

**RESISTANCE TRAINING FOR PATIENTS WITH
CHRONIC HEART FAILURE.**

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Declaration

This dissertation summarises original, previously unpublished work conducted at the Austin and Repatriation Medical Centre, Heidelberg, Victoria, in the Departments of Cardiology, Physiotherapy, Respiratory Medicine, Nuclear Medicine and Clinical Pharmacology. With the exception of procedures that, for ethical reasons, needed to be collected by qualified medical personnel, this dissertation is the result of work performed solely by the author. Data analyses were conducted at the Austin and Repatriation Medical Centre and Victoria University of Technology, Footscray, Victoria.

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Preface

Data reported in this dissertation has been submitted for presentation at the Australian Cardiology Conference in Brisbane in August 1996 and the Australian Cardiac Rehabilitation Association meeting also in Brisbane in August 1996. The Abstract has been presented as follows:

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Abstract

Effects of resistance weight training on muscle strength, endurance and aerobic capacity in patients with chronic heart failure. T.M Ryan, D.L. Hare, S.E. Selig, H. Krum, A-M Pellizer, T.V. Wrigley. Austin and Repatriation Medical Centre, Heidelberg, Victoria. 3084 and Victoria University, Footscray Victoria 3011

Chronic heart failure (CHF) patients are limited in functional capacity by muscle fatigue and breathlessness. The effects of resistance training on muscle strength and endurance and functional aerobic capacity were evaluated in 9 men (63 ± 11 years; mean \pm s.d) with CHF (LVEF $26 \pm 6\%$). Training comprised bilateral upper and lower body resistance exercises for 3 sessions per week for 11 weeks on hydraulic equipment. Before and after training, patients underwent assessment of strength and endurance (Merac isokinetic system), functional 6-minute walk and peak aerobic (VO_{2peak}) capacity. Basal forearm blood flow was measured using strain gauge venous occlusion plethysmography. Vagal tone was assessed using heart rate variability. No medical complications arose during training or testing sessions.

There were increases in upper body strength (42 ± 8 ; $P = 0.037$) and increases in lower body strength ($22 \pm 9\%$, $P = 0.044$) and endurance ($17 \pm 11\%$ n.s). There were no significant changes in the average distance walked in six minutes (pre-training: 454 ± 21 meters; post-training; 475 metres) or VO_{2peak} (pre-training; 17.3 ± 1.6 ml/kg \cdot min $^{-1}$; post-training; 17.3 ± 1.4 ml/kg \cdot min $^{-1}$). However, oxygen consumption for the full range of submaximal workloads decreased by an average of 7% ($P < 0.0001$, t-tailed t-test) and minute ventilation also fell by an average of 6% ($P = 0.007$). Responsiveness to vasodilator stimuli was not altered. Baroreflex sensitivity increased non-significantly. A favourable trend in autonomic status and vascular tone was observed.

Thus resistance training in CHF patients increased muscle strength and endurance while reducing the demand for oxygen and ventilation at submaximal workloads. This might allow safer and easier performance of usual daily activities by CHF patients. Further research is needed to verify these preliminary data.

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Glossary of Terms

**Acute Myocardial Infarction
(AMI)**

Gross necrosis of the myocardium as a result of interruption of the blood supply to the area.

**Activities of Daily Living
(ADL)**

Activities involved in self care and domestic duties.

**Cardiac Rehabilitation
Program (CRP)**

Comprehensive regimen of risk management education, exercise and reassurance with a view to resuming usual activities generally following cardiac surgery or AMI but applying to all groups of cardiac patients.

**Coronary Artery Disease
(CAD)**

Pathological process causing obstruction to the arteries supplying the myocardium. Patients mostly present with either sudden death, AMI, angina or chronic heart failure.

**Chronic Heart Failure
(CHF)**

Condition caused by impairment of heart muscle function generally refers to patients with chronic left ventricular systolic dysfunction, although it can include impairment of diastolic left ventricular function and can also include right ventricular failure.

**Coronary Artery Graft Surgery
(CAGS)**

Surgical bypass of obstructions in coronary arteries.

**Electrocardiograph
(ECG)**

A graphic tracing of the instantaneous electrical potential caused by the excitation of the heart muscle and usually detected on the body surface.

Endurance Training

Cardiorespiratory endurance refers to the ability of the total body to sustain prolonged, rhythmical exercise. Endurance training refers specifically to exercise activities that allow more efficient function of the cardiovascular and respiratory systems.

Exercise Intensity

Subject's own perception of exercise-related effort. This can be quantified using the Borg scale from 1-20 for measurement of exercise-related symptom / effort intensities.

Hydraulic Resistance Training

Training load is determined as the product of how rapidly and forcefully a person can move hydraulic fluid through an aperture by exerting force against a lever arm. There is no preset speed and the resistance can be varied by changing the size of the aperture. The speed and resistance remain specific to the person. The amount of torque generated and the speed at which it is generated will differ for every person at any resistance setting chosen.

Isokinetic dynamometry

Work, power and fatigue can be measured using isokinetic dynamometers which provide muscle loading by controlling the velocity of limb movement as opposed to loading by external weights.

Left Ventricular Ejection Fraction (LVEF)

The ratio between left ventricular stroke volume (SV) and end-diastolic volume (EDV)

$$\frac{(EDV-ESV)}{EDV}$$

$$EF = \frac{EDV - ESV}{EDV} = SV/EDV$$

Maximum Voluntary Contraction (MVC)

A maximum voluntary contraction is an isometric measurement of strength (peak force or torque). Once this measurement been ascertained, training protocols can be designed and based on a percentage of this standard; i.e. 30% of the maximum capacity (30% MVC).

Rate Pressure Product (RPP)

Heart rate (in beats per minute) multiplied by systolic blood pressure (mmHg) - a clinical measure of myocardial oxygen demand.

Risk Stratification

Grading the risk of death and complications.

Risk Stratification

Grading the risk of death and complications.

Functional Class

Grading of functional impairment of cardiac patients. This is commonly done using the New York Heart Association (NYHA) functional classification.

Class**NYHA I**

Patients with cardiac disease but without resulting limitations of physical activity. Ordinary physical activity does not cause undue fatigue, palpitations, dyspnea, or anginal pain.

NYHA II

Patients with cardiac disease resulting in slight limitation of physical activity. They are comfortable at rest. Ordinary physical activity results in fatigue, palpitations, dyspnea or anginal pain.

NYHA III

Patients with cardiac disease resulting in marked limitation of physical activity. They are comfortable at rest. Less than ordinary physical activity causes fatigue, palpitations, dyspnea, or anginal pain.

NYHA IV

Patients with cardiac disease resulting in inability to carry on any physical activity without discomfort. Symptoms of cardiac insufficiency or of the anginal syndrome may be present even at rest. If any physical activity is undertaken, discomfort is increased.

Chapter 1 Literature Review

1.0 Introduction

The World Health Organisation states that rehabilitation is considered to be an essential part of the care that should be available to *all* cardiac patients. The goals of rehabilitation being to reduce morbidity and mortality, improve functional capacity and symptomatology and enable the cardiac patient to return to a useful and personally satisfying role in society (WHO Technical Report Series 831, 1993).

Recent advances in cardiac care have contributed to the improved survival of patients with chronic heart failure (CHF), a condition characterised by fatigue on exertion and breathlessness. Together these symptoms limit exercise capacity and quality of life. Opportunities for these patients to improve their tolerance to exercise have been limited in the past and appropriate training regimens are needed for these chronically disabled patients for whom even modest improvements in working capacity can substantially improve their independence and quality of life.

While recent research (Coats et al., 1992) has demonstrated the positive effects of aerobic training for patients with CHF no published studies to date have evaluated the safety and efficacy of resistance weight training in this population. Resistance training for patients with coronary artery disease (CAD), in the absence of heart failure, has been demonstrated to improve quality of life, strength and cardiovascular endurance (Kelemen et al., 1986; Stewart et al., 1988; Ghilarducci et al., 1989; Sparling et al., 1990, Stewart 1989, Butler et al., 1987, Franklin et al., 1991; McCartney et al., 1991; Squires et al., 1991).

Resistance activities have not previously been advocated for patients with CHF due to concerns of hemodynamic compromise during this type of training. However

McKelvie et al. (1995) demonstrated that for CHF patients, resistance exercise produces hemodynamic responses that are no greater than those found with cycling. It has also recently been documented for a variety of cardiac patients that weightlifting using relatively few repetitions and low-moderate loads (resistance) result in clinically acceptable arterial blood pressure and ECG responses (Haslam et al., 1988; Lightfoot et al., 1989; Cononie et al., 1990; Kelemen, 1989; Stewart et al., 1988; Featherstone et al., 1993; Goldberg, 1989) without compromising cardiac function (Butler et al., 1987). These studies indicate that selected cardiac patients may safely participate in a combined aerobic and resistance training program.

The rationale for the inclusion of resistance training in the rehabilitation of CHF patients is that i) structural and functional deficits in skeletal muscle appear to be strongly associated with fatigue; ii) CHF patients are returning to occupations and leisure activities which require lifting weights and other forms of 'resistance' activities; iii) by increasing muscle strength and endurance, everyday tasks may be performed at lower percentages of the new maxima, thereby reducing fatigue, whilst improving quality of life and patients' safety; iv) patients who have led sedentary lifestyles for many years may have an aversion to traditional aerobic training activities, but may be more likely to comply with exercise programs that include resistance exercises; (iv) severely limited patients who are unable to tolerate generalised (aerobic) exercise may benefit from a localised exercise regime, repeated for different body segments.

The purpose of this thesis, therefore, was to examine the safety and efficacy of exercise training with an emphasis on resistance exercise in the rehabilitation of patients with CHF.

Chapter 2

2.0 Review of Literature

2.1 Congestive or Chronic Heart Failure (CHF)

CHF describes a life-threatening syndrome characterised by insufficient cardiac output. The major symptoms of CHF are fatigue on exertion and breathlessness (Clarke et al., 1996). The New York Heart Association (NYHA) applies a functional classification to patients with heart disease. Most CHF patients are in functional classes II and III (see glossary). The American Association of Cardiovascular and Pulmonary Rehabilitation Risk Stratification (1991) for the purposes of prescribing exercise, describes CHF patients as having a left ventricular ejection fraction (LVEF) of less than 35% at rest.

2.1.2 CHF and Exercise Tolerance

Left ventricular ejection fraction (LVEF) is a predictor of survival in CHF, but correlates poorly with exercise tolerance or fatigue in exercise (Franciosa et al., 1981), as do central haemodynamic variables (Szlachcic et al., 1985). Medical treatments which quickly restore hemodynamics do not improve exercise tolerance as rapidly (Fink et al., 1986), demonstrating that cardiovascular function and fatigue from exercise are not inextricably linked in CHF. LVEF is relatively unchanged by aerobic exercise training in CHF, whilst muscle aerobic metabolism and local blood flow may be markedly improved (Sullivan et al., 1988).

Many of the defects that have been described in skeletal muscle in CHF are strongly correlated with fatigue and provide a rationale for exercise training. These defects appear to be due to a combination of deconditioning (including disuse atrophy) and chronic hypoperfusion. Some of the functional deficits common in CHF are tabulated below (Table 2.1 and 2.2).

Muscle Function	CHF patients	Control
Knee extensor function MVC (ft-lb)	80 ± 4	90 ± 6
Endurance ratio	0.51 ± 0.003	0.58 ± .0.2
Work (ft-lb)	1,075 ± 116	1,390 ± 110
Submaximal exercise tolerance- 9 minute walk(m)	367 ± 32	667 ± 27

Table 2.1 Serial measurements (Mean ± SEM) of muscle function comparing CHF group to age-matched sedentary controls without CHF (*from Yamani et al., 1995*).

Response	Rest		Maximal Exercise	
	CHF	Control	CHF	Control
Heart Rate (bpm)	85 ± 5	91 ± 4	118 ± 7	170 ± 4
Mean Blood Pressure (mmHg)	84 ± 3	95 ± 4	92 ± 3	130 ± 5
VO ₂ (ml/min)	275 ± 11	304 ± 14	1,008 ± 82	1,941 ± 96
RER	0.83 ± 0.02	0.85 ± 0.01	1.11 ± 0.04	1.19 ± 0.03
Leg blood flow (l/min)	0.3 ± 0.1	0.5 ± 0.1	3.5 ± 0.2	5.6 ± 0.6
Femoral lactate (mg/dl)	13 ± 1	9 ± 1	49 ± 3	71 ± 10
Leg arteriovenous Oxygen difference (ml/dl)	9.1 ± 0.5	10.2 ± 0.9	11.9 ± 0.6	13.7 ± 1.0

Table 2.2 Systemic hemodynamic and metabolic responses to exercise in a group of CHF patients compared to a control group of normal male subjects with normal exercise capacity. The controls had normal activity levels, were not involved in any training program and were not taking any medications (*from Wilson et al., 1993*). bpm: beats per minute; VO₂: systemic oxygen consumption; RER: Respiratory gas exchange ratio.

2.1.3 Mechanisms Limiting Exercise Capacity in Patients with CHF

Studies have consistently demonstrated that the development of fatigue for a given work rate is greater in patients with heart failure than among healthy subjects (McKelvie et al., 1995; Oka et al., 1993; Szlachcic et al., 1985). It has been postulated that this fatigue may be related to the inability of the cardiovascular system to provide the required blood flow for the activation of large muscle mass and / or abnormalities of skeletal muscle structure or function in these patients.

Several groups have provided evidence that the fatigue seen in CHF is not due to central hemodynamic factors (in particular, not associated with low ejection fraction or reduced blood flow to working muscles) (Franciosa et al., 1981; Massie et al., 1987).

There are both similarities and differences between the exercise limitations associated with CHF and those seen in physical deconditioning. The similarities are confined mainly to the gross measures of poor exercise tolerance and reduced skeletal muscle mass.

2.1.4 CHF and peripheral blood flow

The relationship between chronic peripheral perfusion and changes to muscle structure and function is unclear, with several investigators proposing an important role for hypoperfusion (Wilson et al., 1993; Zelis et al., 1975), while others have downplayed its significance (Minotti et al., 1990). CHF patients have reduced peripheral vasodilator capacity during exercise and post-ischaemic reactive hyperaemia (Zelis et al., 1975). Mechanisms may include impaired arteriolar compliance and increased vasoconstriction. However, chronic hypoperfusion does not appear to be the dominant cause of muscle fatigue in CHF since there are

metabolic deficiencies even after controlling for perfusion (Massie et al., 1987; Minotti et al., 1990).

2.1.5 Skeletal Muscle Atrophy in CHF

Sedentary living results in a greater loss of muscle strength than muscle bulk (Berg et al., 1993). In contrast, CHF patients exhibit greater muscle atrophy, particularly of Type IIb fibres, while strength is relatively well preserved (Massie et al., 1996). Yamani et al. (1995) also found that muscle strength was well maintained in a group of asymptomatic CHF patients, compared to age-matched, healthy, sedentary controls. Skeletal muscle atrophy often occurs early in the course of the disease (Minotti and Massie 1992). In CHF, large muscles are more susceptible to atrophy than small ones, although the latter still exhibit the characteristic fatigue of CHF, suggesting intrinsic (metabolic) abnormalities in all skeletal muscle (Buller et al., 1982). Mancini et al. (1992) reported that the decreased muscle mass occurring in a group of CHF patients was modestly correlated to the impairment of exercise capacity and low VO_{2peak} .

2.1.6 CHF and skeletal muscle histochemistry and biochemistry

Histological (Derman et al., 1994) and biochemical (Sullivan et al., 1990) abnormalities of muscle are stronger predictors of fatigue in CHF patients than primary circulatory deficiencies (Massie et al., 1987) or muscle atrophy (Mancini et al., 1992). CHF patients exhibit an increased percentage of type IIb fibres, atrophy of type IIa and type IIb (Glycolytic) fibres (Sullivan et al., 1990) and no change of type I fibres, compared to control subjects (Mancini et al., 1989).

These changes are only partly explained by disuse atrophy. Some CHF patients (e.g. dilated cardiomyopathies) appear to exhibit generalised (i.e. skeletal muscle)

myopathies (Dunnigan et al., 1987). Despite muscle wasting in CHF (Miyagi et al., 1991), maximal force per unit of muscle is unchanged (Minotti et al., 1993). The volume density of mitochondria is reduced and this correlates with the severity of the CHF (Drexler et al., 1992). Although Massie et al., (1996) found no differences in capillaries per muscle fibre in CHF patients when compared to normal subjects, Drexler et al., (1992) showed that the capillary length density is reduced in CHF.

While glycolytic enzyme levels are normal in CHF, oxidative enzymes are reduced (Sullivan et al., 1990) and there is an early shift towards glycolysis and lactate production at low relative exercise intensities (Massie et al., 1987). Carey et al. (1996) recently measured lower levels of oxidative enzymes in lung transplant recipients, a group who exhibit exercise limitations similar to those seen in CHF. The transplant group had elevated resting levels of lactate and inosine monophosphate (IMP), a marker of metabolic stress. Broqvist et al., (1992) found lower levels of adenosine triphosphate (ATP) and creatine phosphate (PCr), even at rest, which provides a rationale for measuring muscle metabolites at rest, as this may provide some information about patients' metabolic state.

Taken together, the changes in histochemistry and biochemistry indicate a shift from aerobic to anaerobic metabolism in CHF. This is consistent with the observed earlier onset of blood lactate accumulation in CHF patients during incremental exercise (Sullivan et al., 1990). The greater contribution from anaerobic processes during exercise is also evident from the rapid depletion of PCr and early muscle acidosis (Chati et al., 1994). Additionally, Wilson et al. (1985) observed a more rapid rise in the inorganic phosphate to PCr ratio (Pi/PCr) with incremental workloads.

2.1.7 CHF and skeletal muscle metabolism

An abnormality in intrinsic skeletal muscle performance may also contribute to the reduction in exercise performance. Belardinelli et al. (1995) conducted a training study in which CHF patients underwent a supervised program of cycling for 30 minutes at 40% peak VO_2 , three times per week for eight weeks. They concluded that the mechanism responsible for their study's favourable change in exercise capacity involved an increase in mitochondrial density, which reflects an improvement in the oxidative capacity of trained skeletal muscles.

Although previous studies have shown that the magnitude of this improvement is dependent on the intensity of the training stimulus used, patients with mild CHF may take advantage of low intensity exercise training sufficient to minimise untoward cardiovascular events. Mortality in CHF patients has been shown to be associated with exercise tolerance and not only left ventricular ejection fraction (Johnson et al., 1993).

Minotti and Massie, (1992) also used resonance imaging to find that muscle size is smaller in CHF patients and that muscle strength, but not muscle endurance, is proportional to muscle size. They studied nine patients with heart failure and nine control subjects who performed repetitive finger flexion of the non-dominant forearm at sub-maximal workloads 15 minutes per day for four weeks. The patients with heart failure continued to have a greater decline in phosphocreatine and pH during exercise than control subjects. This training regimen improved both the endurance and metabolism of the trained muscle but had no effect on the untrained forearm. Although this result indicates that training improves the muscle abnormalities characteristic of CHF patients, it does not prove whether the initial changes are due

to deconditioning or determine to what extent systemic training can improve overall exercise capacity.

Muscle metabolism of patients with heart failure has been examined using magnetic resonance imaging (MRI). Massie et al. (1988) examined changes in forearm skeletal muscle metabolism during gradual incremental flexor digitorum superficialis exercise in eleven patients with CHF and seven age-matched controls using MRI. In their study the increase in the Pi/PCr ratio and decrease in pH found in forearm skeletal muscle during exercise were similar to the changes observed by Wilson et al. (1993). The pronounced increase in the inorganic phosphate, phosphocreatine ratio and decrease in pH was thought to reflect a loss of muscle mass rather than an intrinsic muscle abnormality.

Adamopoulos et al. (1993) and Mancini et al. (1988) conducted studies in patients with heart failure which examined muscle metabolism during calf muscle (a weight bearing muscle) exercise and found abnormalities similar to those in the forearm. The results from these studies would endorse the conclusion that in patients with heart failure there is an intrinsic abnormality in skeletal muscle metabolic function. This data would support a primary abnormality of muscle metabolism as the reason for impaired exercise performance rather than muscle atrophy or alteration in skeletal muscle blood flow.

2.1.8 Breathlessness

The exercise capacity of patients with CHF is limited by dyspnoea (breathlessness), fatigue or both (Rossi 1992). While the mechanisms causing breathlessness in CHF patients stimulate much debate, a number of factors are likely to be involved. Sullivan et al. (1988) pointed out that there is very little relation between pulmonary

artery pressure and dyspnoea. Rossi (1992) argued that it has become increasingly clear that although the mechanism of breathlessness is complex, it is unlikely to be related to acute changes in pulmonary capillary pressure as had been previously suggested.

While respiratory muscle function had been thought to contribute to breathlessness, Sullivan et al. (1988) demonstrated that the primary mechanism of an abnormally increased ventilatory rate in CHF is an abnormal increase in physiological dead space per breath. The researchers suggested that this is caused by ventilation-perfusion mismatching, resulting from an abnormally low cardiac output. Rossi (1992) argued that if right ventricular function is a significant determinant of pulmonary perfusion, one would not expect to see a correlation between pulmonary artery pressure and dyspnoea, because the pulmonary artery pressure would fall as the right ventricular ejection fraction deteriorates.

2.1.9 Conclusion

CHF is a debilitating disease with a poor survival rate at five years from onset. The major symptoms of CHF are fatigue on exertion and breathlessness, which together limit exercise capacity and quality of life. Recently, a consensus has emerged that the deterioration of muscle structure and function is the most important mechanism causing fatigue, and perhaps even breathlessness in CHF. As a corollary, the classical theory that left ventricular dysfunction explained the intolerance of CHF patients to exercise has largely been discarded in favour of the peripheral mechanisms. Unlike healthy people, oxygen extraction by the muscles, rather than oxygen delivery, appears to be the limiting factor in maximal exercise in CHF patients.

Nearly three decades ago, the hemodynamic interrelation between the heart and the peripheral circulation was recognised and provided the rationale for vasodilator therapy. It is now becoming clear that neurohormonal interactions between the periphery and the heart are important determinants of the symptoms and prognosis of patients with CHF. Interventions that alter these interactions are now accepted therapeutic approaches. Exercise should be considered one of these (Minotti and Massie, 1992).

2.2 Endurance training and CAD

In healthy controls endurance training causes improvements in peripheral circulation and muscle metabolism but not muscle hypertrophy. Training adaptations within muscles include improvements in oxidative metabolism and blood flow to muscles and fibres (Wilmore and Costill, 1988).

As a response to effective physical training, heart rate and rate-pressure product for given work levels decreases (Kellerman, 1992). Expected training effects include a decrease in heart rate, systolic blood pressure, muscular blood flow, lactic acid concentration and myocardial oxygen demands. Other responses include increases in the arteriovenous oxygen difference for maximal and submaximal work, concentration of oxidative enzymes, larger mitochondrial mass and maximal oxygen consumption. In CHF patients, aerobic training caused a reduction in ventilatory requirements during exertion (Coats et al., 1992), which was attributed to lower anaerobic metabolism in skeletal muscle and / or improved pulmonary gas exchange after training.

