptoms in the intervention group was noted [13, 14]. The third study did not demonstrate significant haemodynamic changes at the completion of the programme compared to baseline [8]. Only 1 study has compared exercise on land to exercise in the water though was for a duration of 3 weeks only. Whilst no increase in VO2 peak was noted, it did however demonstrate a significant increase in plasma nitrate in the water group which may reflect an improvement in endothelial function in this group.

When determining safety of exercise in water, parameters of exercise capacity are considered more appropriate than echocardiographic measures. Water aerobics and swimming have been found to correspond to 4 METs or a $VO2_{peak}$ of 14 mls/kg/min[9]. Slow swimming (20metres/ minute) has been found to equate to horizontal cycling on land at 100W. As such, patients with a $VO2_{peak}$ of <15mls/kg/min or anaerobic threshold <10ml/kg/min should be cautioned regarding the safety of water activities. Further to this, despite haemodynamic deterioration during slow swimming, 1 study reported that patients maintained a feeling of well being, thus introducing further concerns regarding safety. [2]

Another important consideration with regard to safety is the patient's chronotropic response to exercise stress testing. Patients with CHF regulate cardiac output predominantly by changes in heart rate rather than stroke volume. An inadequate heart rate response during exercise stress testing may therefore be another guide with regard to advice pertaining to exercise in water[8].

Implications for Practice

Whilst the number of publications regarding CHF and water based exercise has increased significantly in the past 2 years, establishing firm guidelines for this patient group is difficult due to low subject numbers and significant variation in methodology. At this time however, current recommendations include the following [2, 9]:

- Decompensated heart failure is an absolute contraindication to immersion and swimming
- Water temperature should be thermoneutral
- Patients with severe CHF who tolerate sleeping flat are safe to sit or conduct gentle therapeutic exercise in warm water provided they are in an upright position and immersed no deeper than the xiphisternum
- Water based exercise should only be conducted in the presence of exercise professionals with a sound knowledge of water-dynamics.
- Patients require at least a $VO2_{max}$ of 15mls/kg/min and anaerobic threshold of >10ml/kg/min during a symptom limited exercise stress test to be considered safe for gentle exercise in water.[9] An inappropriate heart rate response during exercise stress test should highlight added caution.
- Patients meeting the above criteria, and especially those with an implantable defibrillator, should be notified of the safety precautions associated with exercise in water and should advised to never swim alone
- The Borg scale is able to be used for self monitoring during hydrotherapy. [15]

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4. Tai Chi and Chronic Heart Failure

Tai Chi has long been practiced in China, commencing initially as a form of martial art. It combines fundamental postures that flow smoothly from one to the next as well as relaxation and deep diaphragmatic breathing. Whilst a number of different styles have developed, Chen, Yang and Tai Chi Chih are the most commonly reported styles in the literature. Documented benefits of Tai Chi include improved balance, reduced fear of falling, increased strength, increased functional mobility, increased flexibility, sleep enhancement, increased cardiovascular function, improved quality of life and increased psychological well being. More recently, there have been reported benefits for patients with cardiac disease.

The evidence

Despite the advocated benefits, the research base for Tai Chi remains poor. The majority of information in the literature stems from case reports, editorial letters, review reports and announcements, with only 3 randomized controlled trials specific to CHF. Studies vary in design and commonly lack accurate description regarding duration, frequency and type of Tai Chi. In addition to this, large discrepancies exist in terms of experience of subjects and practitioners, which may influence outcomes. From the information available it would appear that Tai Chi is able to provide some psychological and physical benefits to patients with chronic conditions and it does appear to be safe. Further research is required to determine quantitative benefits of this form of exercise as well as providing a more scientific foundation for potential mechanisms of benefit.

Possible Benefits

Balance and Falls

A number of studies report improved balance and postural stability in the older population following a course of Tai Chi exercise[1,2,3]. One study however suggested that this improvement was not significant when compared to results from a balance training class[4]. Reduction of multiple falls has been reported to be as high as 47.5% though this study exhibited significant bias[2].

Cardiorespiratory Function

Studies have shown that Tai Chi equates to low – moderate intensity aerobic exercise though this is dependent upon the type of Tai Chi used. Tai Chi Chih for example is a modified version of Tai Chi that may be performed in sitting or standing and provides a preferable alternative for patients with severe exercise intolerance. The energy cost of Tai Chi Chih in healthy subjects has been calculated to be 1.5-2.0 METS, with heart rate increases ranging from 43-49% predicted maximum levels[5]. Other versions of Tai Chi require 2.9 METS and a maximum oxygen uptake of less than 40% [6].

Whilst some studies have shown an increase in $VO2_{peak}$[7], others have not[8]. Despite no impact upon oxygen consumption, the latter study did show some significant changes in a CHF population. Both the 6 minute walk distance and plasma BNP concentrations significantly improved in this randomized controlled trial, which is an interesting finding and warrants further investigation in a larger population. Whilst thought to have a positive influence on neurohormonal mechanisms[9], Tai Chi has not been shown to alter catecholamine levels in patients with CHF[8].

With respect to cardiovascular risk factors, Tai Chi has been reported to decrease blood pressure in both healthy subjects as well as patients post myocardial infarct [10,11,12]. This has not been a consistent finding among all studies however, possibly due to such variable methodology. Lipid profiles have also been reported to improve following a 10 week course of Tai Chi exercise[13].

Strength and Flexibility

Knee extension strength and flexibility have consistently been shown to improve following multiple sessions of Tai Chi exercise[7,13] though again studies are quite variable in design with significant bias. These changes are considered most substantial after 40 or more Tai Chi sessions.

Psychological Benefits

Tai Chi has been reported to improve quality of life[8, 14] and self efficacy[15]and has a positive impact on mood, including depression and anxiety[16]. These effects have been noted in both beginners as well as experienced practitioners though the majority of these studies are not specific to heart failure. It is possible however that these benefits may be more the result of the social interaction that occurs with group activities[17] rather than the exercise alone. One study also reported a positive benefit on sleep stability in patients with heart failure who underwent a 12 week Tai Chi exercise course in addition to usual care when compared to a usual care only group[18]. This was also thought to impact upon quality of life.

Whilst numerous studies have investigated the impact of Tai Chi on various health parameters, the majority of this research has not been specific to patients with heart failure. Scientific method is also questionable in many studies and at this stage, few randomized controlled trials have been conducted. Despite this, the current evidence would suggest that Tai Chi is a safe, low cost and effective means of providing low-moderate level aerobic exercise for patients with chronic heart failure and can be tailored to address the individual's needs. It appears to have positive physical and psychological benefits though the mechanism of these improvements and in particular, the relevance of these changes in heart failure, requires further evaluation.

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