While walking is promoted for CAD patients, Grais, (1991) pointed out that many activities of daily living require arm work to a greater extent than leg work. Studies

have shown that the favourable physiologic adaptations to aerobic exercise are largely specific to the muscle groups that have been trained. Kelemen et al. (1986) found that improvement in aerobic capacity in cardiac patients can be accomplished with less vigorous exercise than previously observed in normal subjects. The intensity of training needed to elicit the desired training effects appears to be low for both aerobic (Belardinelli et al., 1995) and resistance training (Daub et al., 1996) and this enhances the usefulness of exercise training for CHF patients.

2.2.1 Resistance training and CAD

Strength can be defined as the maximum ability to apply or to resist force. Power is simply the product of strength and speed, and is measured by $\text{power} = \text{force} \times \text{velocity}$. The capacity of muscle to repeatedly develop near maximal force is termed muscular endurance.

Both muscular endurance and power are dependent upon levels of strength (Wilmore and Costill, 1988). Weight training has traditionally been recognised for its contributions to strength, power and / or muscular endurance (Wilmore, 1977). Electromyographic (EMG) studies indicate that the strength gains from resistance training can be partly attributed to neuromuscular adaptations such as improved co-ordination and increased activation of muscles (Braith et al., 1989).

Facilitation of motor unit recruitment through reducing autogenic inhibition and / or increasing general neural traffic, as well as increased synchronisation of motor unit firing, are possible neurogenic explanations for increased strength with training, particularly during the early stages of training (Wilmore and Costill, 1988). Possible myogenic factors include hypertrophy of individual muscle fibres, increases in

myofibrils and filaments, and hyperplasia. Power is increased by gains in strength and / or speed.

In studies of healthy adults Fleck (1987, 1988), found that resistance training can result in adaptations of the cardiovascular system including morphological heart changes, systolic and diastolic cardiac function, heart rate, blood pressure and acute responses to resistance training. Kelemen and Stewart (1985) found that combined resistance and aerobic training appeared to be an efficient form of training for enhancing both strength and cardiovascular endurance in CAD patients. When added to a cardiac rehabilitation program this training was found to be both safe and effective, with improvements in fitness parameters similar to those observed in healthy individuals. McCartney et al. (1991) also concluded that combined aerobic and weight-lifting training was a more effective method of increasing aerobic performance and strength than traditional aerobic training alone.

Cardiac exercise rehabilitation programs for CAD patients had omitted strength training activities, particularly isometric exercise, due to concerns regarding the risks of cardiovascular incidents such as ventricular arrhythmias, systolic hypotension and ischaemia (Fleck, 1988; Kelemen et al., 1986; Faigenbaum et al., 1990; Haslam et al., 1988; Featherstone et al., 1993; Wiecek et al., 1990; McCartney et al., 1989; Ghilarducci et al., 1989; Squires et al., 1991). Haslam et al. (1988) questioned this assumption when they measured intra-arterial blood pressure directly during weight training and found pressures to be within a clinically-acceptable range at 40% of one maximum voluntary contraction (MVC).

Research into patients with ischaemic heart disease (IHD) had suggested that isometric exercise may also precipitate arrhythmias, angina pectoris, and left

ventricular dysfunction during exercise (Stewart 1989; Franklin et al, 1991; Atkins et al., 1976; Sparling et al., 1990). In a study conducted by Bertagnoli et al. (1986) however, a combination of isometric and aerobic exercise was well tolerated in patients with CAD. These researchers did emphasise the fact however, that their findings may not extend to patients with more severe coronary disease or low exercise capacity.

Several other studies have also shown that isometric exertion fails to elicit angina pectoris, ischaemic ST segment displacement or ventricular arrhythmias among selected cardiac patients (Franklin et al., 1991; DeBusk et al., 1978). Haissly et al. (1974) concluded that cardiac patients have a relatively good tolerance for isometric testing. Butler et al. (1987) studied the effects of circuit weight training at 60% MVC in patients with CAD and found that left ventricular (LV) wall motion abnormalities on echocardiography improved with combined aerobic and resistance weight training activities whilst they worsened with treadmill exercise at 85% of maximal heart rate.

In this study Butler et al. (1987) found that a worsening of wall motion occurred in five of sixty-one left ventricular segments during aerobic exercise, but in only one segment during circuit weight training. No subject showed ischaemic ST segment abnormalities or angina pectoris during MVC testing. These researchers also concluded that combined aerobic and resistance training appears to be as safe or safer than treadmill or bicycle exercise for CAD patients.

Similarly, Featherstone et al. (1993) found that myocardial oxygen supply-to-demand balance was more favourable with maximal repetition weight lifting than with maximal treadmill exercise. They measured lower limb (bilateral) and upper limb (unilateral)

strength of CAD patients using free weights and reported no symptoms or electrocardiographic abnormalities during lifting. Haennel et al. (1991) also found a decrease in heart rate and an increase in stroke volume at sub-maximal workloads in CAGS patients training on hydraulic resistance equipment. This study compared the effects of hydraulic circuit training on a group of CAGS patients to a non-exercising control group and concluded that patients recovering from CAGS can safely participate in a hydraulic resistance training program with the expectation of improving muscular strength and endurance.

Following three years participation in a combined aerobic and resistance training program, CAD patients were found to have significant improvements in arm and leg strength and self efficacy (Stewart et al., 1988). While this study was not randomised, the researchers concluded that when performed at a moderate level, resistance training appears to be a safe low-risk exercise in patients with cardiac conditions. Stewart (1989) went on to suggest that resistance training contributes to better health by preventing musculo-skeletal problems of the lower back, helping to reach and maintain desirable body weight with favourable modification of risk factors for CAD and improving self image and self efficacy.

A further argument for the inclusion of resistance training in cardiac rehabilitation programs is the potential for gains in cardiovascular endurance. Haennel et al. (1991) reported an average increase of 14% in peak VO_2 in CAGS patients who had participated in eight weeks of incremental hydraulic resistance training while McCartney et al. (1991) found a 15% increase in the maximal power achieved in a group of CAD patients who had undergone ten weeks of combined resistance and aerobic training as compared with a 2% increase in the aerobic control group.

In a prospective, randomised evaluation of CAD patients during ten weeks of resistance and aerobic training, Kelemen et al. (1986) found a significant increase in treadmill time (12% in Bruce treadmill time) in the resistance training group of patients with a history of myocardial infarction, angina and CAGS compared to the control group who maintained their regular aerobic exercise regimen.

Resistance training also demonstrated a significant increase in peak oxygen consumption and a reduction in heart rate at a given sub-maximal workload on the leg cycle ergometry test after resistance training in a study conducted by Wilke et al. (1991). The study also found that the combined aerobic and resistance training program was the more popular form of upper extremity training than weight carrying. Conversely, in a study designed to determine the effects of resistance training on risk factors for CAD, 11 healthy untrained males (Hurley et al., 1988) were found to have significant increases in strength (50% Upper Limb and 33 % Lower Limb) without alterations in VO_{2max} . This study did conclude however, that resistance training can lower other risk factors for CAD independent of changes in VO_2 .

It has further been contended (Haennel et al., 1991) that increases in strength may attenuate heart rate and blood pressure responses to a given load because that load would then represent a lower percentage of maximum voluntary contraction (MVC). These researchers implied that such improvements would facilitate a safe return to employment, although this endpoint was not specifically addressed by the study (Haennel et al., 1991).

Other proponents for the inclusion of resistance training for patients with CAD also argue that many activities of daily living, as well as vocational and recreational

activities, place demands on the cardiovascular system which more closely resemble heavy resistance exercise than aerobic exercise (Faigenbaum et al., 1990; Sparling et al., 1990; Butler et al., 1987; Franklin et al., 1991; McCartney et al., 1989).

A growing number of researchers have studied the effects of resistance training in various populations of patients with a range of coronary conditions (Table 2.3). Generally their results support the inclusion of resistance training in cardiac rehabilitation programs although there is much conjecture as to inclusion and exclusion criteria and resistance training limitations. Debate continues regarding the type and intensity of resistance training, the selection of patients likely to safely benefit from training and the possible aerobic improvements likely to be obtained from resistance training. There is also a range of opinions as to the degree to which strength and muscular endurance gains are to be made by cardiac patients through resistance training.

There does appear to be consensus on several points. Increasing research suggests that complementary resistance training, when appropriately prescribed and supervised, has favourable effects on strength, aerobic power, blood pressure, blood lipids and psychosocial well being (Franklin et al., 1991). A number of researchers (Kelemen 1989; Featherstone et al., 1993) agree that combined resistive / aerobic training may facilitate central and / or peripheral cardiovascular change which may improve aerobic power better than aerobic training alone. These researchers stressed the importance of proper supervision of patients and the need for the careful selection of patients. It is generally agreed that resistance exercise should not be substituted for aerobic exercise in cardiopulmonary rehabilitation programs but should be used as a supplement to aerobic training.

Authors	Sessions per week	Program Length	Training Program	Inclusion	LVEF	Time Post AMI	Training Intensity	Reps/Duration	Tests	Results : Training Group
Haennel et al., 1991	3	8 weeks	Aerobic Resist	CAGS NYHA I&II		10 weeks	70% VO ₂	12-16	VO ₂ MVC	P.Torque increase LL 89-111 Nm UL 68-81 Nm 11% increase VO ₂
Sparling et al., 1990	3	6 weeks	Resist	AMI Cabg		24 months	30-40 % MVC	12-20	MVC	22% increase in strength
Stewart 1989	3	10 weeks	Resist	AMI CAGS		3 months	40 % MVC	10-15	MVC	24% increase in strength
Franklin et al., 1991	3	10 weeks	Resist			3 months	30 % MVC	10-15	MVC	Undefined Increase in strength
Kelemen et al., 1986	2	10 weeks	Resist	CAD		3 months	40% MVC	10-15	MVC VO ₂	24% increase in strength. 11% increase in treadmill time
Mc Cartney et al., 1991	2	10 weeks	Resist Aerobic	AMI CAGS		1 month	40-80 % MVC		MVC Isokinetic	21-43% increase in strength 15% increase in maximal power
Ghilarducci et al., 1989	3	10 weeks	Resist	AMI CAGS		3 months	80% MVC	8-12	VO ₂ MVC	12-46% increase in strength
Wilke et al., 1991	3	12 weeks	Aerobic Resist	AMI IHD		6 months	70% MVC	7-12	VO ₂ MVC	30% increase in UL and 35% LL strength
Faigenbaum et al., 1991	2	Test only	Resist	CAGS AMI		3 months	75 % MVC	15	MVC VO ₂	HR and Systolic BP higher during VO ₂ than MVC

Not reported	Reps : Repetitions	Resist : Resistance training	Isokin. Isokinetic	L.L : Lower Limb	U.L: Upper Limb
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Table 2.3 Summary of trials of exercise training in patients with CAD

Authors	Sessions per week	Program length	Training Program	Inclusion	LVEF	Time Post AAMI	Training Intensity	Reps/Duration	Tests	Results : Training Group
Belardinelli et al., 1995	3	8 weeks	Aerobic	CHF NYHA II & III	31%	3 months	40% VO ₂		VO ₂ Muscle biopsy	17% increase in Peak VO ₂ . High correlation found between the increase in peak oxygen uptake and mitochondrial density.
McKelvie et al., 1995		Test only	Resist Aerobic	CAD & CHF NYHA I-III	27%		70% peak HR 70% MVC		VO ₂ peak MVC Direct BP- ultrasound	LV function well maintained during unilateral leg press ex. No significant difference in LV response between cycling and resistance exercise performed at the same relative intensity.
Yamani et al., 1995		Test only	Resist Aerobic	CAD & CHF NYHA I - IV	5-37%	6 months			VO ₂ peak Isokinetic 9 min. walk	Skeletal muscle function is abnormal in CHF patients but impaired function did not last beyond a few minutes after ex.
Koch et al., 1992	3	12 weeks	Resist	CHF	<40%	3 months	Increment	Increment	MVC QoL GXT	Total muscular strength increased from 77kg to 112kg QoL increased 63% GXT improved by 34%
Conn et al., 1982	3-5	12 weeks	Aerobic	CHF	20%	12 weeks				Increase in calculated METS by 1.5 METS; no change in LVEF
Sullivan et al., 1988	3-5	16-24 weeks	Aerobic	CAD & CHF NYHA I-III	9-33%	3 months	75% peak HR	60 min.	VO ₂ peak	Increase in peak VO ₂ 3.8ml/kg; increased leg arteriovenous O ₂ difference of 1.6ml/dl; increase peak exercise leg blood flow by 0.5 litres/min.
Coats et al., 1990	5	8 weeks	Aerobic	CHF NYHA II & III	18%		70-80% peak HR	20 min.	VO ₂ peak	Exercise duration increased by 2.2 min. Peak VO ₂ increased by 3.2 ml/kg/min. Improvement in symptom scores
Coats et al., 1992	5	8 weeks	Aerobic	CHF NYHA II-III	20%	3 months	70-80% peak HR	20 min.	VO ₂ peak	Exercise time increased by 2.6 min. Peak VO ₂ increased by 2.4 ml/kg/min. Improvement in symptom scores. Reduced sympathetic tone.
Not reported		Reps : Repetitions	Resist : Resistance training	Isokin : Isokinetic	L.L : Lower Limb	U.L : Upper Limb				

Table 2.4 Summary of trials of exercise training in patients with CHF

2.2.2 Exercise Training and CHF

Rossi (1992) argued that the doctrine that heart failure is an absolute contraindication to physical training and rehabilitation should no longer be accepted. He argued on the basis that uncontrolled, retrospective studies have suggested possible beneficial effects of training in subjects with moderate or even severe left ventricular dysfunction without evidence of clinically manifest congestive heart failure.

A range of studies have examined the potential efficacy of exercise training for patients with CHF (Table 2.4). McKelvie et al. (1995) points out that although the effects of exercise training have been examined in only a relatively small number of CHF patients, the results have been promising, as exercise training has been found to improve exercise capacity and reduce symptoms. Additionally it is pointed out that conversely, limiting physical activity may not only be unnecessary but may also be undesirable because it could lead to further disability.

Several authors argue for the inclusion of CHF patients in exercise rehabilitation programs based on similar arguments to those used for the inclusion of CAD patients. Conn et al. (1982) examined the ability of patients with severely impaired left ventricular function to participate in an exercise rehabilitation program. Ten patients with a resting LVEF of less than 27% after myocardial infarction participated in a supervised exercise program with a follow-up period of 4 to 37 months. None of the patients had a decrease in ejection fraction with exercise and the mean exercise capacity improved from 7.0 ± 1.9 METS to 8.5 ± 2.9 METS. The oxygen pulse (maximal oxygen uptake/maximal heart rate), which was used to assess the effect of training, increased from 12.8 ± 2.5 ml/beat to 15.7 ± 3.2 ml/beat after training ($p < 0.01$).

Goble et al. (1991) separately stratified patients who had pulmonary oedema in a coronary care unit in a prospective randomised study of high and low intensity exercise after AMI, demonstrating that these patients could safely participate in exercise training and significantly improve their functional capacity. Kellermann (1992) found that while physical training does not change left ventricular end-diastolic pressure, end-diastolic volume, ejection fraction or segmental contractility, no deterioration was found after short-term training in patients with ejection fractions below 45% and there was an improvement of cardiocirculatory performance for given work tasks. This included a decrease in heart rate, systolic blood pressure and the rate-pressure product. It also produced an increase of stroke volume, overall physical work performance, oxygen pulse, and in some instances, the rise of the angina pectoris threshold heart rate and threshold rate-pressure product in patients with angina pectoris.

While Kellermann (1992) does not believe that there is irrefutable evidence that proves physical training has an effect on longevity, it was postulated that there are a number of important physiologic and psychological benefits to be accompanied by prolonged exercise therapy in selected CHF patients. Results from Belardinelli et al. (1995) concluded that low intensity exercise training improves exercise capacity as well as lactate threshold and peak oxygen uptake in patients with mild CHF. The researchers believe that increased aerobic capacity is strongly associated with changes in the mitochondrial content, but not capillarization of skeletal muscle. Conclusions reached suggest that skeletal muscle in patients with mild CHF can adapt metabolically and functionally to low intensity training (Belardinelli et al., 1995).

While some authors speculate that ventricular function improves with training, others have found unchanged left ventricular dimensions and conclude that training has no direct influence on the myocardium, either beneficial or detrimental (Kellermann 1986). Koch et

al. (1992) found that ventricular function at rest was not significantly modified by rehabilitation whether for the end diastolic diameter of the left ventricle, the percentage of shortening of the left ventricle, or the ejection fraction at rest. They concluded that modifications include morphology as much as cellular histochemistry which is responsible for a considerable decrease in muscular performance. It was also thought to be the cause of an aggravation of the initial imbalance from excessive loss of peripheral energy. It was therefore argued that training enables this vicious circle to be broken by giving the muscle back its ability to perform.

It was less than a decade ago that researchers held the view that resistance training was deleterious to the well-being of coronary patients. Today resistance training is an integral component of most cardiac rehabilitation programs for CAD patients (McKelvie et al., 1995; McCartney et al., 1991). Our understanding of the correlation between deconditioning and CHF compels researchers to examine the possible efficacy of all forms of physical training for this population.

2.2.3 Aerobic Training and CHF

It had been assumed in the past that patients with extensive myocardial damage and severely depressed left ventricular function had either limited exercise capability or an excessive risk for exercise - related morbid events. Furthermore, their ability to achieve a cardiovascular training effect had been questioned. Sullivan et al. (1988) studied the pathophysiologic basis of increased exercise ventilation in the presence of CHF. Twelve patients with CHF with an LVEF of between nine and 33% trained for 60 minutes three to five times per week at 75% of their peak oxygen uptake. After 16 to 24 weeks of training the patients had a 3.8 -ml/min per kg increase in peak oxygen uptake. The study concluded that activation of abnormal reflexes due to hemodynamic derangements during exercise were not important in determining ventilation.

In a controlled crossover trial of eight weeks of exercise training, Coats et al. (1992) examined 17 men with stable, moderate to severe CHF (LVEF $19.6 \pm 2.3\%$). The increases in exercise tolerance and peak oxygen uptake achieved following aerobic training were indicative that an exercise training program can improve exercise performance and ventilation in CHF patients. The percentage increase in exercise time or peak oxygen consumption was similar to that seen in training programs in normal subjects and patients with ischaemic heart disease without heart failure. A significant shift away from sympathetic toward enhanced vagal activity was also detected after training.

In the aerobic training study conducted by Belardinelli et al. (1995) 27 patients with mild CHF were trained at 40% of peak oxygen uptake three times per week for eight weeks. Results included an increase in peak oxygen uptake (17% $p < 0.0001$), lactic acidosis threshold (20% $p < 0.0002$) and peak work load (21% $p < 0.002$) in the trained group only. The researchers concluded that patients with stable CHF can achieve significant improvement in functional capacity from a low intensity exercise training regimen. The mechanism thought to be responsible for this favourable effect involves an increase in mitochondrial density, reflecting an improvement in oxidative capacity of trained skeletal muscles.

Lee et al., (1979) studied 18 patients with a previous myocardial infarction and an LVEF of 18%. The patients were instructed to train at 70-80% of their maximal heart rate for 20 to 45 min ~ four days/week. Training continued for an average of 19 months and resulted in an improved incremental exercise time of 1.1 min, with no change in LVEF. Jetté et al. (1991) randomised ten patients with CHF for an exercise program and for eight usual treatments. A significant improvement in peak oxygen uptake from 1.0 to 1.2 litres/min was observed after training.

Conn et al. (1982) demonstrated the ability of ten patients who had sustained a myocardial infarction and who had a residual LVEF of less than 27%, to both safely undertake a closely supervised program of physical training and to attain a training effect. The program consisted of stretching exercises, bicycle ergometry and walking / jogging three to five times per week. For the first month patients completed exercises at a pulse rate of less than 100 b.p.m. Thereafter, exercise intensity during ergometry and walking / jogging sessions was prescribed to produce brief periods of maximal heart rates of 70% to 80%. No adverse cardiovascular events (syncope, ventricular fibrillation, accelerated angina, myocardial infarction or symptoms of increased congestive heart failure) occurred during the exercise sessions. Although these patients with severely depressed ventricular function were not randomly selected for this study, the principle of the potential trainability of patients with severely depressed left ventricular function is important.

Neurohormonal interactions between the periphery and the heart are important determinants of the symptoms and prognosis of patients with CHF (Minotti, 1992). Training, by virtue of its effects on muscle and the peripheral circulation, may reverse these abnormalities. Whether the peripheral abnormalities that are now recognised as important determinants of exercise capacity are initiated by deconditioning continues to stimulate debate, but it is clear that many of these issues can be reversed by exercise training and that activity restriction should be avoided in most patients with CHF.

2.2.4 Strength and Endurance Training and CHF

The most consistent and striking change in CHF is increased muscle fatigability defined by the decline in maximal voluntary force during sustained contraction and diminished anaerobic endurance during repetitive exercise (Minotti, 1992). Studies have consistently demonstrated that the development of fatigue for a given absolute workload is greater in

patients with heart failure than amongst healthy subjects (McKelvie et al., 1995; Oka et al., 1993; Szlachcic et al., 1985).

Despite the obvious potential benefits of strength and anaerobic endurance training for patients with CHF, it is commonly believed that resistance training should be used with caution for patients with poor LV function because of the perceived risk of developing further wall motion abnormalities or arrhythmias during isometric or isodynamic exertion (Effron, 1989; Atkins, 1976; Franklin, 1991).

Some early studies of isometric exercise demonstrated that LV function was compromised in functionally-limited patients (NYHA Class III) who also had ischaemic heart disease (Kivowitz et al., 1971) however, the deterioration was only transient. When aerobic training was supplemented with resistance exercise in men with CAD there was a lower incidence of arrhythmias and ischaemia (Daub et al., 1996) and LV wall motion abnormalities (Butler et al., 1987) during the resistance components of the programs than the aerobic components.

In hypertensive and cardiac patients with normal left ventricular (LV) function at rest, resistive training increases LV mass index without deleterious effects on LV systolic and diastolic function. However, in patients with abnormal resting LV function, resistive training might have adverse effects on LV systolic function. Effron (1989) echoed the sentiments of many researchers when he stated that moderate levels of resistive training can be a useful adjunct to cardiac rehabilitation programs with the caveat that it be used with caution in patients with abnormal LV function at rest.

In their randomised, controlled study of 25 men and women with CHF (LVEF < 40%) following three months of aerobic and resistance training, Koch et al. (1992) used a

graded approach to build up a small number of muscle groups at a time to simultaneously avoid too much pressure on the heart. The training elicited significant increases in total muscle strength (77 ± 20 kg to 112 ± 24 kg) and performance during the exercise test with increasing load. Maximal muscle strength improved by 34% in the rehabilitation group with no improvement in the control group. The actual training methodology is unclear but these researchers claim that LV function was not significantly modified by rehabilitation with no significant bradycardia effects either at rest or during exercise. Systolic blood pressure was said not to have been modified by the program.

The finding of 34% improvement in performance was thought to be due to the effect of training on peripheral vessels, since the function of the left ventricle was not improved. The researchers concluded that physical training for patients with CHF means an increase in muscular strength and better adaptation to effort through a purely peripheral action. The study concluded that the risks appear to be very slight if the exercises are adapted to patients who have been carefully selected and monitored.

In a non-randomised study, McKelvie et al., (1995) compared the hemodynamic responses of ten CHF patients to resistance exercise and cycling. Blood pressure responses to training were measured via intra-brachial artery catheter. There were no observed adverse symptoms, arrhythmias or ST segment abnormalities. Compared to cycling, resistance unilateral leg press exercise produced a comparable systolic blood pressure, a lower heart rate and higher diastolic blood pressure which theoretically suggests better myocardial perfusion. Findings from this study support the use of submaximal resistance training by selected CHF patients. The response of CHF patients to bilateral and upper extremity resistance exercise has yet to be investigated.

2.3 Exercise testing

While it is possible to monitor a few selected physiological parameters during exercise in a natural environment, there are many limitations on those variables that can be assessed accurately without disturbing performance (Wilmore and Costill 1988). Comprehensive assessment of human performance however, requires the use of a wide variety of assessment tools and is conducted more safely and in much greater depth under the highly-controlled conditions in a laboratory.

2.3.1 Aerobic Testing

Exercise scientists agree that the best laboratory measure of cardiorespiratory endurance capacity is an individual's maximal oxygen uptake ($\text{VO}_{2\text{max}}$). Oxygen uptake is measured directly while the individual exercises at increasing intensities either on a treadmill or bicycle ergometer. With the increase in speed and /or grade on the treadmill, or in resistance of the cycle ergometer, there is a corresponding increase in oxygen consumption. Eventually the maximum ability to deliver oxygen to the active muscle mass is reached, and the oxygen uptake will plateau as the rate of work continues to increase (Wilmore and Costill, 1988).

Maximal exercise testing involves exercising a patient to a sign or symptom-limited end point, which is commonly manifested as severe leg fatigue or dyspnoea. Electrocardiographic and physiological ischaemic indicators seen on exercise testing identify not only those patients who have coronary artery disease, but are useful indicators of the severity of the disease. In most exercise laboratories, the electrocardiographic criteria for ischemia involves a net change of 1 mm or more of either horizontal or down sloping ST-segment depression (Irwin and Techlin, 1985).

2.3.2 Strength & Anaerobic Endurance Testing

There is no universally accepted standard measure which is considered representative of total body muscular strength in the same manner that $\text{VO}_{2_{\max}}$ is considered representative of cardiorespiratory endurance capacity (Wilmore and Costill, 1995).

A common method of evaluating muscular strength has been the isometric assessment of MVC. Once one repetition has been ascertained, training protocols are designed and based on a percentage of this standard; i.e. 30% of the maximum capacity (30% MVC).

The concept of isokinetic exercise and the introduction of isokinetic dynamometers interfaced with computers have expanded the choice of instrumentation for clinical measurement of muscle performance. Isokinetic systems provide muscle loading by controlling the velocity of limb movement as opposed to loading by external weight (Wrigley and Grant, 1995). This allows a muscle group to work maximally throughout its range of motion. Assessment of concentric, eccentric and isometric muscle contractions can be measured depending on the specific instrument used. These instruments can be used to quantitatively document torque during muscle contraction and joint motion. Work, power and fatigue can be calculated from the data (Harms-Ringdahl, 1993).

2.4 Exercise Testing and CHF

To date there have been few published studies that have evaluated the potential efficacy of any form of exercise training for patients with CHF (Rossi, 1992). Specific testing protocols for this population are therefore also lacking and tend to be modifications or adaptations of assessment tools used for the broader CAD population.

2.4.1 Aerobic Testing and CHF

Protocols to test aerobic capacity have varied significantly in CHF patients. Most commonly VO_{2peak} is measured during treadmill exercise, usually using a modified Naughton Protocol. McKelvie et al. (1995) used a graded incremental exercise protocol on a cycle ergometer to measure the peak power output of each of ten CHF patients while Kellermann (1992) linked cardiocirculatory performance for given work tasks. Belardinelli et al. (1995) measured exercise capacity as well as lactate threshold and peak oxygen uptake in patients with mild CHF. Koch et al. (1992) used performance during the exercise test as a measure of aerobic capacity.

2.4.2 Strength & Anaerobic Endurance Testing and CHF

While many researchers have used MVC assessment to measure muscle strength, Asmussen, (1981) and Atkins (1976) question the safety of this procedure for patients with CAD. Asmussen found a significant increase in the occurrence of ventricular arrhythmias during isometric stress testing. Some 38% of the patients tested using a hand grip dynamometer developed ventricular arrhythmias, a 16% increase above the incidence with dynamic testing. In the study all patients who developed arrhythmias did so at 50% maximal voluntary contraction and only 11 % at 25% of MVC. Atkins (1976) reported similar findings and recommended that stress tests based on isometric exercise should only be performed where facilities for monitoring and resuscitation are available. On the contrary McKelvie et al. (1995) found resistance exercise and cycling produced similar hemodynamic responses.

Haennel et al. (1991) studied the efficacy of hydraulic resistance training of patients recovering from CAGS surgery. They used isokinetic testing to assess muscular strength and anaerobic endurance and their findings support the contention that isokinetic testing

may negate some of the risks involved in isometric testing as in the use of the MVC assessment.

2.5 Heart Rate Variability

Neurohumoral modulation of cardiovascular function is an important component of the hemodynamic alterations in patients with chronic congestive heart failure. Analysis of heart rate variability is a non-invasive means of investigating the autonomic control of the heart (Saul et al., 1988).

2.5.1 Heart Rate Variability and CHF

Heart rate variability (HRV) is a non-invasive parameter of neurohormonal (mainly autonomic) modulation of heart rate. HRV reflects the variability of RR intervals on the surface ECG or “instantaneous heart rate”. This technique has been extensively validated as a reproducible, non-invasive method for assessing autonomic activity. The pattern of RR intervals may be displayed visually as a simple tachogram and then analysed statistically in the time domain (e.g the standard deviation of all RR intervals over the entire recording, after removing artefacts and ectopic beats). Low HRV is a powerful prognosticator of sudden death (Algra et al., 1993).

The variability of heart rate and respiratory signals both derived from ambulatory electrocardiographic recordings were analysed with power spectral analysis to evaluate autonomic control in 25 patients with CHF (Saul et al., 1988). Findings demonstrated a marked derangement of heart rate modulation in patients with severe CHF. The frequency characteristics of fluctuations in these patients are consistent with abnormal baroreflex responsiveness to physiologic stimuli and suggest that there is diminished vagal, but relatively preserved sympathetic, modulation of heart rate (Saul et al., 1988).

2.6 Forearm Blood Flow and CHF

Regional blood flow to exercising skeletal muscle is reduced in patients with CHF and is a key factor determining the limitation of exercise capacity (Poole-Wilson et al., 1988). Minotti et al. (1992) found that forearm blood flow during submaximal exercise was not changed by aerobic training. This observation is consistent with studies in both normal subjects (and patients with CHF) that suggest that peripheral blood flow at a given submaximal work load was unchanged or decreased after training (Sullivan et al., 1988; Belardinelli et al., 1995). Although a redistribution of flow to the exercising muscles cannot be excluded, the crucial point for patients with mild CHF is that improvements in exercising muscle oxidative capacity can be achieved without an increase in limb blood flow or cardiac output.

2.7 Blood Pressure and CHF

Although there are numerous possible mechanisms by which both aerobic and resistive exercise training can reduce blood pressure, the diverse aetiology's of hypertension make it difficult to attribute all changes to a universal mechanism (Goldberg, 1989). As with autonomic function, Coats et al. (1992) found in patients with moderate to severe ischaemic heart failure that an exercise training program can improve hemodynamics. Training responses of the CHF patients in this study were mostly consistent with a normal response to regular exercise training.

2.8 Quality of life

Quality of life is now generally regarded as an important outcome of clinical management and research trials. It is often used as a multi-dimensional term to cover the functional, psychological, cognitive and social aspects of living. Some quality of life scales have been designed to incorporate a range of dimensions but it is very important to be able to sensitively and reliably measure specific aspects of this quality. This is especially

important for the measurement of depression, which, often in a relatively mild form, is commonly found in cardiac patients (Hare and Davis, 1996).

2.8.1 Quality of Life, CHF and Exercise Training

Patients with cardiac disease potentially have many physical, psychological, and social problems. With adequate rehabilitation, most patients can return to enjoyable, productive lives (Hare & Davis, 1996). Kellermann (1992) found that physical training can improve the emotional stability of CHF patients. While the study did not find any correlation between training intensity and psychologic effect, patients were found to have a decrease in fear, anxiety, and frustration as a consequence of training. The study also claimed that exercise enhanced patient's return to work, their self-esteem and general motivation to life. Other findings included a significant drop in absence at work and decreased dependency on drugs.

In their study of CHF patients and graded physical exercise, Koch et al. (1992) found that changes in quality of life were estimated by patients to have improved by 63% in the rehabilitation group and only 4% in the control group. The researchers also point out that 80% of the patients asked for training to be continued over a longer period of time. Stewart et al. (1989) also concluded that when performed at a moderate level, resistance training appears to improve self image and self efficacy in patients with coronary conditions, although this was not a specific study of CHF patients.

2.9 Perceived exertion

Patient's perceptions of exercise-related symptom intensities can be recorded using the Borg scale from 6 - 20 for measurement of exercise-related symptom intensities.

Ben-Ari and Kellermann (1983) examined the physiologic and perceptual responses to very low and moderate intensity training programs in CAD patients. Perceptual responses were obtained using Borg's scale consisting of grades 6 to 20. Four months of low intensity training showed a significant ($p=0.001$ to 0.08) decrease in perceived intensity at similar work loads. An additional four months of moderate intensity training resulted in further decreases in perceived exertion. McCartney et al. (1991) used the Borg scale (0 - 10) to measure changes of perceived exertion in ten CAD patients following 20 sessions of exercise training. The study found that the time to a Borg scale leg effort rating of 7 (very severe) while cycling at 80% of initial maximal power increased by 109% in the combined resistance and aerobic training group as compared to 11% in the aerobic control group. The study concluded that lower ratings of perceived exertion in the weight-trained patients may result in patients being able to perform strenuous activities of daily living with a diminished perception of effort.

Chapter 3

3.0 Significance and aims of the project

A number of recent studies have demonstrated that resistance training programs using low, moderate or high resistance are physiologically safe and effective for strength development in patients with CAD, CAGS, or who have had a previous myocardial infarction (Verril et al., 1992; Butler et al., 1987; Ghilarducci et al., 1989; Haennel et al., 1991; Haslam et al., 1988; Kelemen et al., 1986; Sparling et al., 1990; Stewart et al., 1988).

Further investigation into the safety and efficacy of such programs for patients with CHF have been called for as protagonists recognise the potential benefits to be gained from regular physical activity for this population (McKelvie et al., 1995; Koch, 1992, Belardinelli et al., 1995).

The primary aim of this study is to examine the effects of sub-maximal resistance training for patients with CHF on exercise tolerance. The secondary aim is to assess the effects of this training on quality of life, cardiorespiratory efficiency and power and some parameters of autonomic function and peripheral blood flow. Similar methodologies have previously been applied to study the effects of aerobic training in CHF, but not to resistance training.

If resistance training is found to be a safe and effective method of increasing strength and endurance in CHF patients, cardiac rehabilitation programs will be able to incorporate resistance training for CHF patients who are commonly excluded or restricted in current programs.

3.1 Adherence to Cardiac Rehabilitation Programs

One of the major limitations in cardiac rehabilitation programs is adherence to the exercise regime. The drop out rate during some rehabilitation programs is high, even in programs with high staff : patient ratios (Kelemen & Stewart, 1985) and up to 50% of cardiac patients fail to continue regular exercise after participating in secondary rehabilitation programs (Oldridge 1991; Rothstein et al., 1987; Ward et al., 1991). A resistance regime may provide diversity (Franklin, 1991) and therefore benefit patients who find it difficult to commit themselves to traditional aerobic training (Kelemen & Stewart, 1985; Oldridge, 1991 & Rothstein et al., 1987).

3.2 Activities of daily living and recreation

Many activities of daily living, as well as vocational and recreational activities, place demands on the cardiovascular system which more closely resemble resistance exercise than aerobic activity (Faigenbaum et al., 1990). Improvement in muscle strength and anaerobic endurance, as well as cardiovascular endurance, enables the individual to perform occupational and leisure tasks with more ease, and perhaps with less demand on the cardiovascular system (AACPR, 1991 and Stewart, 1989). This study contends that overall improvement in upper and lower body strength will allow CHF patients to perform everyday lifting activities at a lower energy cost and with greater efficiency of movement. Improved work tolerance from peripheral adaptations within trained skeletal muscle may enhance the ability of patients to resume routine activities of daily living.

3.3 Vocational Considerations

Increasing numbers of younger men and women are surviving acute myocardial infarctions and surgical procedures performed on the heart (AACPR, 1991). Many of these people are now returning to full-time employment and cardiac rehabilitation programs will need to address vocational issues relating to work capacity which include strength and endurance. This includes patients with not only ischaemic damage to the myocardium, but also those with other processes resulting in poor myocardial function.

Chapter 4

4.0 Methods

4.1.1 Inclusion Criteria

- i) Patients with a history of stable chronic heart failure (NYHA II & III)
- ii) LVEF less than 40%.
- iii) Male or female
- iv) No age restriction
- v) No change in medication in the three months prior to participation in the study

4.1.2 Exclusion criteria

- i) Patients whose conditions were likely to be exacerbated by exercise such as angina or musculo-skeletal conditions.
- ii) Patients with limited English were also excluded on the grounds that they may have difficulty in completing the quality of life questionnaires and understanding the instructions given during the training program.
- iii) Patients who would have difficulties getting to the hospital for the three training sessions per week because of their geographical location.

4.1.3 Ethical considerations

Patients obtained informed medical clearance (i.e. the treating cardiologist was aware of the nature of the study and believed that the risk of any major adverse event was low in that particular subject (Appendix A). Patients were informed in writing and verbally of the experimental procedures and signed a letter of consent prior to commencement (Appendix B). This study was approved by the Human Experimentation Ethics Committee of Victoria University of Technology and the

Austin and Repatriation Medical Centre (hereafter referred to as "hospital") Committee of Human Ethics in Research. In all aspects this study conformed to the Australian National Health and Medical Research Council (N.H & M.R.C) guidelines.

4.1.4 Patient population

Nine males (63.1 +/- 11.1 years) with chronic heart failure (NYHA II & III) (LVEF 26% ± 6%) volunteered for this study (Table 4.1). Eight patients had a history of ischaemic heart disease (IHD) and one had congestive cardiomyopathy (CCM). Six were in sinus rhythm (SR), two were in atrial fibrillation (AF) and one was paced.

Patient	Age	LVEF	History	Rhythm	NYHA
1	55	35	IHD	SR	2
2	53	21	IHD	SR	3
3	80	21	IHD	Paced	2
4	31	31	IHD	SR	2
5	75	24	CCM	AF	3
6	58	20	IH.D	AF	2
7	66	27	IH.D	SR	2
8	54	17	IH.D	SR	3
9	75	25	IH.D	SR	3
Mean	63.1	24.6	8 IHD	6 SR, 2 AF,	
SDEV	± 1.2	± 5.7	1 CCM	1 Paced	
± SEM	±4	±2			

Table 4.1 Cardiac profiles for the nine patients; LVEF, history, rhythm, NYHA classification

Table 4.2 Research Design indicating the timetable for the Heart Failure Study including assessments and training schedule.

Week 1	Week 2	Week 2	Week 3 - 14	Week 15	Week 15
Day 1	*Day 1	*Day 2	Training Sessions	*Day 1	*Day 2
Initial Interview	Assessments Heart Rate Variability	Assessments Isokinetic Strength and Anaerobic Endurance Tests	Monday 9 am Wednesday 9 am Friday 9 am • Warm Up • Resistance & Aerobic Training • Cool Down	Heart Rate Variability	Isokinetic Strength and Anaerobic Endurance Tests
Demographic Data Collection	Forearm Blood Flow	Six Minute Walk Test		Forearm Blood Flow	Six Minute Walk Test
Quality of Life Questionnaires completed	Blood Tests			Blood Tests	Quality of Life Questionnaires
	Exercise Tolerance VO _{2peak}			Exercise Tolerance VO _{2peak}	
	24 Hour Holter Monitor			24 Hour Holter Monitor	

* Day 1 and Day 2 indicate consecutive days

4.2 Study Design

This was a prospective, uncontrolled, observational, outcome study with patient assessment before and after an eleven week program of circuit training including resistance exercise. The pattern of data collection is outlined in Table 4.2.

The order of assessments was standardised and not randomized so as to minimise effects of subsequent tests. For example, Quality of life questionnaires were completed before the exercise assessments. Heart rate variability, forearm blood flow and blood tests were completed prior to exercise testing. Maximal exercise testing (VO_2) was completed on a day separate from the isokinetic tests and six minute walk. For practical reasons, Quality of Life assessments were administered at the completion of the training program, after the other assessments.

4.2.1 Hypotheses

4.2.2 Primary hypothesis

Muscle strength and endurance can be safely increased in CHF patients.

4.2.3 Secondary hypothesis

Resistance training will also improve:

- i) Aerobic exercise capacity ($\text{VO}_{2\text{ peak}}$)
- ii) Functional capacity on six minute walk
- iii) Quality of life

4.2.4 Possible associations:

- i) Improvement in peripheral blood flow
- ii) Increased vasodilatory capacity
- iii) Increased vagal tone
- iv) Reduced sympathetic activity
- v) Improved neurohormonal balance

4.3 Exercise Tests

4.3.1 Six minute walk

Functional aerobic capacity was assessed using a six minute walk protocol before and after the training program (Appendix C). Patients were advised to cover as much ground as they could in the allocated six minutes. An indoor corridor was used with markers 20 metres apart and the distance calculated to measure total distance walked. Only standardized encouragement was allowed.

4.3.2 Measurement of peak oxygen consumption (VO_{2peak})

VO_{2peak} tests were conducted in an exercise laboratory at the hospital where emergency protocols existed, resuscitation equipment (defibrillator and emergency drug cart) was available and trained personnel were present. VO_{2peak} was determined as the peak oxygen consumption measured during a symptom-limited graded exercise test on an electronically-braked bicycle ergometer (Ergomed, Siemens, USA). Seat height was adjusted for each individual patient (the same setting being used for pre- and post-tests). A physician and a qualified ECG technician used a digitised electrocardiograph (Marquette, Model Code12, USA) to record and monitor the ECG. A Pulse oximeter (Oxi-Radiometer, USA) was used to monitor arterial oxygen saturation. The attending physician determined blood pressure at minute intervals using a mercury sphygmomanometer. Patients had their nasal airways occluded by a nose clip while cycling and wore running shoes, socks and loose fitting long pants. A disinfected and dried non-rebreathing valve (Hans-Rudolph, California) was used to collect expired air.

VO_{2peak} was determined using open circuit spirometry. Expired air was measured by a Beckman metabolic measurement cart (Beckman MMCI, California, 1975).

This system takes into account the standard gas laws. A mixture of 5% CO₂ (certified to $\pm 0.1\%$), 15% O₂ (certified to $\pm 0.2\%$) and balance N₂, was used to calibrate the gas analyses (OM-II for O₂, LB-2 for CO₂) immediately before and after each VO_{2peak} test. The same gas mixture was used for the pre- and post-testing. Calibration of the gas flow turbine was performed using a certified 3 litre syringe (Hans-Rudolph, USA).

The exercise protocol consisted of an incremental test to volitional fatigue. Patients' perception of exercise-related symptoms were recorded using a modified Borg scale (Borg 1973; Appendix C). They were asked to score their feelings of breathlessness and leg fatigue during the most difficult minute of the test. Subjects began cycling at ten watts (W), with the resistance increased by 10 W.min⁻¹. During each minute, the following measurements were made: heart rate, oxygen saturation, VO₂, minute ventilation (V_E (BTPS)), carbon dioxide production (VCO₂) and respiratory exchange ratio (RER = VCO₂/VO₂).

Signs and symptoms for stopping VO_{2peak} tests:

1. Severe chest pain suggestive of angina
2. Severe dyspnoea
3. Marked apprehension, mental confusion or lack of co-ordination
4. Sudden onset of pallor and sweating
5. Onset of cyanosis
6. SaO₂ falling below 80%
7. Electrocardiographic signs:
 - Frequent ventricular premature beats, particularly when showing the R on T wave, frequent runs of 3 or more, and paroxysmal ventricular tachycardia

- Second or third degree heart block
- Ischaemic changes, marked S-T depression
- T wave inversion, or the appearance of a pathological Q wave
- Appearance of bundle branch block pattern

8. Blood Pressure signs:

- Any fall in systolic pressure below the resting value
- A fall of more than 20mmHg in systolic pressure occurring after the normal exercise rise
- Systolic BP in excess of 300 mmHg or a diastolic in excess of 140mmHg

Anaerobic Thresholds:

Graphs were developed from VO₂ data for :

- i. VE versus VO₂
- ii. VCO₂ versus VO₂
- iii. VE/VO₂ versus VO₂
- iv. VE / VCO₂ versus VO₂

Pre-training and post-training results were plotted individually and without any form of identification. V-slope anaerobic threshold results were independently estimated by five independent arbitrators. The mean score for the five evaluations was determined to estimate anaerobic threshold. These results were then analysed using a matched pairs t-test to estimate levels of significance.

4.2.3 Determination of muscular strength and anaerobic endurance

Isokinetic dynamic muscle testing was conducted on an isokinetic concentric dynamometer (MERAC[®]USA). The system was calibrated prior to the implementation of the study. The system was set to anatomical zero and gravitational torque compensation for each patient. Seat height, seat-back tilt and

length, seat bottom length, dynamometer height, and all attachment settings were recorded during the first assessment and replicated for the post-assessment. Lower limb strength and endurance were assessed using knee flexion / extension at $60\text{ }^{\circ}\cdot\text{s}^{-1}$ (peak torque of three repetitions) and $120\text{ }^{\circ}\cdot\text{s}^{-1}$ (peak torque of 20 repetitions), respectively. Upper limb strength and endurance were measured using a push / pull adaptor: strength was assessed at $60\text{ }^{\circ}\cdot\text{s}^{-1}$ (peak torque of three repetitions) and endurance at $180\text{ }^{\circ}\cdot\text{s}^{-1}$ (peak torque of 20 repetitions). Each testing session was conducted using the protocol outlined in Table 4.3.

Patients blood pressures were checked immediately before and after each testing session. The patients' ECG were monitored throughout strength and muscular endurance assessments. A defibrillator and a critical care nurse were present during all testing sessions.

Procedure	Detail
Stretch Program	<ul style="list-style-type: none"> • Five minute slow cycle • Five upper limb range of movement stretches • Four lower limb range of movement stretches
Patient Stabilisation	Patients are strapped into the dynamometer to minimise extraneous body movements and to isolate the joint being tested.
Blood Pressure and ECG check	Resting Blood pressure was recorded and ECG electrodes were placed on the patient to monitor rhythms during testing.
Instruct patient on procedures	Patients were instructed on breathing technique (to avoid valsalva) and each step of the test was explained in detail prior to familiarisation.
Familiarisation sets	Patients were given three familiarisation sets prior to testing at each velocity for each joint tested. Rest periods of sixty seconds were used between sets.
Strength and endurance tests	Following the testing protocol outlined in the text, patients were tested with one minute rest periods between each velocity.
Blood Pressure and ECG check	Resting Blood pressure was recorded and ECG electrodes are placed on the patient to monitor rhythms during testing.

Table 4.3 Strength and anaerobic endurance testing protocol

4.3.4 Heart rate variability (HRV)

Neurohumoral modulation of cardiovascular function was analysed using heart rate variability as a non-invasive means of investigating the autonomic control of the heart (Saul et al., 1988; Kamen and Tonkin, 1995). A thirty minute ECG was recorded from precordial electrodes. The R-R interval was measured from the ECG by an AMLAB (Assoc. Measurement, Sydney) system, which has a verified resolution of +/- 1 msec. The data was recorded on disk for subsequent processing. The ECG was analysed according to the following :

(i) simple tachogram; this was inspected for artefacts and aberrant beat-to-beat intervals (eg premature ventricular contractions, PVC's); these were removed prior to further processing; (ii) spectral analysis (Fast Fourier transform of the tachogram time series; (iii) Poincaré plot: this is a scatter plot of the current R-R interval and the preceding interval. This provides an indication of correlation patterns inherent in the R-R interval. (iv) correlation dimension was calculated using the Grassberger & Procaccia (1983) algorithm, as implemented in commercially available software (Insite, California). The correlation dimension algorithm assumes statistical stationarity. This required recording periods where psychophysiological stimuli remain constant. These tests were therefore conducted in a quiet room and patients were assessed whilst lying down. HRV was assessed in the time domain using the root mean square of successive differences (RMSSD) as the primary measure of parasympathetic function.

4.3.5 Forearm blood flow (FBF)

Effects of resistance exercise training on peripheral vascular responsiveness were assessed by measuring changes in forearm blood flow before and after the training program using strain gauge venous occlusion plethysmography. Following baseline

(BL) measurements, FBF responses to vasodilator stimuli were tested via submaximal hand grip exercise at 15, 30 and 45% of maximal voluntary contraction (MVC) and peak reactive hyperaemia (PRH) following 4 minutes of limb ischaemia.

4.3.6 Resting Blood Pressure

Resting blood pressures were measured in both lying and standing postures, using a digitised automatic sphygmomanometer system (Critikon Dynamap, USA). Each measurement was repeated four times and the mean blood pressures were reported for pre- and post-training.

4.3.7 Quality of life

Quality of life was measured using three questionnaires designed to elicit responses to a range of psycho-social and emotional questions (Appendix C). All three questionnaires have been validated (Rector, 1993; Hare & Davis, 1996, Spielberger et al., 1970). Overall quality of life was tested using the Minnesota Living with Heart Failure questionnaire (Rector, 1993). Depression was evaluated using the Cardiac Depression Scale (Hare, 1993, 1996) and the Spielberger State Anxiety Score (Spielberger et al., 1970) was used to measure anxiety.

4.4 Exercise training

Training sessions were conducted three times per week for eleven weeks. To allow for adequate recovery from the initial assessments, subjects began the training program one week after the pre-tests. Three days recovery was allowed between the conclusion of training and the post-tests. During the early stages of the program training sessions took up to twenty minutes. By the end of the eleven week program some subjects were exercising for up to fifty minutes.

Sessions were conducted at the same time and on the same days each week in the Physiotherapy Department of the hospital. They only performed resistance training whilst being monitored on an ECG / defibrillator by a qualified cardiac nurse. Patients underwent resting blood pressure, ECG and heart rate checks before and after each training session. Patients were also advised to report all signs and symptoms during training.

4.4.1 Training Protocol

A modified circuit training regimen with a range of aerobic equipment (stationary cycles, upper body ergometers and walking) was used. For the resistance training a hydraulic weight training system (Total Power Hydra-gym[®] Hydra-Gym, Australia) was utilised.

Circuits consisted of a combination of three hydraulic resistance exercises preceded and followed by a number of aerobic activities including stationary cycling, walking and upper limb ergometry. Patients were instructed to exercise at a level that they felt comfortable during all exercise activities. A specific training protocol was used during resistance training activities however, patients selected their own speeds and resistance settings for the aerobic training equipment.

1. Cycle (aerobic activity)
2. Chest press (resistance activity)
3. Arm cycle (aerobic activity)
4. Leg flexion / extension (resistance activity)
5. Walk (aerobic activity)
6. Shoulder press (resistance activity)
7. Stationary cycle (aerobic activity)
8. Walk (cool down) for 5 minutes

Pre-exercise heart rates were used as references to determine work / rest ratios. It was felt that a pre-exercise rather than a true resting heart rate was a more appropriate reference, since pre-exercise heart rates were more representative of the subject at “rest” in the hospital environment. Furthermore, the measurement of true resting heart rates would have required patients to monitor their own heart rates at home on awakening. There was no way to ensure the reliability and compliance of patients to measure and record their own resting heart rates. Patients were instructed to rest for five minutes prior to the pre-exercise heart rate being recorded. Patients were given car parking passes to the car park closest to the department in which they would be training. This was done in an attempt to limit and standardise the amount of walking that would be done by patients prior to a training session.

Work / Rest Protocol, based on pre-exercise and recovery heart rates

Prescribed rest intervals were determined by heart rate. The next work interval was initiated once the heart rate had returned to within 10% of the pre-exercise heart rate. Recovery was therefore defined as a return to within 10% of the pre-exercise heart rate (Table 4.4).

Week	1-2	3-4	5-6	7-8	9-10	11
¹ Work interval for each exercise (secs)	30	30	40	40	50	60
Rest interval between exercises (secs)	Time for heart rate to return to within 10% of pre-exercise heart rate.					
² Number of Circuits	1	1	1	2	2	2-3
³ Resistance Setting	2	⁴ Increase by one setting when an increase of 25% in reps over two consecutive sessions is achieved				
Cycle (mins)	2 - 3	3 - 4	4 - 5	5 - 6	6 - 7	7 - 8
Arm Cycle(mins)	1 - 2	2-3	3-4	4-5	5-6	6-7

Table 4.4 Work / Rest Protocol

¹ Work interval for each exercise in seconds.

Patients are encouraged to continue to perform each of the three resistance activities for the full duration of each work interval for each session. In weeks 1 and 2, patients complete thirty seconds of continuous leg extension work before resting. They then complete thirty seconds of the chest press exercise before resting. They then complete thirty seconds of the shoulder press exercise before resting. These three activities constitute one circuit of resistance exercises.

² Number of Circuits. A full circuit includes all aerobic and resistance exercise activities. In weeks 1-6, patients complete one circuit only of all activities. In week seven they complete a second full circuit of resistance and aerobic activities. In week eleven complete a third circuit.

³ Resistance Setting

Settings on the Hydra-Gym determined the velocity at which the lever arm could move. A low velocity setting corresponds to a high resistance and therefore greater muscle force. Training intensity was defined by 1) machine setting (velocity) which

is inversely proportional to the resistance offered by the machine and 2) the relative effort of the patient (maximal or submaximal). There were six resistance settings for each of the three activities.

4Increases in resistance settings. Resistance began on setting two for all patients. A record of the number of repetitions achieved during each work interval was kept for each of the three resistance activities (Appendix D). Progression to the next velocity/resistance setting on the Hydra-Gym was determined by the number of repetitions achieved within a given work interval in the two previous training sessions. When a patient remained symptom-free and recorded an increase of 25% in the number of repetitions achieved in a work interval during two consecutive training sessions, the resistance/velocity of that particular resistance activity was increased to the next setting.

Patients were instructed to work at a speed that they could manage comfortably. During the initial training sessions many patients exerted what appeared to be a maximal effort. These patients were encouraged to work at a more comfortable pace. Most patients therefore tended to work submaximally during the training sessions.

Maximal allowable work load for the upper body trainer was set at one watt per kilogram of body weight. i.e. a patient weighing 80 kilograms worked at a maximum of 80 watts. Patients were encouraged to work at their own speed and were advised to adjust the work load settings on the aerobic equipment according to how they were feeling on the day. Peak and average heart rates, blood pressure and cardiovascular signs and symptoms (i.e. pain, inconsistent heart rate or blood pressure, dizziness, pallor etc.) were monitored throughout all training sessions.

4.5 Statistical analyses

Strength and endurance tests were analysed using repeated measures analysis of variance (ANOVA), for within SUBJECT effects, for TRAINING (pre-versus post-training) and for EXERCISE (eight strength and endurance exercises). Univariate posthoc analysis (Neuman-Keuhls) was used to identify the locations of significant ANOVA effects. The recovery times for training were analysed in the same way. All other data, with the exception of the quality of life questionnaires and the Borg ratings of perceived exertion, were analysed using paired, two-tailed t-tests. The questionnaires and the Borg ratings were analysed using a non-parametric method (Wilcoxon signed-ranks matched-pairs test). A significance level of $p < 0.05$ was accepted for all statistical analyses.

Sub-maximal ventilation results were determined and cross-referenced between the nine patients. Results were graphed and statistically analysed using a matched pairs t-test.

Chapter 5

5.0 Results

5.1 Training Results

5.1.1 Heart rate recovery

During the eleven weeks of training heart rate recovery time decreased while the actual time patients were involved in resistance training (training interval-time) increased from 30 sec to 60 secs. Heart rates were monitored during each bout of resistance training (knee flexion-extension; chest push-pull and shoulder press). Heart rate recovery was measured in seconds and recovery time was measured as the time elapsed for heart rate to return to within 10% of pre-exercise heart rate.

There was a significant decrease in heart rate recovery time (Table 5.1) following each of the resistance training activities during the eleven week training program ($p < 0.001$ for each of the three resistance activities).

Heart rate recovery for eight patients during eleven week training program following shoulder press resistance activity.										
**	P	P	P	P	P	P	P	P		
*S	1	2	3	4	5	6	7	8	Mean	STDEV
1	140	60	85	70	65	30	30	30	64	37
2	83	70	80	70	100	30	20	30	60	30
3	110	60	70	40	65	30	30	130	67	37
4	110	110	70	60	30	30	50	30	61	34
5	110	60	80	60	40	30	20	40	55	29
6	100	70	50	30	60	40	30	30	51	25
7	90	110	60	30	60	30	45	30	57	30
8	90	75	60	30	30	30	30	30	47	25
9	110	60	30	30	60	20	40	30	48	29
10	120	60	60	30	30	20	30	40	49	32
11	40	40	30	30	40	40	50	30	38	7
12	30	60	30	60	40	40	20	30	39	15
13	120	30	30	60	100	30	20	40	54	37
14	120	110	40	60	60	30	30	30	60	36
15	120	0	40	30	70	30	30	15	42	37
16	52	60	40	115	60	30	30	20	51	30
17	25	30	30	30	60	40	30	15	33	13
18	30	30	20	40	60	30	30	20	33	13
19	30	30	40	30	60	20	20	20	31	14
20	30	45	30	30	45	30	30	30	34	7
21	40	50	20	20	60	30	30	15	33	16
22	30	60	40	30	25	20	15	20	30	14

Table 5.1 Heart rate recovery for eight patients during eleven week training program following shoulder press resistance activity. Note: The ninth patient was paced so there was no change in heart rate.
*S: Session Number ** P: Patient.

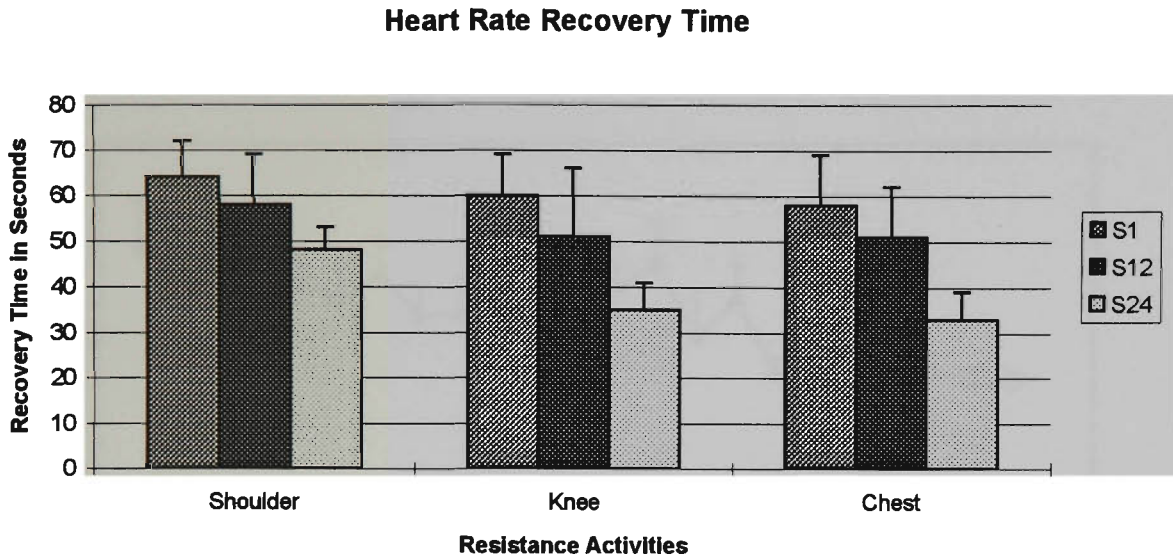


Fig. 5.1 Mean \pm SEM heart rate recovery time for each of the three resistance activities during sessions one, 12 and 24. *S: Session Number.

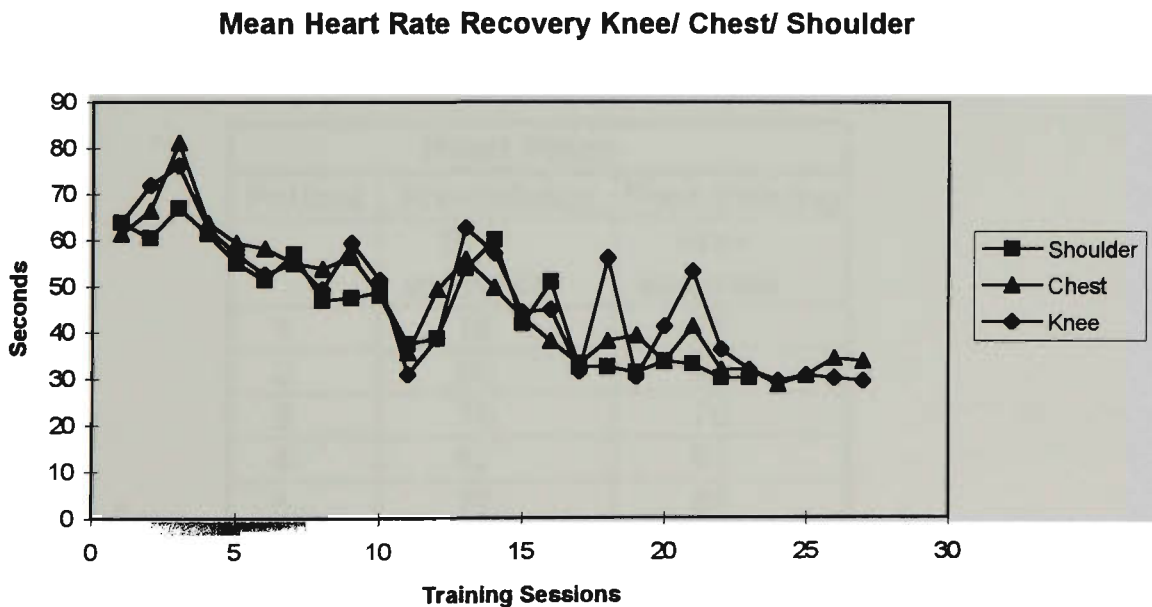


Fig. 5.2 Mean heart rate recovery times for eight patients for shoulder push-pull, knee flexion-extension and chest push-pull activities during the eleven week training program.

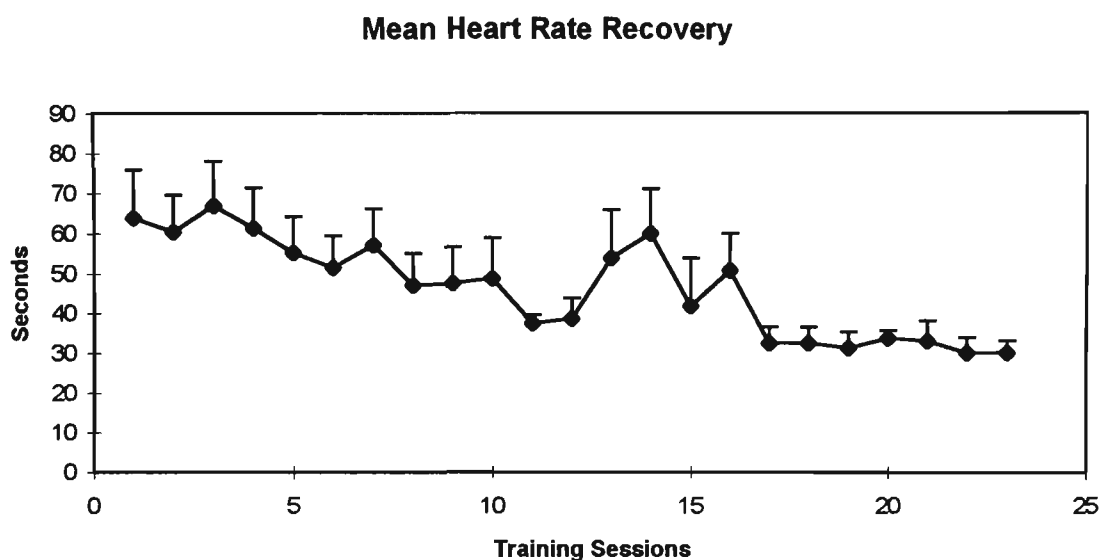


Fig. 5.3 Mean \pm SEM heart rate recovery times for eight patients following shoulder push-pull activity.

5.1.2 Pre-exercise heart rate

No significant changes in pre-exercise heart rate before or after the training program were recorded (Table 5.3).

Heart Rates		
Patient	Pre-training	Post-training
	Pre-exercise	Pre-exercise
1	76	77
2	80	91
3	70	70
4	57	61
5	77	85
6	79	91
7	91	87
8	78	73
9	71	68
Mean	75.4	78.0
STDEV	9.16	10.78
SEM	± 1	± 1.2

Table 5.2 Pre-exercise heart rates before and after the eleven week training program.

5.1.3 Changes in repetitions performed

All patients increased the number of repetitions completed in each training session over the eleven weeks of training for each of the three exercise activities (Fig. 5.4).

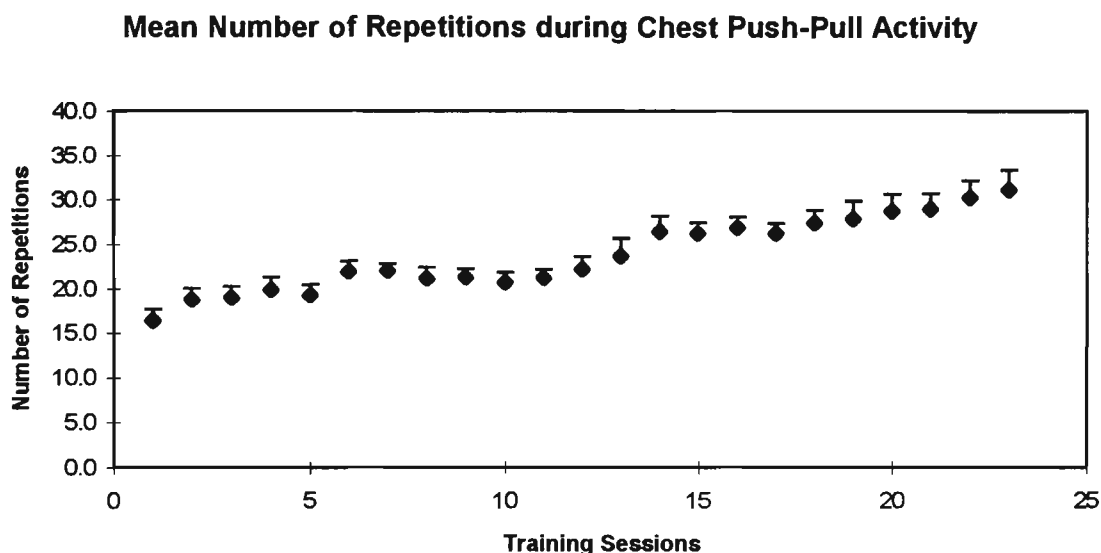


Fig. 5.4 Mean \pm SEM number of repetitions of chest push-pull activity performed by the nine patients in each of the training sessions.

There is a clear association between increases in exercise time and number of repetitions achieved (Fig. 5.5).

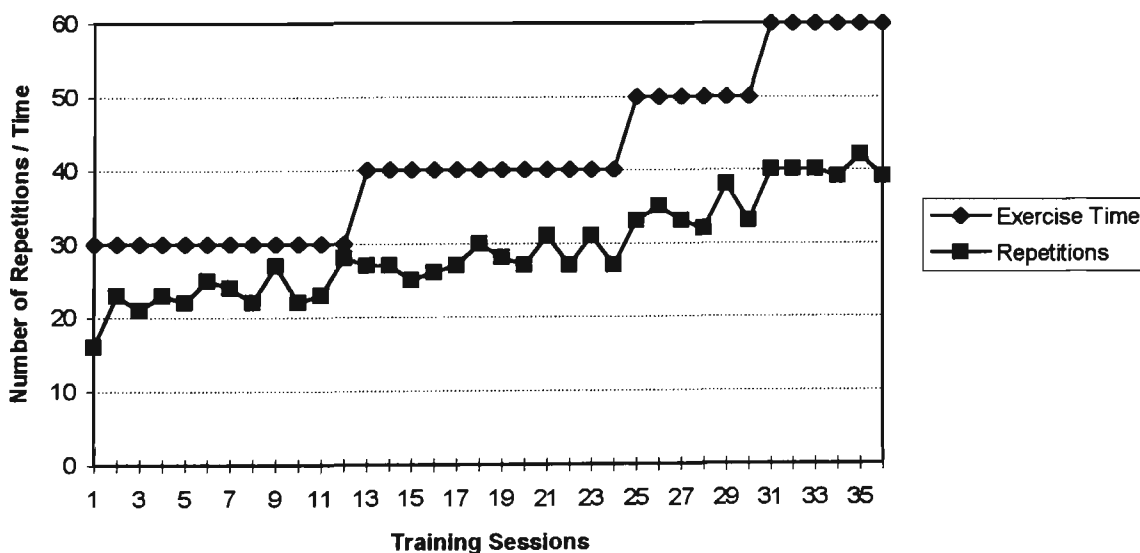


Fig. 5.5 Case Study : Exercise time and number of repetitions of the chest push/pull performed by one sample patient.

5.1.4 Peak heart rates during resistance training

There was no significant change in peak heart rates during resistance training (Fig 5.6)

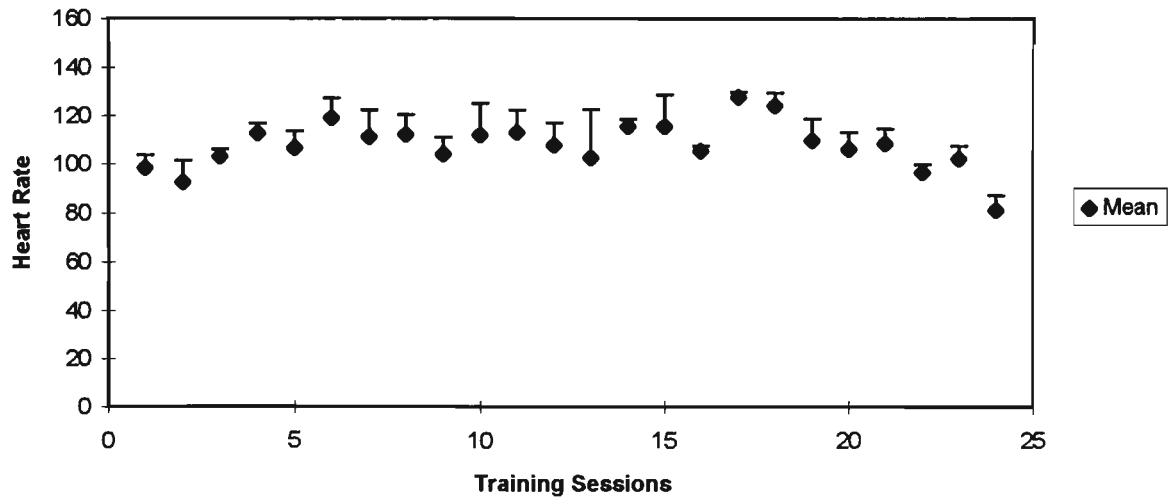


Fig. 5.6 Mean \pm SEM maximum heart rates achieved during the chest push pull resistance activity.

5.1.5 Changes in Resistance Settings

Resistance settings increased during the training program (Fig. 5.7).

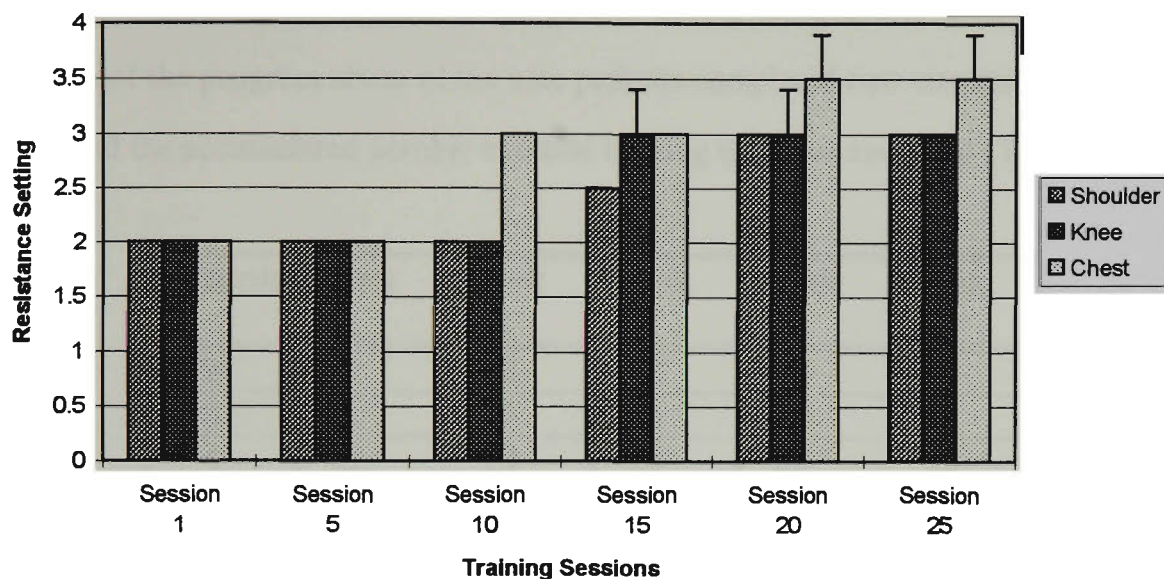


Fig. 5.7 Mean \pm SEM resistance settings for each of the three resistance activities.

5.1.6 Summary of changes in results for training parameters

Parameters	Chest	Shoulder	Knee
	Push/Pull	Press	Flexion/Extension
Pre-Exercise Heart Rate	Δ Nil	Δ Nil	Δ Nil
Peak Heart Rate	Δ Nil	Δ Nil	Δ Nil
Number of Repetitions	↑	↑	↑
Resistance Settings	↑	↑	↑
Recovery Times	↓	↓	↓

Table 5.3 Changes recorded during training in a range of parameters.

5.1.7 Cardiovascular Training

Time allocated to aerobic training was dependant on a number of patient self-reported measures and on the performance of the patient during the previous session. During the course of the program seven of the nine patients completed two circuits of aerobic training and the accumulated aerobic exercise training time was recorded (Table 5.5).

Patients	Week 2	Week 4	Week 6	Week 8	Week 10
P2	6	12	18	25	30
P3	6	10	15	20	25
P4	6	10	15	20	30
P5	6	10	15	20	30
P6	6	6	8	10	12
P7	6	8	10	15	20
P8	6	8	10	15	22
P9	6	8	10	12	15
Mean	6	9.00	12.63	17.13	23.00
±SEM	±0.6	±1	±1.4	±1.9	±2.5

Table 5.4 Total aerobic exercise time - aggregate of stationary cycling and arm ergometry for nine patients.

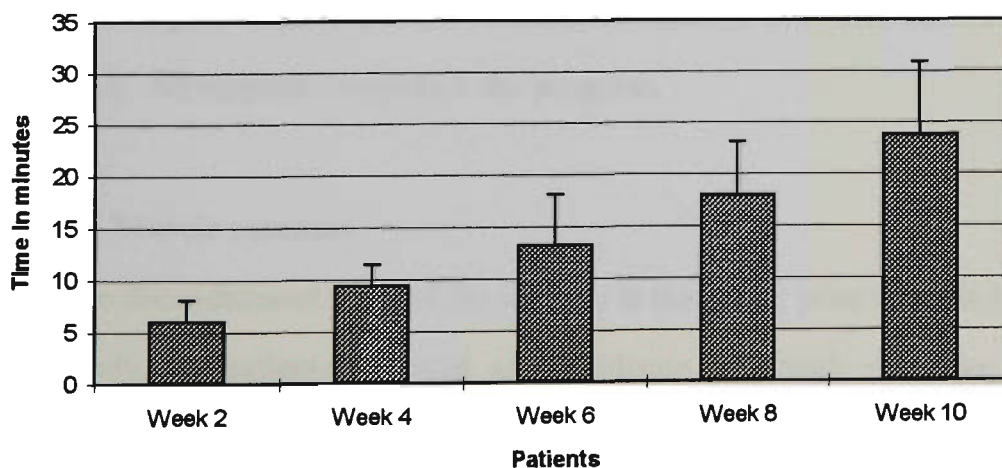


Fig. 5.8 Mean \pm SEM total aerobic exercise time.

5.1.8 Safety

There were no medical complications during the training program. There were several runs of VT recorded during resistance training in individual patients however these same patients had recorded similar arrhythmias on holter monitor testing and during the exercise tolerance tests. No patient developed difficulties during any aspect of the training or testing procedures.

5.1.9 Patient' s anecdotal self reporting

Patients reported that their ability to walk further with less effort increased during the course of the program. Many stated that as the training program progressed they were better able to cope with more strenuous activities such as walking up an incline. Some patients reported that they were sleeping more soundly and several patients pointed out that they had more energy by the end of the program.

5.1.10 Attendance

A 98% attendance rate was recorded for the training program. During the three hundred individual training sessions, only six occurrences of non-attendance were recorded. One patient missed three consecutive sessions and three others missed one session each. All subjects completed the program.

5.1.11 Muscle soreness

Despite the deconditioned state of the patients in this study prior to their involvement in this study, no patients reported any incidence of muscle soreness during the program.

5.2 Muscular strength & endurance

5.2.1 Assessments

There were increases in upper body strength (Peak Torque $42 \pm 8\%$ mean \pm S.E, $p < 0.001$, MANOVA) and anaerobic endurance (Total Work $24\% \pm 8\%$, $p < 0.05$). Percentage change based on the mean of individual changes.

	STRENGTH						ENDURANCE					
	Chest Push Peak Torque Newton Meters 60 ^o /s			Chest Pull Peak Torque Newton Meters 60 ^o /s			Chest Push Total Work Joules 120 ^o /s			Chest Pull Total Work Joules 120 ^o /s		
	Pre	Post	%	Pre	Post	%	Pre	Post	%	Pre	Post	%
Mean	162	207.4	31%	110.2	155.2	53%	84.8	92.7	13%	72.8	92.1	35%
STDEV	58.4	65.8	17%	47.1	41.4	46%	26.1	29.3	31%	30.8	30.3	35
\pm SEM	6.5	7.3	1.8	5.2	4.5	5	3	3.2	3.4	3.4	3.3	3.8

Table 5.5 Upper limb isokinetic strength and endurance results. Post : Post Training Pre : Pre Training. % : % change (Post - Pre).

	STRENGTH						ENDURANCE					
	Knee Extension Peak Torque Nm 60 ^o /s			Knee Flexion Peak Torque Newton Meters 60 ^o /s			Knee Extension Total Work Joules 180 ^o /s			Knee Flexion Total Work Joules 180 ^o /s		
	Pre	Post	%	Pre	Post	%	Pre	Post	%	Pre	Post	%
Mean	108.9	139	26%	43.4	50.1	17%	91.1	105.7	16%	42.5	40.8	18%
STDEV	33.4	57.1	35%	25.3	32.1	45%	27.9	40.7	27%	23.2	22.3	60%
\pm SEM	3.7	6.3	3.8	2.8	3.5	5	3	4.5	3	2.5	2.4	6.6

Table 5.6 Lower limb isokinetic strength and endurance results.

Lower body strength improved by an average of $22 \pm 9\%$ (combining results for knee extensors and flexors) while lower body endurance improved by $17 \pm 11\%$ (combining results for knee extensors and flexors). Similarly Chest Push - Pull data was combined into a single statistic for upper body strength and endurance.

5.2.2 Strength

Upper limb strength

Chest Push peak torque at 60 deg/s increased by a mean of 31%.

Chest Pull peak torque at 60 deg/s increased by a mean of 53%.

Lower Limb Strength

Knee Extension peak torque at 60deg/s increased by a mean of 26%.

Knee Flexion peak torque at 60 deg/s increased by a mean of 17%.

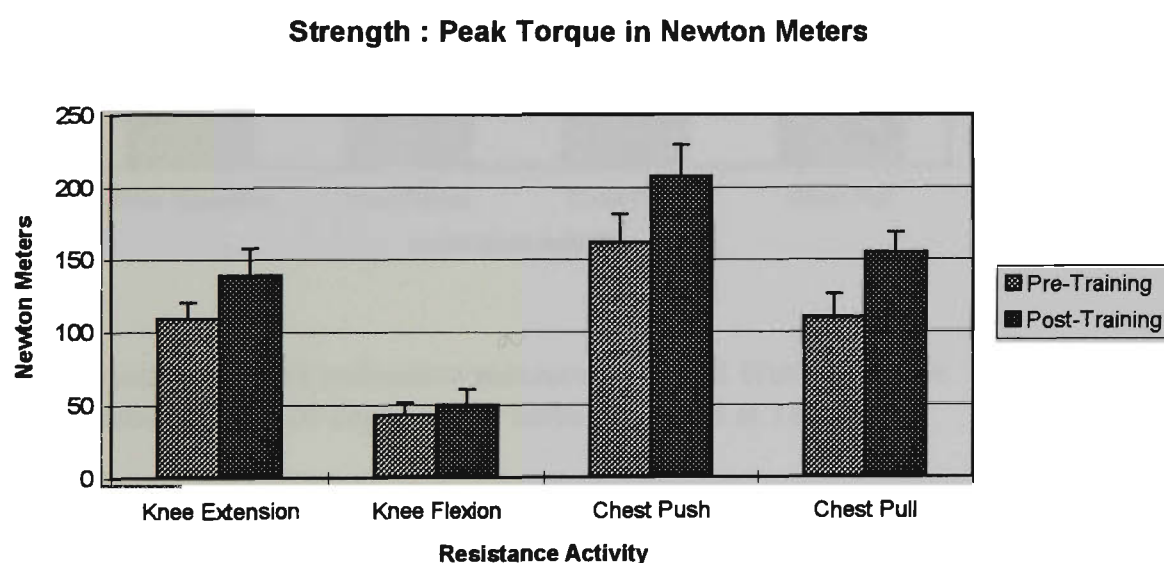


Fig. 5.9 Mean strength for upper and lower limbs measured as Peak Torque in Newton Meters at 60 deg/s.

5.2.3 Anaerobic Endurance

Upper limb anaerobic endurance

Chest Push total work increased by a mean of 13%.

Chest Pull total work increased by a mean of 35%.

Lower limb anaerobic endurance

Knee Extension total work increased by a mean of 16%.

Knee Flexion total work decreased by a mean of 18%.

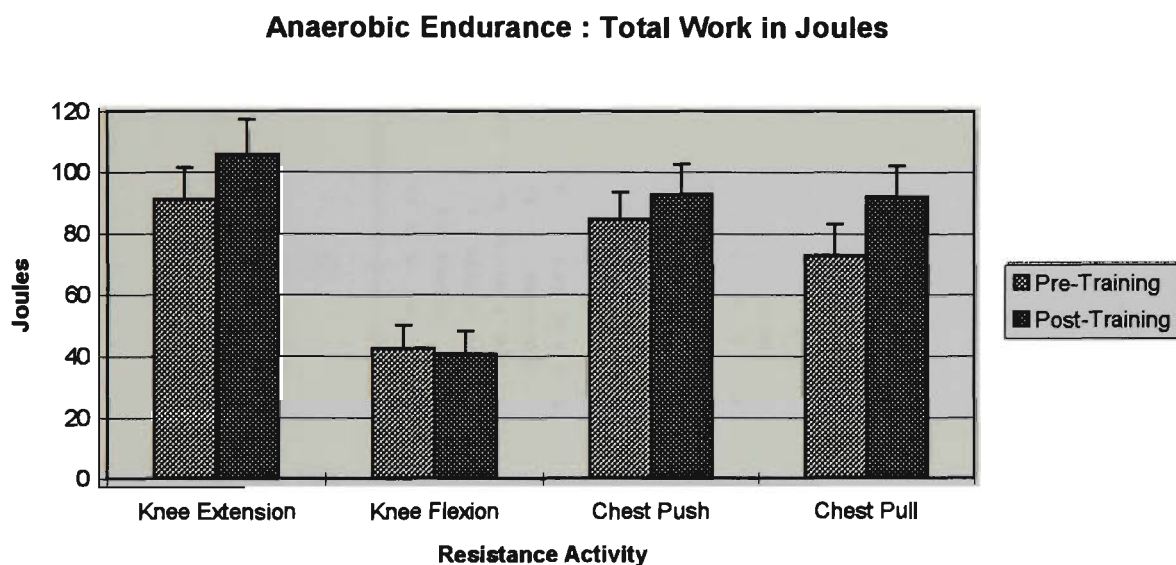


Fig. 5.10 Mean anaerobic endurance measured as Total Work in Joules. Upper limbs measured at 120 deg/s, lower limbs measured at 180 deg/s.

5.3 VO₂peak Test

There were no significant changes in VO₂ peak (pre-training $17.3 \pm 1.6 \text{ ml kg}^{-1}\text{min}^{-1}$ post training: $17.3 \text{ ml kg}^{-1} \text{ min}^{-1}$), (Table 5.9). Oxygen consumption for the full range of submaximal workloads decreased by an average of 7% ($p < 0.0001$), (Fig. 5.11) and minute ventilation also fell by an average of 6% ($p < 0.007$), (Fig. 5.12).

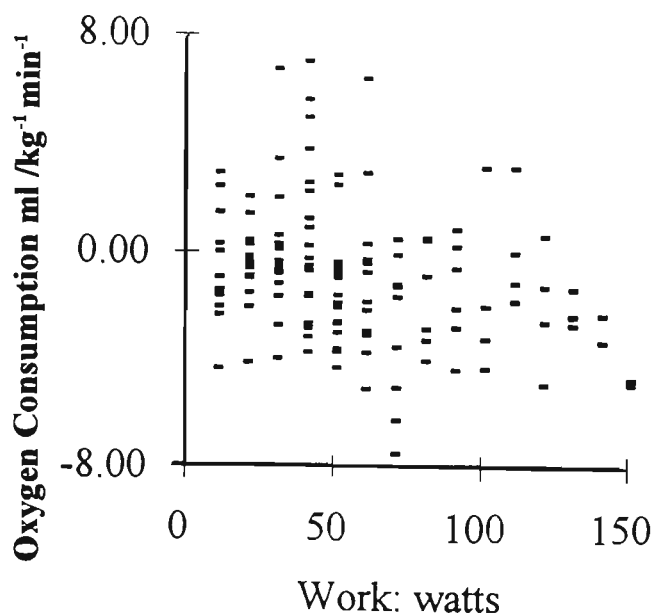


Fig. 5.11 Difference in oxygen consumption: post training versus pre-training ($p < 0.0001$)

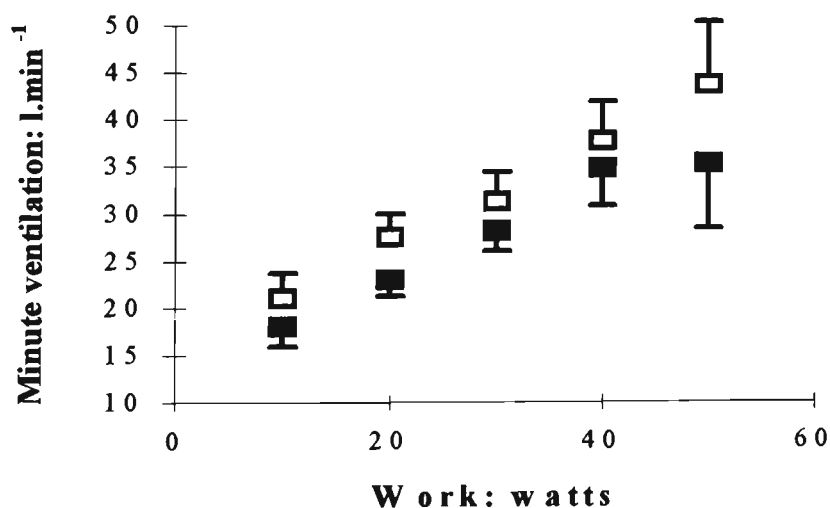


Fig. 5.12 Minute ventilation ($\text{l}\cdot\text{min}^{-1}$) during the graded exercise test. Only the first five stages are included, as all 9 patients were able to exercise up to this point. \square = pre-training; \blacksquare = post-training.

There was no significant change in respiratory exchange ratio (RER), (Fig. 5.13) or carbon dioxide production (Fig. 5.14).

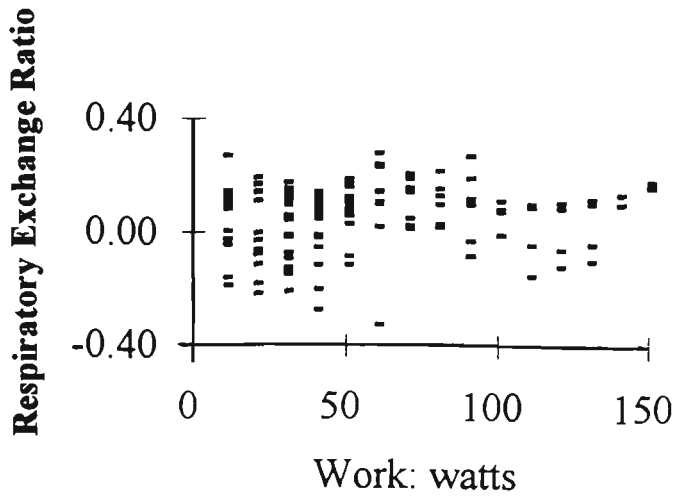


Fig. 5.13 Difference in RER: post-training versus pre-training.

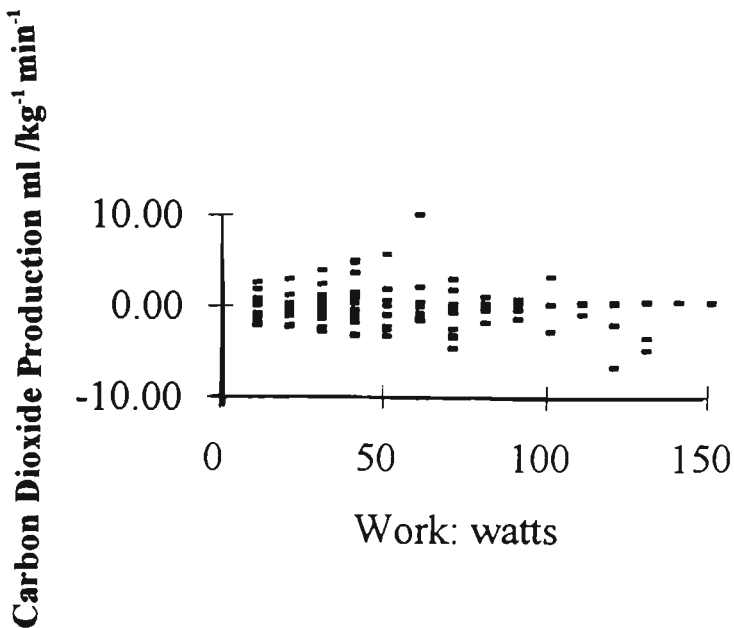


Fig 5.14 Difference in carbon dioxide production: post-training versus pre-training.

5.3.1 Anaerobic Threshold

There was no significant difference in anaerobic threshold before and after training (Table 5.9). Results were taken from four independent evaluators (A, B, C & D) who were blinded to the identity of patients and whether graphed results were for pre- or post- training.

The mean difference in anaerobic threshold was 4% (ml/kg/min)

Patient	A	B	C	D	Mean	%Δ
1 : Pre	16	18	16	14.5	16	
1 : Post	15	14	15	13.5	14	-11%
2 : Pre	9	10	9	9.5	9	
2 : Post	10	10	9	9.5	10	3%
3 : Pre	13	11.5	12	10	12	
3 : Post	14	X	10	10	11	-3%
4 : Pre	X	X	X	7.5	8	
4 : Post	X	X	17	10.5	14	83%
5 : Pre	24	22	21	17	21	
5 : Post	21	19	15	15	18	-17%
6 : Pre	14	X	15	15.5	15	
6 : Post	X	14	14	13.5	14	-7%
7 : Pre	X	X	X	12	12	
7 : Post	12.5	13	12	10.5	12	0%
8 : Pre	X	X	15	13.5	14	
8 : Post	18	17	17	12	16	12%
9 : Pre	15	15	13	13	14	
9 : Post	10.5	13	10	10.5	11	-21%
Mean						4%
STDEV						0.3
SEM						0.1

Table 5.7 Anaerobic threshold results : post-training minus pre-training.
*X - unable to determine a specific reading

5.3.2 Perceived Exertion

A modified Borg scale (1-10) of perceived exertion was used to elicit scores of patient's perceptions of their level of fatigue at the completion of the $\dot{V}O_2$ cycle test. Patient's responses for shortness of breath and leg fatigue were recorded. These results, taken following peak work were recorded before and after the eleven week training program and these results were compared using a non-parametric Wilcoxon Matched-Pairs Signed-Ranks Test.

There was a significant change in Borg Scores for leg fatigue (pre-training 6.3 ± 2 , post training 3.9 ± 2 , $p < 0.0423$). Shortness of breath scores were not significantly different (Table 5.10) indicating a significant reduction after training in perceived leg fatigue but not dyspnoea at maximal exertion.

Patient	Shortness of Breath			Leg Fatigue		
	Pre - Training	Post - Training	% Δ	Pre - Training	Post - Training	% Δ
1	5	5	0%	7	3	-57%
2	9	9	0%	7	9	29%
3	7	4	-43%	8	4	-50%
4	5	3	-40%	5	3	-40%
5	4	7	75%	3	3	0%
6	1	1	0%	7	3	-57%
7	1	1	0%	8	1	-88%
8	6	9	50%	5	6.5	30%
9	9	7	-22%	7	3	-57%
Mean	5.2	5.1	0.0	6.3	3.9	-0.3
STDEV	3	3	0	2	2	0
SEM	1.0	1.0	0.1	0.6	0.8	0.1

Table 5.8 Scores for perceived exertion (Borg) taken during the $\dot{V}O_2$ tests.

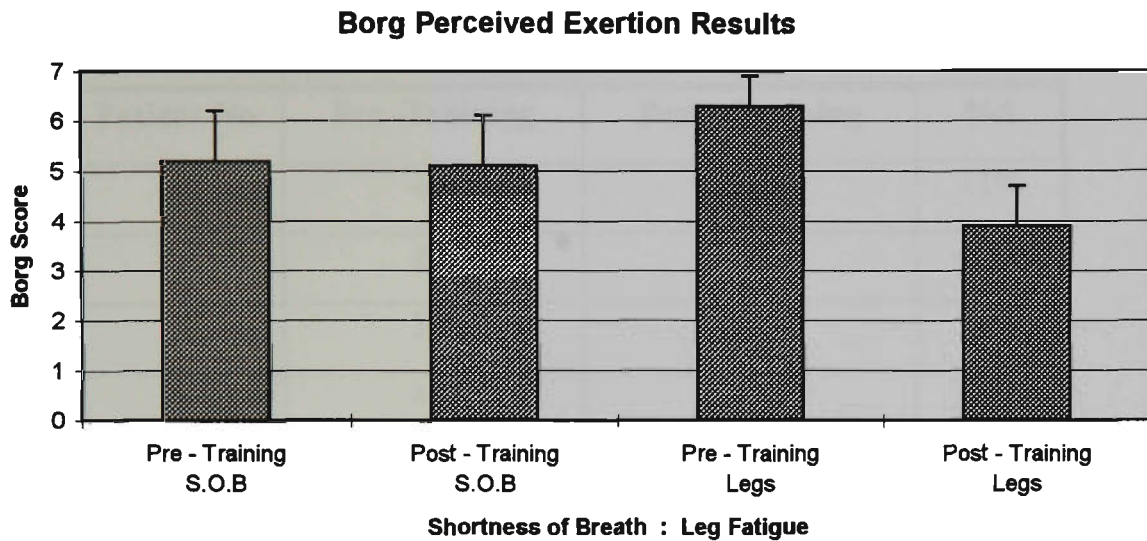


Fig 5.15 Perceived exertion : shortness of breath and leg fatigue.

5.3.3 Six Minute Walk Test

There was a trend but no significant changes in the average distance walked in six minutes (pre-training 454 ± 21 metres; post training: 475 ± 21 metres. Paired t-test results, $p < 0.236$).

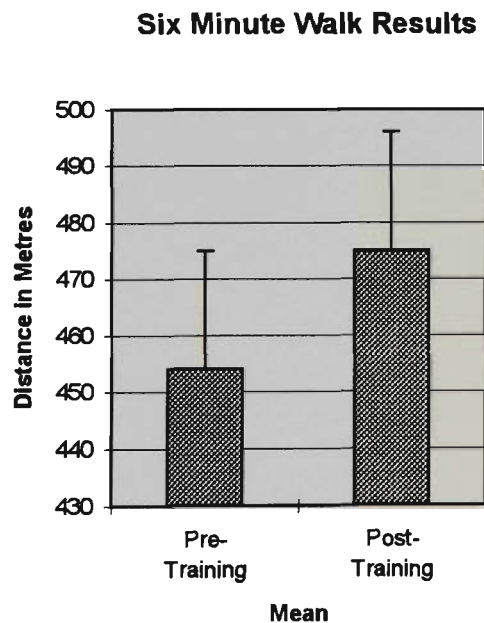


Fig 5.16 Mean functional aerobic fitness results (six minute walk)

	Distance in Metres		
Patient No	Pre -Training	Post - Training	%Δ
1	465	514	11%
2	495	436	-12%
3	390	488	25%
4	465	530.6	14%
5	336	363	8%
6	426	446	5%
7	480	473	-2%
8	557	574	3%
9	475	449	-6%
Mean	454	475	5%
STDEV	64	62	0
±SEM	±21	±21	0

Table 5.9 Functional aerobic fitness assessment (six minute walk)

5.4 Haemodynamics

5.4.1 Autonomic Status

Baseline FBF significantly increased over the training period with only small additional increases after vasodilation stimuli. There were trends in increased Baroreflex sensitivity but these failed to reach statistical significance.

	Base Line	15% MVC	30% MVC	45% MVC	Peak reactive hyperaemia	BRS
Pre	4.5 ± 0.9	8.5 ± 1.6	12.5 ± 2.6	15.8 ± 3.3	36.7 ± 5.9	8.3 ± 1.3
Post	7.6 ± 1.9	11.9 ± 2.3	16.0 ± 3.3	21.9 ± 4.6	39.1 ± 6.3	12.0 ± 2.5

Table 5.10 Summary of results for the venous occlusion plethysmography. and BRS (Baroreflex Sensitivity) (M/sec/MM Hg) was measured non-invasively $p < 0.05$ on paired t-test

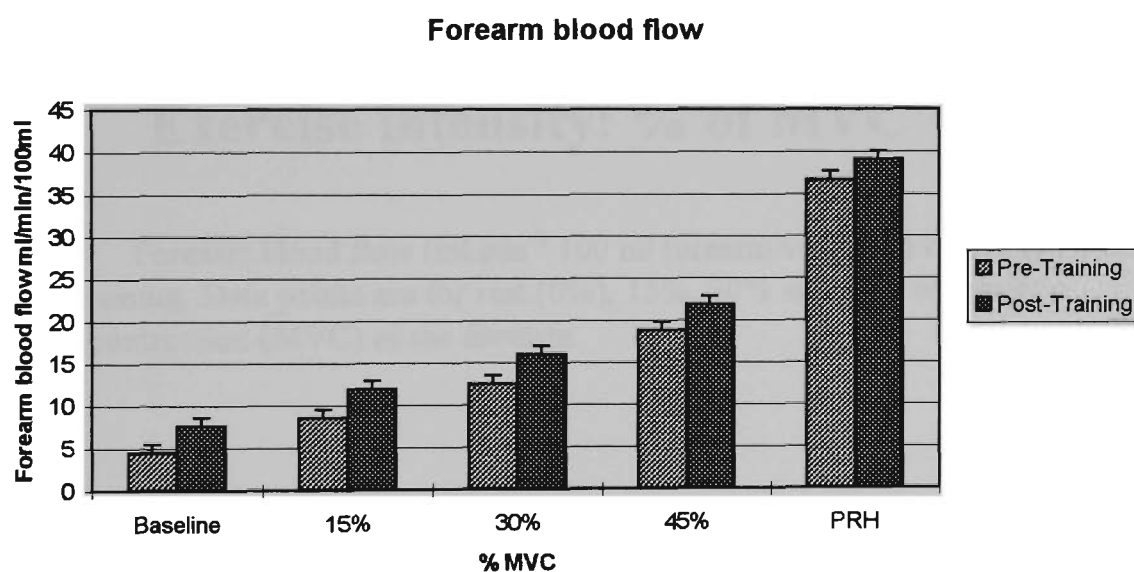


Fig 5.17 Forearm blood flow results.

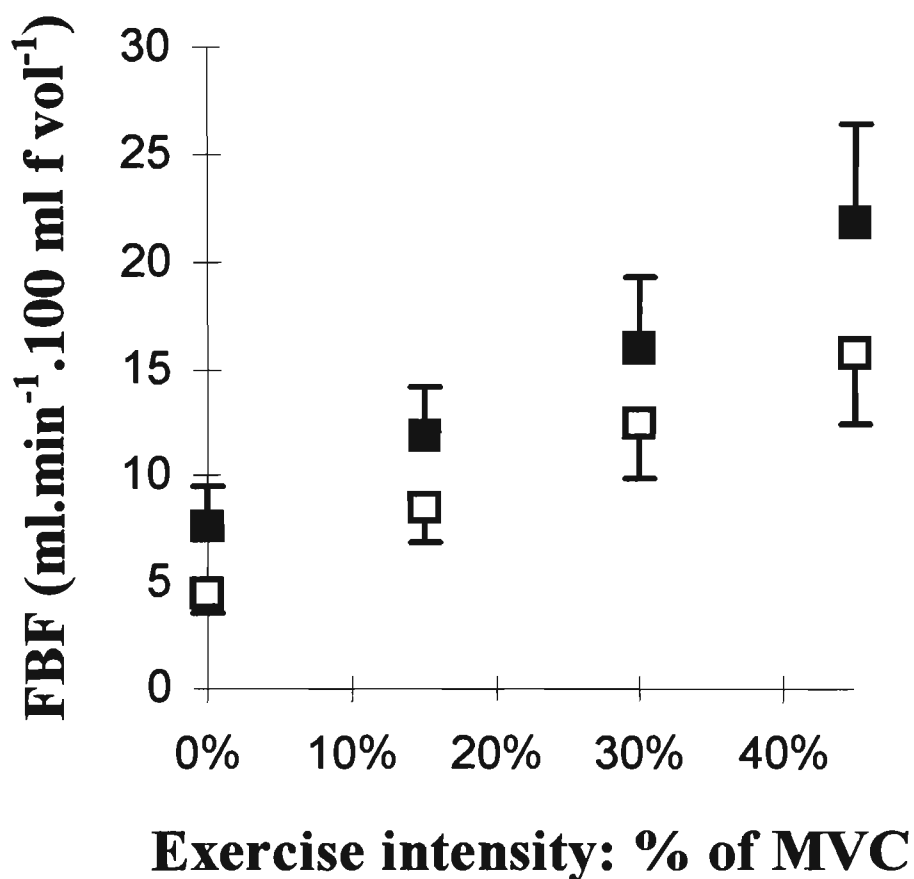


Fig. 5.18 Forearm blood flow (ml.min⁻¹.100 ml forearm volume⁻¹) before (□) and after (■) training. Data points are for rest (0%), 15%, 30% and 45% of maximal voluntary contraction (MVC) of the forearm.

5.4.2 Blood Pressure

There was no change in blood pressures taken in either lying or standing before or after the training program.

Resting blood pressures pre- and post- training taken in Lying						
	Pre-training	Pre-training	Post-training	Post-training	SBP	DBP
1	133	83	54	80	-59%	-4%
2	123	68	114	79	-7%	16%
3	84	60	81	55	-4%	-8%
4	171	99	161	95	-6%	-4%
5	118	64	110	69	-7%	8%
6	110	70	118	71	7%	1%
7	134	71	134	78	0%	10%
8	96	57	92	64	-4%	12%
9	140	71	142	81	1%	14%
Mean	123	71	112	75	0%	0%
STDEV	26	13	33	12	20%	9%
±SEM	±9	±4	±11	±4	±0	±0

Table 5.11 Resting blood pressure in lying, pre- and post-training

Resting blood pressures pre- and post- training taken in Standing						
	Pre-training	Pre-training	Post-training	Post-training	SBP	DBP
1	115	81	105	74	-9%	-9%
2	107	66	106	71	-1%	8%
3	79	63	79	59	0%	-6%
4	154	90	142	86	-8%	-4%
5	137	65	117	62	-15%	-5%
6	100	64	118	69	18%	8%
7	143	75	123	68	-14%	-9%
8	93	65	91	61	-2%	-6%
9	130	73	138	80	6%	10%
Mean	118	71	113	70	-3%	-2%
STDEV	25	9	20	9	10%	8%
±SEM	±8	±3	±7	±3	±0	±0

Table 5.12 Resting blood pressure in standing, pre- and post-training.

5.5 Quality of Life

5.5.1 Cardiac Depression Scale (CDS)

No statistical difference between results.

Cardiac Depression Scale			
Patient	Pre-training	Post-training	%Δ
1	85	64	-25%
2	122	84	-31%
3	72	42	-42%
4	88	78	-11%
5	78	82	5%
6	95	101	6%
7	152	152	0%
8	64	125	95%
9	137	103	-25%
Mean	99	92	-3%
STDEV	31	33	41%
\pmSEM	\pm10	\pm11	\pm0

Table 5.13 Cardiac Depression Scale.

5.5.2 Spielberger

No statistical difference between results.

Spielberger			
Patient	Pre-training	Post-training	%Δ
1	21	20	-5%
2	44	50	14%
3	26	20	-23%
4	34	24	-29%
5	43	45	5%
6	37	48	30%
7	50	50	0%
8	23	52	126%
9	50	42	-16%
Mean	36	39	11%
STDEV	11	14	47%
\pmSEM	\pm4	\pm5	\pm0

Table 5.14 Spielberger questionnaire.

5.5.3 Minnesota Questionnaire

No statistical difference between results.

Minnesota			
Patient	Pre-training	Post-training	%Δ
1	44	25	-43%
2	82	87	6%
3	56	3	-95%
4	15	15	0%
5	38	36	-5%
6	22	31	41%
7	64	64	0%
8	55	12	-78%
9	74	61	-18%
Mean	50	37	-21%
STDEV	22	28	43%
\pmSEM	\pm7	\pm9	\pm0

Table 5.15 Minnesota questionnaire.

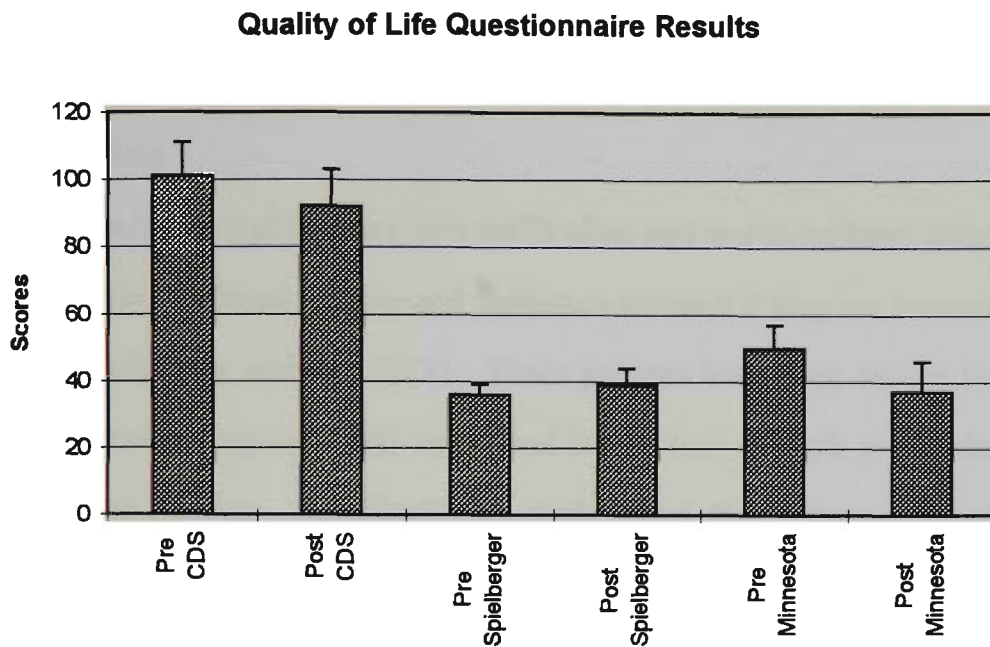


Fig. 5.19 Quality of life questionnaire.

Chapter 6

6.0 Discussion

This study demonstrates that patients with stable class two and three heart failure can safely participate in combined aerobic and resistance exercise if they are continuously monitored both clinically and with ECG. These patients have been shown to have significant potential to improve their upper and lower limb strength and endurance through resistance training. Specifically the study found that resistance training is not only safe, but also effective in increasing muscle strength and endurance and peripheral blood flow whilst reducing the demand for oxygen and ventilation at submaximal workloads.

Until recently, CHF patients had generally been excluded from cardiac rehabilitation programs because it was felt that the acute and chronic risks of exercise training outweighed the potential benefits. However, a body of recent evidence indicates that patient-specific exercise training programs are not only safe, but highly desirable in relation to improved quality of life and survival.

There are many physiological arguments why exercise training could be beneficial in patients with CHF. While concerns regarding the balance between risk and benefit for this population have yet to be allayed, results of this study and others like it (McKelvie et al., 1995; Koch et al., 1992; Yamani et al., 1995) are promising. Further long term randomized trials are needed to confirm the clinical benefits and impact of exercise training on morbidity and mortality (McKelvie et al., 1995).

The effects of aerobic exercise training on CHF patients have been widely examined and have gained acceptance as a safe and potentially beneficial therapeutic

intervention for CHF patients (Coats et al., 1992). Resistance training which specifically improves muscle strength is now routinely advocated for patients with coronary artery disease (McKelvie and McCartney 1990; McCartney et al., 1991; Kelemen et al., 1986; Stewart et al., 1988; Ghilarducci et al., 1989; Sparling et al., 1990; Stewart 1989; Butler et al., 1987; Franklin et al., 1991; Squires et al., 1991; Haennel et al., 1991) but has yet to be advocated for patients with CHF because of concerns about potential hemodynamic responses.

McKelvie et al., (1995) demonstrated that resistance exercise produces hemodynamic responses that are no greater than those found with cycling. Previous studies (McKelvie and McCartney 1990; Verrill et al., 1992) have found that even if patients develop angina during aerobic exercise they are less likely to develop symptoms during resistance exercise. These results support the findings of this study which found that during 120 individual training sessions no medical complications occurred and no patient developed difficulties during any aspect of the training or testing procedures.

6.1 Muscular strength & endurance

The significant increase found in bilateral upper body strength ($42 \pm 8\%$ mean) in the group of nine CHF patients involved in this study is a clear indication of the potential for gain in these patients. Other studies have shown that when weight training is added to a traditional cardiac rehabilitation exercise program for CAD patients, significant increases in muscular strength occur (Kelemen 1986 and Haennel et al., 1991).

Previous studies with comparable results for increases in upper limb strength were conducted by Wilke et al., (1991) and Koch et al., (1992) on CAD patients. Wilke

and associates demonstrated a 30% increase in upper limb strength in a group of ten asymptomatic cardiac patients who participated in 12 weeks of aerobic and upper limb resistance training using variable resistance machines. Koch et al., (1992) found a 35% increase in overall muscle strength in a group of 11 patients (NYHA II-III) following combined resistance training involving the incremental loading of a small number of muscle groups at a time and simultaneously.

Lower limb strength also significantly improved in our patients with increased peak torque of $22 \pm 9\%$ from baseline indicating a distinctive training effect. Upper limb endurance results demonstrated a $24\% \pm 8\%$ increase in total work, also reflecting increased exercise tolerance. The mean lower limb endurance results, while not statistically significant, suggest a similar trend towards improvement ($17 \pm 11\%$).

Greater increase in upper limb strength than lower limb.

The majority of patients in this study had been walking regularly prior to and during the training program. Their lower limbs were therefore likely to be less deconditioned than their upper limbs and this may account for the greater potential for gains in upper limb strength. The training program also included more upper limb resistance work. Patients completed two upper limb resistance activities (chest push / pull and shoulder push / pull) and only one activity for the lower limbs (knee flexion / extension). Patients also completed upper limb ergometry (arm cycling), as well as lower limb ergometry during the aerobic component of the program.

An increase in upper limb strength on its own will increase functional submaximal endurance. This increase in exercise capacity may enable CHF patients to manage activities of daily living, such as performing household tasks with less physical exertion. Stewart (1989) suggested additional benefits of increased strength

including the prevention of musculo-skeletal problems, the maintenance of desirable body weight and favourable modification of risk factors for coronary artery disease and improvements in self image and self efficacy.

Significant increase in knee flexion total work.

Knee Flexion total work increased by a mean of 18%. Whilst five of the nine patients gained in knee extension total power (range 1% - 104%), one patient remained unchanged and three registered a decrease in total power (range -5 to -23). The patient who recorded the most significant decrease in total power for knee flexion had experienced an exacerbation of his knee pain the week prior to the test and had significantly reduced scores for all tests involving the lower limbs (six minute walk, VO_{2peak} test).

Extent of increases in mean peak torque.

Upper limb strength increases were comparable to other studies conducted on patients with CAD. For example Haennel et al., (1991) found an increase of 22 Nm in lower limb strength following eight weeks of hydraulic resistance training in CAGS patients. This study found an increase of 30 Nm in quadriceps strength in the CHF patients tested after 11 weeks of hydraulic training. Haennel also found an increase of 13 Nm in upper limb strength whilst our CHF study found an increase of 45 Nm in chest push strength.

Other researchers found a range of strength results in CAD patients. Most tend to give cumulative scores for strength for example Sparling et al., (1990) found a 22% increase in total strength, Stewart et al., (1989) recorded a 24% increase in strength as did Kelemen et al., (1986). Patients studied by McCartney et al., (1991) elicited a 21-43% increase in strength. These studies used the % MVC assessment protocol

and therefore results cannot be compared specifically with the current study. Only this study and the research conducted McCartney et al., (1991) and Haennel and associates (1991) used isokinetic testing procedures.

Comparison of muscular strength (peak torque).

Strength assessments in the Haennel study (Haennel et al., 1991) were conducted on a Cybex II isokinetic dynamometer during exercise at 180 deg/s. The current study assessed strength using a Merac isokinetic dynamometer during exercise at 60 deg/s. A lower increase in strength would be expected at 180 deg/s than at 60 deg/s (Table 6.1).

Joint	Haennel HCT Group	Current Study	Haennel HCT Group	Current Study
	Pre - Training	Pre- Training	Post - Training	Post - Training
Knee Extension	89 ±11 N.m	109 ± 33 N.m	111 ± 10 N.m	139 ± 57 N.m
Knee Flexion	68 ± 6 N.m	43 ± 25 N.m	81 ± 5 N.m	50 ± 32 N.m

Table 6.1 Comparison of lower limb strength results following training between current study and the hydraulic circuit training study conducted by Haennel et al., (1991) (N=8) and the current study (N=9)

This study and those cited above indicate the importance of skeletal muscle power to meet the challenges of whole body exercise and this should be emphasised in CHF patients whose exercise tolerance is low. Mechanisms of resistance training may include partially reversing skeletal muscle atrophy and metabolic deficits caused by deconditioning. By increasing the muscle strength and endurance of CHF patients, everyday tasks may be performed at lower percentages of the new maxima, thereby reducing fatigue, whilst improving quality of life and patient safety.

6.2 Exercise tolerance (VO_{2peak})

Concerns regarding the possible compromise of LV function have precluded CHF patients from resistance training in the past (Effron 1989). Some early studies of isometric exercise demonstrated that LV function was compromised in functionally-limited patients (NYHA Class III) who also had ischaemic heart disease (Kivowitz et al., 1971) however, the deterioration was only transient. When aerobic training was supplemented with resistance exercise in men with coronary artery disease there was a lower incidence of arrhythmias and ischaemia (Daub et al., 1996) and LV wall motion abnormalities (Butler et al., 1987) during the resistance components of the programs than the aerobic components.

Training intensities and changes in VO_{2peak} .

Studies that have examined the effects of exercise training in patients with CHF have predominantly used a study design that does not include randomisation or a control group (McKelvie et al., 1995). There has been considerable variation in the type of exercise training in these studies although all have focused on cardiovascular activities rather than resistance training, working patients at heart rates of 70-80% and for training programs in excess of the eleven weeks of this study.

Lee et al., (1979) studied 18 patients with a previous myocardial infarction and an LVEF of 18%. The patients were instructed to train at 70-80% of their maximal heart rate for 20 to 45 min ~ four days/week. Training continued for an average of 19 months and resulted in an improved incremental exercise time of 1.1 min, with no change in LVEF. Conn et al., studied 10 patients who had suffered a myocardial infarction three months earlier, had an average LVEF of 20% and trained three to five sessions per week for 35 to 45 minutes for an average of 13 months. After training, they found an increase in exercise performance of 1.5 metabolic equivalents (METS). Sullivan et al., (1988) studied 12 patients with congestive heart failure with an LVEF of between 9 and 33%. The patients trained for 60 minutes three to five times per week at 75% of their peak oxygen uptake. After 16 to 24 weeks of training the patients had a 3.8 -ml/min per kg increase in peak oxygen uptake.

Coats et al., (1992) recruited 17 patients with congestive heart failure with an average LVEF of 20%. These patients trained on a cycle ergometer at home at 70-80% peak heart rate for 20 minutes five days per week for eight weeks. After training there was a significant improvement in peak oxygen uptake of 2.4 ml/min per kg. Jetté et al., (1991) randomised ten patients with congestive heart failure for an exercise program and for eight usual treatments. The patients trained for 55 minutes five days per week for four weeks. A significant improvement in peak oxygen uptake from 1.0 to 1.2 litres/min was observed after training.

Studies that have included resistance training in the cardiac rehabilitation of CAD patients were conducted by Haennel et al., (1991) and Kelemen et al., (1986). Haennel and associates found a 14% increase in peak $\dot{V}O_{2\text{peak}}$ for a group of CAD patients after eight weeks of hydraulic circuit training and Kelemen found a 12% increase in treadmill time among CAD patients following ten weeks of circuit weight

training. Both studies used a circuit training regimen which differs from the combined aerobic and resistance training protocol used in this study.

Surprisingly, a combination of resistance and aerobic training in patients with CAD has been found to be more beneficial than aerobic training alone in improving aerobic power and capacity, without increasing the incidence of cardiovascular complications (Kelemen et al., 1986; McCartney et al., 1991). In contrast, we did not find a significant change in VO_{2peak} with our predominantly resistance training regimen. This may be the result of our small experimental group (N=9) and the extent of the variability of the cohort. The duration of our training program (eleven weeks) may also have been insufficient to facilitate a change in VO_{2peak} .

Exercise tolerance test (VO_{2peak}) protocol

The lack of a significant change in aerobic power found in this study may also in part be explained by some aspects of the measurements used (Haennel et al., 1991). In normal individuals, the criteria for estimation of maximal aerobic power are well defined. Those are the attainment of a plateau in heart rate and VO_2 with exhaustion in the face of increasing workloads. In patients with heart disease, there are practical difficulties in observing these criteria. The conventional practice of resorting to symptom limited graded exercise tests (SL-GXT) under these circumstances may well underestimate the "maximal" value and thereby distort the effect of a training program.

In the present study, the physiological endpoints such as heart rate and VO_{2peak} were quite different. Similarly the scores for perceived exertion, if accepted as a reflection of maximal exertion, were significantly different between patients. Thus the maximal nature of the effort exerted during the tests could be questioned.

Oka et al., (1993) and Sullivan et al., (1990) suggest ventilatory threshold as an alternative to maximal exercise testing for CHF patients to assess functional capacity. In the Oka study 31 of 45 CHF patients (69%) had a measurable ventilatory threshold. The authors argue that given the difficulty in detecting ventilatory threshold in some patients with CHF, it is a less reliable measure of functional capacity than needed. They advocate further study to correct measurement difficulties and enhance clinical use.

Improvement in metabolic efficiency

Similar to Coats et al., (1992) in their CHF aerobic training protocol, we did find a decrease in minute ventilation (and VO_2) for a range of submaximal workrates, indicating an improvement in metabolic efficiency for relatively low work rates. Coats and associates found that the slope of the ventilation-to-carbon dioxide production relation was correlated positively with the severity of CHF and the slope was significantly improved by physical training. These findings may explain the reduced sensation of breathlessness found in the Coat's study and may allow a greater respiratory reserve during endurance exercise.

These findings have practical benefits for the CHF patient who wishes to follow an active lifestyle because it will enable the patient to exercise at a relatively lower percentage of $\text{VO}_{2\text{peak}}$ with less fatigue and more safety. Severely limited patients who are unable to tolerate aerobic exercise may also benefit from a localised exercise regimen, repeated for several body segments. An additional benefit may also be derived by those patients who are severely deconditioned and who have an aversion to traditional aerobic training programs who may be more likely to comply with exercise programs that include resistance exercises.

The lack of a significant change in aerobic power in this study supports the contention of Kelemen (1989) and Featherstone et al., (1993) that resistance training should serve as a supplement to, rather than a replacement for, aerobic exercise in Cardiac Rehabilitation Programs.

6.2.1 Six minute walk test

There were no significant changes in the average distance walked in six minutes (pre-training 454 ± 21 metres; post training: 475 ± 21 metres. Paired t-test results, $p < 0.236$). Of the nine patients, six patients increased the distance walked in six minutes by a range of 5-25%. This indicates that there may have been a more significant training effect on some patients than others.

The patient that gained the greatest improvement for example was the oldest of the nine patients and had not been participating in regular physical activity prior to his involvement in the program. He may well have had the greatest potential for gain.

Of the three patients that registered a decline in the distance walked over six minutes, two had developed knee pain, one as a result of gout and the second was thought to be an irritation of a musculo-ligamentous strain. Both had a reduction in a number of lower limb tests including the isokinetic knee flexion/extension and the bicycle ergometer test. The third patient complained of angina pain during the six minute walk re-test and this may account for his 6% decline in distance walked.

None of the patients paused during either the pre or post -training 6 minute walk tests and no adverse cardiovascular events occurred during testing.

Yamani et al., (1995) compared the sub-maximal exercise tolerance in a group of CHF patients to a group of age-matched sedentary controls. They tested both groups using a 9 minute walk protocol and found that exercise capacity was significantly reduced in the CHF groups. The study found that 17 of 18 patients versus two of ten subjects paused at least once during the protocol. The extra three minutes involved in this protocol may account for the difference between the incidence of patients pausing during this test and the results of this study however, as there was no training involved in the Yamani research it is not possible to compare results.

Kelemen et al., (1986) evaluated the efficacy of circuit weight training at 40% MVC and aerobic training at 85% of the maximal heart rate attained during treadmill testing with a group of CAD patients. Results included a significant increase in treadmill time from 619 to 694 seconds in the circuit training group while the treadmill time of the non-exercising control did not change. Higher aerobic training heart rates and the fact that these patients did not have heart failure may account for the difference in results between Kelemen's findings and the current study.

6.3 Autonomic Status and CHF

Basal FBF was increased in these patients following the resistance exercise training program. However neither the absolute nor the percent increase in FBF from base line in response to vasodilator stimuli was different pre-vs post exercise training. Therefore the eleven week resistance exercise training program did not improve peripheral vascular responsiveness to specific vasodilator stimuli but did result in increased basal peripheral blood flow. There were trends in increased Baroreflex sensitivity but these failed to reach statistical significance. The small sample size is thought to be the most likely explanation for this lack of significant change. Sullivan et al., (1988) studied 12 patients with CHF with an LVEF of 9-33% (NYHA I to III). The patients trained for 60 minutes three to five times per week at

75% of their peak oxygen uptake. After 16 to 24 weeks of training, the patients had a 1.6 ml/dl increase in leg arteriovenous oxygen difference and a 0.5 -litre/min increase in peak exercise leg flow.

Symptomatic benefits derived from resistance exercise may be explained by improvements in basal peripheral blood flow or by other mechanisms.

6.4 Blood Pressure

There was no significant change in blood pressure prior to or following the training program. There are no other studies that have explored the effect of resistance training on blood pressure in CHF patients however, in their study on patients with CAD, Kelemmen and associates (1986) reported no changes in resting or exercise blood pressures over the ten week training period.

6.5 Quality of Life

The small sample size of this study is the most obvious explanation for the lack of a significant statistical difference found between the pre and post training results for any of the three quality of life questionnaires. Overall quality of life was tested using the Minnesota Living with Heart Failure questionnaire (Appendix C). Depression was evaluated using the Cardiac Depression Scale (Appendix C) and the Spielberger State Anxiety Score was used to measure anxiety (Appendix C). Reductions in scores for the three questionnaires are interpreted as a positive response as they reflect a reduction in either impairment to quality of life, depression or anxiety.

For practical reasons, Quality of Life assessments were administered at the completion of the training program, after the other assessments. This possibly renders the final quality of life measures more sensitive to performance than the other

final assessments. The fact that all patients completed the program and the attendance rate of 98% perhaps belies the extent to which the patients found their involvement in the training sessions therapeutic. External factors such as family and financial concerns, the fact that the program finished the week before Christmas and a range of other variables may account for the apparent lack of psychological and emotional impact of the program on the participants.

Significantly the oldest participant in the study (82 year old) recorded the most significant improvement for all three questionnaires after the study. This patient, a widower living in a retirement village, had significantly lower scores for depression and anxiety and higher scores for overall quality of life than the other eight patients prior to the training program. This patient had significantly greater decreases for all three parameters at the completion of the program. Interestingly the other eight patients were all married!

The CDS scale which looks at depression found only a mean 3% decrease in depression amongst patients. The mean range of responses however was broad (score -45 to + 92 : a negative score indicative of a decrease in depression). Questions focused on a range of issues such as *I have dropped many of my interests and hobbies.... my concentration is as good as it ever was...I get pleasure from life at present.... I may not recover properly... I am not the person I used to be... dying is the best solution for me... my problems are not over yet... I am concerned about my capacity for sexual activity....* Results may reflect the fact that some patients gained more from their involvement in the training program than others. Timing may have had the greatest impact on this particular parameter as many of the patients reported feeling particularly emotionally vulnerable at Christmas time.

The Spielberger questionnaire which looks at anxiety found only a mean 11% decrease in anxiety amongst patients. The mean range of responses however was also broad (score -29 to +126% : a negative score indicative of a decrease in anxiety). Results may again reflect the fact that some patients gained more from their involvement in the training program than others.

The Questionnaire rated many emotional responses such as ... *feeling calm... secure... tense.... regretful.... at ease.... upset.... anxious etc.* Again the fact that the program finished the week before Christmas may have had a significant impact on the participant's responses at the completion of the program. The fact that there had been a great deal of apparent camaraderie amongst the patients during the program and a degree of concern about how patients were going to maintain their involvement in a similar program in the future may also have had an impact on these results.

The Spielberger-trait anxiety inventory (Spielberger et al., 1970) was not specifically designed for this population of patients and does not appear to have been used with CHF patients before. It was also designed twenty-five years ago and may not be as relevant to this generation of patients.

The Minnesota Questionnaire indicated that overall quality of life had also not significantly altered statistically for the nine patients following the training program. With a mean reduction of 21% and a range of -78 to +41 there was a greater improvement in quality of life than the other two parameters tested.

The extent to which improved physical function impacted on this result is unclear but the majority of the questions asked in this questionnaire focus on physical indicators such as ... *the extent to which your heart failure caused swelling in your ankles... made you sit or lie down to rest during the day... made walking or climbing stairs difficult... made working around the house or garden difficult... made your sleeping well at night difficult etc....* suggests that improvement in physical function had an impact on the quality of life of some of the participants.

Unlike the Spielberger questionnaire, the Minnesota was developed specifically for patients with heart failure and is relatively contemporary having been designed in 1987. Results may therefore be more relevant than the Spielberger.

Limitations of the testing procedures

Four of the nine patients indicated that English was their second language. The complexity of the questions being asked may well have influenced the responses of these participants despite attempts to explain each of the items on the questionnaires. One patient insisted on his wife assisting him to complete his questionnaire's and this may also have had an influence on the results. This patient did not complete the questionnaires at the end of the training program. The results for the other three patients were highly inconsistent between the three questionnaires with significant changes in results from one questionnaire to another. For example patient eight had a 95% increase in depression, a 126 % increase in anxiety but a 78% decrease in impact on quality of life.

Exercise has the potential to affect mood in a variety of ways that do not entail changes in measured capabilities (Ewart 1989). Improved ability to relax or sleep, pleasant social interactions in exercise classes, or increased optimism resulting from

taking action to improve one's health may encourage more positive self-appraisals. In terms of the potential psychological benefits to be derived from resistance training for cardiac patients, Ewart (1989) suggests that the measured emotional impact of exercise may be affected by the mood dimension one chooses to assess. In his research into the relationship between exercise, mood and self-efficacy in patients undergoing circuit weight training, 52 men were randomised before participation in a ten week training program. Results indicated that changes in self-efficacy and mood indices were unrelated to strength or endurance gains. Ewart therefore argues that exercise produced psychological benefits are independent of physical performance gains, and gains in self-efficacy are accompanied by improved mood.

6.6 Training

6.6.1 Reduction in recovery heart rates

The significant reduction in recovery heart rates during the course of the training program suggests a training effect related to increased exercise tolerance. This trend correlates with the decrease in minute ventilation at sub-maximal work loads found in this study. The functional application of such improvements would potentially be of significant benefit to CHF patients. While this study did not attempt to train patients maximally, the reduction of heart rate recovery time during the training program is a reflection of the benefits of sub-maximal exercise training. Improvements would impact on CHF patients in enabling them to perform activities of daily living with a lower cardiovascular demand.

6.6.2 Attendance

If poor compliance limits or biases the effectiveness of exercise in rehabilitating patients with CAD then the addition of resistance training into traditional cardiac

rehabilitation exercise programs may assist to maintain interest by increasing diversity (Kelemen 1989).

The 98% attendance rate found in this study may reflect a significant element of enjoyment in the activities offered and may in turn have a positive effect on compliance. The fact that despite the deconditioned state of the patients in this study prior to their involvement in the training program, no patients reported any incidence of muscle soreness following the resistance training sessions adds further support to its inclusion on the grounds of encouraging patient compliance.

Wilke et al., (1991) found that the circuit resistance training protocol was a more popular form of exercise training amongst CAD patients than cycling or arm ergometry. A further recommendation by Sullivan et al., (1990) involves the importance of individualising exercise programs for elderly subject for whom the functional conditions of bones, joints and skeletal muscles are an important factor with regards to compliance.

6.7 Limitations of the study

There are several limitations to this study, not the least of which is the lack of a control group. Additional limitations include the relatively small number of patients (N=9) and the absence of female patients. There was no attempt to measure blood pressure during resistance training as it was felt that the only reliable method was directly via intra-arterial line and this invasiveness was deemed to be likely to limit other outcomes.

The quality of life questionnaires may have proven to be more reliable had we recorded repeated measures before and after training. In the present study patient's

responses to the three questionnaire's were recorded only once at the beginning of the program and again after training.

6.8 Summary

Chronic heart failure describes a life-threatening syndrome characterised by insufficient cardiac output. The major symptoms of CHF are fatigue on exertion and breathlessness. Poor exercise capacity is a strong and independent prognosticator in CHF and therefore the role of exercise training is of great interest. Although left ventricular function is also a prognosticator, it correlates poorly with exercise tolerance and responds minimally to exercise training in CHF.

Recently, a consensus has emerged that deterioration of muscle structure and function is the most important mechanism causing fatigue, and perhaps even breathlessness in CHF. The peripheral hypothesis has largely supplanted the classical central hypothesis which proposed that cardiac dysfunction was wholly responsible for patients' fatigue. Traditionally, patients were advised not to exercise, due to the perceived risk of untoward cardiac events or even sudden death. Recently, it has been shown that aerobic (endurance) exercise training is not only safe, but effective in improving some aspects of skeletal muscle structure and function, peripheral blood flow and parasympathetic activity. However, there are many arguments for the contention that aerobic training alone is sub-optimal in terms of restoring skeletal muscle.

It has been the contention of this study that CHF patients lack the physical strength to perform common activities of daily living and few patients have the exercise tolerance to return to employment. Of those who do possess the requisite physical capacity, many lack the confidence to attempt activities that involve even low levels

of muscular exertion. An increase in overall muscular strength may provide a better adaptation to effort which may in turn improve confidence and quality of life.

In summary, this study provides further evidence that the addition of resistance training to a traditional cardiac rehabilitation exercise program does not adversely affect the health and well being of patients with CHF. These patients can perform resistance exercises without the development of adverse cardiovascular responses.

In the present study a clear training effect was demonstrated as the recovery heart rates of patients decreased significantly during the training program. Significant increases in upper and lower limb strength and endurance are also clear indicators of improved physical function. While there was no significant improvement in functional aerobic capacity, resting blood pressure, forearm blood flow or quality of life indices, there was a reduction in the demand for oxygen and ventilation at submaximal workloads (although VO_{2peak} was unchanged) and high compliance and attendance rates throughout the training program.

Conclusion

Combined resistance and aerobic training can therefore be argued as having additional benefits for CHF patients than aerobic training alone. Further randomised studies are required to evaluate the long-term effects of our protocol of resistance training for patients with CHF.

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Appendix A

Cardiologist Correspondence

INFORMATION FOR PHYSICIANS AND CARDIOLOGISTS

TITLE OF STUDY

The efficacy of sub-maximal resistance training for patients with stable heart failure.

RESEARCHERS

PRINCIPAL INVESTIGATOR : Dr David Hare (Cardiologist)

CO-INVESTIGATORS : Ms. Toni Ryan. (D.Ed P.E., Grad Dip. Exercise for Rehab.)
Dr Henry Krum (Dept. Clinical Pharmacology)
Dr Steven Selig (Ph.D. Physiology).
Ms Cathy Nall B.App Sci (Physio) Grad Dip Health Admin, Grad Dip Physio (Cardioth.) MBA
Mr Tim Wrigley (M.Ap Sci)
Dr Anne-Marie Pellizzer (Clinical Pharmacology Advanced Trainee).

AIM OF THIS STUDY

This is a pilot study to examine the potential benefits of hydraulic Circuit Weight Training (CWT) for chronic heart failure patients with an LVEF of less than 40%. We will examine the efficacy of CWT by evaluating specific parameters including muscle strength and endurance, cardiorespiratory capacity, LVEF, heart rate variability and quality of life.

LOCATION

Austin Hospital Cardiology Unit. This will include use of the exercise treadmill on Level 1, the gymnasium on Level 9CD and the Merac Isokinetic Dynamometer in the Physiotherapy Department on Level 3.

INHERENT RISKS, INCONVENIENCE OR DISCOMFORT

Patients will be enrolled in the study only after having obtained informed medical clearance (i.e. the treating cardiologist is aware of the nature of the study and believes that the risk of any major adverse event is low in that particular subject). Patients perceived to have a high risk of exercise induced sudden death will be excluded from the study. **No subject will be admitted to the study without clearance from their treating physician.**

Risks include the possibility of transient increased Left Ventricular (LV) size and reduced contractility, increased workload on the heart, increased risk of arrhythmias, fainting, dizziness, nausea, vaso-vagal responses, delayed onset muscle soreness and fatigue.

The researchers believe that all possible precautions will be taken to ensure the safety of the subjects involved in the study. Studies of resistance training in patients without heart failure and of aerobic training in patients with stable heart failure have both demonstrated benefits without significant adverse events. Patients will undergo a baseline exercise ECG (modified Naughton protocol) and will have telemetry during exercise with ready access to personnel trained in advanced life support and defibrillation.

BENEFITS

Each patient's physical program will be designed specifically for their individual needs based on the results of the pre-program assessments. Programs will be individually graded to ensure that each patient has the opportunity to reach their optimum potential exercise tolerance.

Participants will have opportunities to discuss their concerns in a supportive environment and will have access to the latest technology and education available. They will be given a report of their individual work capacities with guidelines as to how they can continue to improve their physical fitness and work capacity in the future.

Through improved cardiovascular fitness and strength they may have an opportunity to more safely broaden their vocational and leisure options. At patient's request, test results can be passed on to their physician.

EQUIPMENT

For pre and post program assessment of muscle strength and fatigability we will use the **MERAC[®]** Isokinetic system currently located in the Physiotherapy Department.

For the training sessions we will utilize **Hydra-gym[®]** (Hydra-Gym Australia) Total Power Hydraulic Weight Training Equipment which will be located in the gymnasium in 9CD.

TRAINING

We will utilize **Hydra-gym[®]** (Hydra-Gym Australia) Hydraulic Weight Training Equipment as incorporated into the **PACE[©]** circuit training system, a **Repc[®]** bionic stationary bicycle and a **Monark[®]** upper limb ergometer.

CIRCUIT WEIGHT TRAINING (CWT) SESSIONS

Circuits consist of a combination of three hydraulic resistance stations interspersed with aerobic activities including stationary cycling, walking and upper limb ergometry. (See Attachment 1). Three patients at one time can participate in the circuit and the regimen will follow the standardised order of :

1. Warm up (stretch and aerobic movements) for 5 minutes
2. Cycle (aerobic activity)
3. Chest press (resistance activity)
4. Arm cycle (aerobic activity)
5. Leg Flex/ Ext (resistance activity)
6. Walk (aerobic activity)
7. Shoulder press (resistance activity)
8. Stationary Cycle (aerobic activity)
9. Walk (Cool Down) for 5 minutes

TABLE 1**INCREMENTAL WORK-REST PROTOCOL**

WEEKS	1 - 2	3 - 4	5 - 8	9 - 11
Work	30 sec	30 sec	40 sec	40 sec
Rest	60 sec	40 sec	20 sec	10 sec
Repetitions*	6-7	8-9	10-12	12
Resistance Activities*	3	3	3	3
No. of Sets *	1	1	2	2
Workload	40%	40%	40%	40%

* Example of a standardized training protocol.

Subjects will begin by working at 40%** 1RM in week one and will attempt to complete six(6) repetitions at three (3) hydraulic resistance stations interspersed with aerobic activities. If symptom-free, they will attempt to increase their work load each week by a minimum of one additional repetition in each work period for each exercise. i.e. On the Leg Extension Machine, a patient starting at six (6) repetitions in the 30 second work period will attempt to increase this to seven (7) repetitions in the second week, and then eight (8) the week after etc. Once a patient is able to complete twelve (12) repetitions of each exercise in the allocated work period and remain symptom free, they will be able to increase the resistance of that particular machine by one setting. Each subject will work continuously for the 30 minute circuit with minimal rest breaks between stations following the incremented work rest protocol outlined in Table 1. Where appropriate, patients will, in time, be able to complete a second set of the exercise activities.

**Method of evaluating strength using maximum (1RM) resistance against which one full range of motion can be performed. The measured resistance is referred to as 1 Repetition Maximum (1RM).

ETHICAL CONSIDERATIONS

- CWT sessions will be conducted on three mornings with a two day break between these three days (i.e Monday, Wednesday and Friday).
- Patients will be advised to eat a small meal two hours prior to participating in the CWT sessions.
- Patients will be advised against taking hot showers following exercise since the sudden temperature change may result in skin vasodilation and subsequent circulatory compromise.
- Whilst the CWT venue will have facilities for modifying air temperature, patients will by advised not to exercise in extreme temperatures or humidity.
- Ongoing monitoring of heart rate and blood pressure during the eleven week training period.
- Subjects will be trained in appropriate respiratory patterns for resistance training to ensure that Valsalva manouvre will not be a concern.

- At no time will the subjects be required to perform isometric exercise.
- Subjects will be fully briefed prior to giving their consent to participate in the program.
- Subjects will be advised of the risks involved and all participants will be advised of their right to withdraw from the project at any time.
- Subjects will be advised to discuss any concerns or difficulties with their treating doctor and the principal investigator of this study.

QUESTIONS

At any time before the study or during the study, the subject is free to ask any questions regarding the study and is encouraged to discuss the study with their treating doctor.

CONFIDENTIALITY OF DATA

All information and data obtained from the study will be kept strictly confidential. Subjects will not be named in any research reports without the consent of the persons involved.

PRE - POST STUDY ASSESSMENT

Parameters for assessment will include pre and post study assessments of the following :

- i. Muscular Strength
- ii. Muscular Endurance
- iii. Cardiovascular Fitness (Vo_{2max} as assessed by Modified Naughton Exercise Tolerance Test conducted by a cardiologist and has exchange using a metabolic cart)
- iv. Heart Rate Variability
- v. Quality of Life Indices
- vi. Attendance (by log book)
- vii. BNP
- viii. Forearm blood flow

MONITORING PROTOCOLS

PEAK HEART RATES ALLOWED DURING EXERCISE

Patients will be trained to monitor their own level of perceived exertion so that exercise levels can be monitored by patient self-report of symptoms. In general, the exercising heart rate will be kept to not more than 20 beats per minute above the resting rate. Peak heart rates will be established by the supervising cardiologist prior to commencement of the program and will be adhered to in all training sessions. These will be 75% of the maximum demonstrated on baseline ECG. Through the use of Telemetry cardiac rhythm will be monitored regularly through all training sessions. While peak heart rate recordings will be monitored regularly, measured changes are not a part of the data collection for this study.

DIET & MEDICATION

All participants will have the opportunity to participate in nutritional and other education classes as part of their general Cardiac Rehabilitation Program. At no time will subjects be advised to alter the medication regime prescribed by their physicians.

Medical Referral Form

MEDICAL BACKGROUND AND CONTRA-INDICATIONS TO EXERCISE
for cardiac patients participating in the study entitled :

**Efficacy of Sub-Maximal Resistance Training
for Patients with Stable Heart
Failure.**

Patient's Name _____ D.O.B _____

Address _____

Postcode _____

Telephone Number _____ U.R Number _____

i.) Principal diagnosis _____

ii) Other diagnoses _____

iii) Other relevant details of medical status which might affect ability to participate in the study _____

iv) Medications _____

v) Any previous relevant investigations (including LVEF if known).

CARDIOLOGIST'S CONSENT. I have read this form and in my opinion, it is safe for this patient to participate in all aspects of this study. Date ___/___/___

.....
Name of Physician

.....
Signature of Physician

.....
Telephone Number

Appendix B

Cardiologist Patients

PATIENT INFORMATION SHEET

PROJECT

Pilot study of low level resistance training in patients with stable heart failure.

INVESTIGATORS

Dr David Hare, Ms Toni Ryan, Dr Henry Krum, Dr Steven Selig, Ms Cathy Nall, Mr Tim Wrigley, Dr Anne-Marie Pellizzer.

LOCATION

Austin Hospital Cardiology Unit. This will include use of the exercise treadmill on Level 1, the gymnasium on Level 9 and the Merac Isokinetic Dynamometer in the Physiotherapy Department on Level 3.

PURPOSE OF THE STUDY

You have been asked to participate in this study because you have the condition "chronic heart failure," where the heart muscle cannot pump blood as vigorously as usual. The purpose of this study is to identify whether hydraulic resistance training activities result in improvements in fitness and overall well being for patients with stable heart failure. Resistance training involves the use of muscle groups to work through a range of motion to push and pull against a smooth hydraulic force. (See picture in Appendix 1). You will be using the muscles in your legs and your upper body during the training program.

Many studies indicate that it is possible for patients with heart disease to increase their strength through regular participation in resistance training activities. As a participant in this study you will be required to attend three thirty minute classes each week for eleven weeks in the Cardiac Rehabilitation Unit at the Austin Hospital. Your strength, fitness and overall well being will be tested before we begin the training program and again at the end of the eleven week training program. All sessions will be fully supervised by physiotherapy, nursing and medical personnel.

Once your initial strength and endurance abilities have been established we will be able to increase the resistance of the hydraulic training equipment according to your progress. Over the eleven weeks your program will be individually upgraded according to your specific needs to ensure that you reach your maximum potential exercise tolerance.

INHERENT RISKS

You will be referred to the study by your treating cardiologist or physician who will, prior to referral, have screened you to ensure there is no reason why you should not be included in this study. **You will not be admitted to the study without clearance from your treating heart specialist.**

Risks and possible inconvenience include :

1. Participation in assessments of responses to training before and after the eleven weeks of training. This assessment will include an exercise treadmill test while breathing into a tube to analyse oxygen use and while having the cardiograph continuously monitored. There will be a blood test, a test of muscle strength and endurance, a prolonged 45 minute cardiograph and some questionnaires.
2. Attendance at the gymnasium three times per week each for a period of approximately two hours, for the eleven week duration of the program.

3. The possibility that during or following your participation in resistance exercise activities you may develop some or all of the following :
- Dizziness, nausea, fainting or shortness of breath.
 - Irregular heart beat or transient worsening of heart function which may require treatment (e.g. medication or an electric shock to restart a heart beat).
 - Muscle soreness and fatigue.

SAFETY

The researchers believe that all possible precautions will be taken to ensure your safety during this study. Previous research projects involving resistance training for patients with coronary artery disease have not resulted in any serious complications, injury or worsening of the disease. Your heart rhythm will be monitored during exercise to ensure safety. You will be observed throughout exercise sessions and will be trained to report any symptoms noted.

BENEFITS TO PARTICIPANTS

Your physical program will be designed specifically for your particular needs and your program will be graded to ensure that you reach your optimum potential. Through your participation in the educational component of the study you may gain insights into how best you can reduce your own risk factors for future heart disease and monitor your own physical activities.

You will have opportunities to discuss your concerns in a supportive environment and will have access to the latest technology and education available. You will be given a report of your fitness at the completion of the study and will receive specific advice about how you can continue to improve your physical fitness in the future. Through improved cardiovascular fitness and strength you may be able to broaden your vocational or leisure activities.

QUESTIONS

At any time before or during the study you will be free to ask any questions regarding the study and will be encouraged to do so with the principal investigator or any co-investigators.

CONFIDENTIALITY

Only the investigators will have access to confidential data which identifies you by name. You will be told of any significant or new findings that develop during the course of the study. All information and data obtained from the study will be kept strictly confidential. Patients will not be named in any research reports without the consent of the persons involved. If you request, test results can be passed on to your family doctor or specialist.

Contact phone numbers :

Dr David Hare : 496 3002 (After Hours Page : 387 1000)
Dr Henry Krum : 496 5000 Paging Number : 1076 (All hours)
Ms Toni Ryan : 018 362 862

**AUSTIN HOSPITAL
RESEARCH CONSENT FORM**

I, _____ agree to participate in a research project entitled : The efficacy of sub-maximal resistance training for patients with stable heart failure, being conducted by Dr David Hare.

1. My agreement entails :

That I will participate in three sessions of supervised hydraulic resistance and aerobic exercise activities in the Cardiac Rehabilitation Gymnasium every week for eleven consecutive weeks. This will involve activities such as stationary cycling and working my leg and arm muscles against the resistance of a hydraulic training system. Both before and after the study I will also be required to undergo additional assessments including muscle strength and fatigue, cardiovascular fitness and blood pressure checks. I understand that my heart will be monitored throughout each training session using a cardiograph and that I will be required to wear a small recorder attached to a belt during exercise activities.

I understand that while the study will be under the supervision of Dr David Hare, other professional persons may assist or act on his behalf.

2. The following risks, inconveniences and discomforts have been explained to me :

- i) Attendance and participation before and after the eleven weeks of training.
- ii) Attendance at the gymnasium three times per week for a period of approximately two hours for the eleven week duration of the program.
- iii) The possibility that during or following my participation in resistance exercise activities I may develop some or all of the following :
 - Heart irregularity which may rarely require treatment (e.g. medication or an electric shock to restart a heart beat)
 - Dizziness, nausea or fainting.
 - Muscle soreness and fatigue.

3. I have read the attached " Patient information Sheet" and understand the general purpose, methods and demands of the study * where appropriate.

4. I understand that the project may not be of direct benefit to me.

5. I can withdraw from the study at any time, without prejudicing my further management.

6. I am satisfied with the explanation given in relation to the project insofar as it affects me and my consent is freely given.

Signatures:

Read over and explained to the patient

Signed by the Investigator _____ **Date** _____

Signed by the Patient _____ **Date** _____

Signed by the Witness _____ **Date** _____

* A brief written description of the study must be shown to any patient prior to their involvement in the proposed study. Please feel free at any time to contact the researcher with regard to any queries or concerns you may have with regard to your participation in this project.

Patient information : Initial Letter

/ / 95

Dear Mr _____

We have arranged for you to attend the Austin Hospital for preliminary tests to determine whether or not you may be a suitable candidate for our Heart Failure Study.

You will be required to attend the hospital on two consecutive days, _____ and _____ next week.

Your appointments are on :

Day _____ Time _____ - _____

Day _____ Time _____ - _____

at the **Clinical Pharmacology Department**, where we met today.

Your parking card is valid for the duration of this study so remember to bring it with you on the day.

We ask that you do not have any alcohol for twenty-four (24) hours prior to these appointments. Also :

- Please wear comfortable loose clothing and runners.
- Do not smoke any cigarettes for two (2) hours before this appointment.
- If possible do not eat food or drink any coffee before you come for two (2) hours.
- **Make sure you take your medications as you would normally do on the day. If you use Ventolin please bring your puffer with you to your appointment.**

If for any reason you are not able to attend these appointments please contact Ms Toni Ryan as soon as possible on telephone XXXXXXXX

Appendix C

Methodology

Assessment Procedure Time Table

Procedure	Time Line : Day
Referral	1
Letter & Patient Information	2
Initial Interview	7
1st Assessment session	14
2nd Assessment session	15
Training	20
1st Re-Assessment session	97
2nd Re-Assessment session	98

Program Procedure

Referral

- Letter & Patient Information
- Parking Card

Initial Interview

- Demographic Study
- Minnesota
- Cardiac Depression
- Spielberger
- Appointment Card

1st Assessment

- Am lab : H.R variability
- Blood Test
- Medical Examination
- E.T.T
- Holter Monitor

2nd Assessment

- Return Holter Monitor
- Forearm Blood Flow
- Strength & Endurance
- 6 Min Walk

Training Program

- Mon, Weds, Fri 10.00-11.00

Re-assessment

1st Assessment

- Am lab : H.R variability
- Blood Test
- Medical Examination
- E.T.T
- Holter Monitor

2nd Assessment

- Return Holter Monitor
- Forearm Blood Flow
- Strength & Endurance
- 6 Min Walk

Appointment 3 : Clinical Pharmacology

Strength & Endurance

Assessment

Strength and endurance tests will be conducted using isokinetic concentric assessments. This involves a preset fixed speed (0 degrees to 500 degrees per second) with resistance that accommodates to the individual at every point in the range of motion. As the joint moves through its available range of motion the efficiency of the muscle changes owing to the length tension ratio changes in the muscle group and changes in the biomechanical skeletal leverage system. An individual will never meet more resistance than the patient can handle because the resistance is equal to the force applied.

We will conduct our muscle testing using the Merac[®] isokinetic concentric dynamometer in the Physiotherapy Department on Level 3.

A passive machine, this system will allow the assessment of both muscle strength and fatigability at angular velocities from 0 to 300 degrees with a torque limit of 300 ft-lb. We will assess knee flexion and extension and chest/shoulder push-pull using the accessory chair. Stabilization will be accomplished through multiple straps to ensure joint isolation.

Determination of Muscular Strength and Endurance

Strength will be measured as changes in muscular strength to ascertain the maximum lifting capacity of three muscle groups. Isokinetic dynamic muscle testing will be conducted on the MERAC[®] Isokinetic Concentric Dynamometer. The joint movement patterns have been selected to most closely simulate the patterns to be used during training on the Total Power Unit.

Assessment Protocol

Movement Pattern	Strength	No. of Repetitions	Endurance	No. of Repetitions
Shoulder Push / Pull	60 ^o /sec	3	120 ^o /sec	20
Knee Flexion / Extension	60 ^o /sec	3	180 ^o /sec	20

Assessment Procedure

The investigator sets up for the Isokinetic Testing Protocol including

- Isokinetic Calibration
- Defibrillator (also to be used for ECG monitoring)
- Computer
- Printer
- Sphygmomanometer
- Stretch Protocol

Jo accompanies the patient to L3 Physiotherapy Dept Isokinetic Testing Room and applies the ECG leads. The investigator conducts the Strength & Endurance protocol whilst Jo monitors the ECG and takes Blood Pressure Readings.

Strength & Endurance Protocol

1. Stretch Program
2. Patient Stabilisation
3. Instruct Patient in breathing technique to avoid valsalva
4. Select System Protocol: *Heart Failure Study*
5. Data information
6. Patient Calibration
7. Run practice sets
8. Run Tests (including 60 sec. rest periods)
9. Print Reports
10. Save Data
11. Break (morning tea)

The investigator then takes the patient to L5 where the 6 minute walk assessment is completed. The patient is given an appointment card to begin training sessions the following week.

Blood Pressure will be monitored immediately after each Movement pattern assessment.

Changes in Strength and Endurance will be statistically analysed.

Exercise patterns to be tested will include :

Chest / Shoulder Push-Pull
Knee Flexion / Extension

Isokinetic Testing Protocol for Strength & Endurance

Protocol 1 - Knee Flexion - Extension

- Computer on
- Remove attachment
- Disk in
- Subject data Seat Set Up:
 Seat back _____ Seat bottom _____
 Seat Tilt *22 Dynamometer Height _____

Attachments

Knee 1-7 (set length)

Base 45°

Dynamometer 45o

Computer : Save to diskette - Done

Subject 5 min warm up(cycle) and stretch

Stretch Program

Strap subject in securely

- Subject Calibrate
- Calibrate limb position- shaft vertical
- Done Down
- Move limb to "O" position - extension
- Done Up
- Calibrate limb weight
- Rest leg
- Done
- System Protocol - Heart Failure
- Start Recording
- Give practice instructions
- Pull leg back
- Explain the level of resistance (60°/sec)
- Push forward as hard and fast as you can 3 times.
- Check comfort and make adjustments if necessary
- 60 sec rest
- Start recording
- Test x 3 reps
- SAVE DATA
- Confirm
- Next set up
- Explain change in resistance (180°/sec)
- Start recording
- 3 x practice
- Give instructions- 10 repetitions
- 10 repetitions
- SAVE DATA
- Confirm - Print Data

Protocol 2 - Upper limb Push/Pull

Subject data

- Seat Set Up:
- | | | | |
|-----------|-----|--------------------|--------------|
| Seat back | 16 | Seat bottom | 2.5 |
| Seat Tilt | *19 | Dynamometer Height | (.25-lowest) |

Attachments

Shaft 1-9 (offset adaptor)

Arm Length - 16" x 24" set at 11

Base 15°

Dynamometer 15o

Six Minute Walk Test

Modified from Guyatt, G.H et al (1985) The Can Med Assoc J. 1982:919-923

The walking test will be conducted in an enclosed corridor (preferably free of distractions) on a course 60 feet (30 metres) long. The corridor will be divided into five foot sections using a method unnoticeable to the patient. Chairs will be placed at either end of the course markers. The distance covered during the preceding walking test will not be revealed to the patient during the study.

Before the test the patient will sit quietly for ten minutes in on of the course marker chairs. These instructions will then be read to the patient :

The purpose of this test is to find out how far you can walk in six minutes. You will start from this point and follow the hallway to the chair at the end, then turn around and walk back. When you arrive back at the starting point, you will go back and forth again. You will go back and forth as many times as you can in the six-minute period. If you need to, you may stop and rest. Just remain where you are until you can go on again. However, the most important thing about the test is that you cover as much ground as you possibly can in six minutes.

I will tell you the time and I will let you know when the six minutes are up
When I say STOP please stand where you are.

Do you have any questions about the test?

Please explain to me what you are going to do.
Repeat the entire instructions if the patient does not seem to understand.

Repeat the sentence:
The most important thing about the test is that you cover as much ground as you possibly can during the six minutes.

Are you ready?

Start when I say go.
During the test, the walking pace of the patient should not be influenced. The test supervisor may walk behind the patient but should not walk with, or rush up behind or rush past the patient.

While walking the patient will be encouraged every 30 seconds with the following phrases:

0-3 min

That's it you've got the idea.

You're doing well

Keep it up now.

3-6 mins

Remember, as far as you can go.

We want you to go as far as you possibly can.

Come on, keep going.

These phrases should be said while making eye contact with the patient. The patient should be spoken to only at the 30 sec. intervals and no response should be made to the patient's questions about time and distance passed.

If necessary the patient may rest in a course marker chair although he/she should not be encouraged to do so.

The patient will be told the time elapsed at 2 and 4 minutes :

You have completed 2 minutes

You have completed 4 minutes.

At the end of the test the patient should not move from where he/she was told to stop. until the distance walked has been recorded. The patient will then be directed to the nearest marker chair and observed for at least ten minutes.

Parameters to be recorded for the walking test :

1) Distance walked

2) Duration of test if patient walked less than 6 minutes.

Modified Borg

- 0 Nothing at all
- 0.5 Very, very light (Just noticeable)
- 1 Very slight
- 2 Slight
- 3 Moderate
- 4 Somewhat severe
- 5 Severe
- 6
- 7 Very severe
- 8
- 9 Very, very severe (almost maximal)
- 10 Maximal

ETT Protocol : Equipment Check list

	Check 1	Check 2
Marquette		
Electrodes		
Abrasive Tape / razor / Alcohol wipes		
Defibrillator		
Beckman Cart		
Sphygmomanometer		
Scales / Height measure		
Room Temperature		
Barometric Pressure		
Bike warm up 2 min		
Borg Scale		
Mouthpieces x 2		
Tissues / Nose Clip		

ETT Protocol

Patient _____

Protocol	Check 1
Switch on Beckman 2 hours prior to testing	
Calibrate Beckman Manual Load : Auto 3 Verifying No: 5709 1st load 5664	
Calibrate Bike 5 min x 50 Watts 3 min x 50 watts = S.State 3 in x 75 watts = S.State	
Take Recordings Ambient Room Temperature. Barometric Pressure	_____ 0 _____ mmHg
Set up Mouthpieces x 2	
Set up Marquette system	
Collect Patient : Height. Weight	_____ cm _____ kg
Contact Doctor & technicians	
Check need for inhaler	
Explain Test	
Explain the Borg Scale	Breathlessness _____ Fatigue _____
Team check on roles and timing	
Begin protocol 10watts/min	
Cool Down 1 min x 25% W : 2 min x 10% W	

Volume Calibration

Vol	Temp	Vol	Temp
26	28.4	34	29.1
28	28.6	36	29.3
30	28.8	38	29.5
32	28.9	40	29.7

Beckman Calibration

Turn all systems on at least 2 hours before assessment	
Volume Calibration	
Volume	
Free Run	
Start	
Calibration Syringe - 30 litres 4 x 7 - vary speeds + 2	
Temp - check table	
Calibrate gases	
Remove mixing chamber tube - measure room air	
CO ₂ - 00.003	
O ₂ - 20.9	
Green cylinder tube - a syringe to crystal chamber.	
O ₂ cylinder - bottom knob	
2.55 - CO ₂	
18.2 - O ₂	
Turn cylinder OFF	
Re-connect crystal chamber	

General Signs and Symptoms

- Severe Chest Pain suggestive of angina
- Severe Dyspnoea
- Marked apprehension, mental confusion or lack of co-ordination
- Sudden onset of pallor and sweating
- Onset of cyanosis
- SaO₂ falling below 80%

Electrocardiographic Signs

- Frequent ventricular premature beats, particularly when showing the R on T wave, frequent runs of 3 or more, and paroxysmal ventricular tachycardia
- Second or third degree heart block
- Ischaemic changes, marked S-T depression
- T wave inversion, or the appearance of a Q wave
- Appearance of bundle branch block pattern

Blood Pressure Signs

- Any fall in systolic pressure below the resting value
- A fall of more than 20mmHg in systolic pressure occurring after the normal exercise rise
- Systolic BP in excess of 300 mmHg or a diastolic in excess of 140mmHg

24 Hour Holter Monitor Check List

	Check 1	Check 2
Holter Monitor		
Blank Cassette		
Batteries		
Pouch		
Alcohol Wipes		
Razor		
Abrasive Tape		
Micropore Tape		
Electrodes x 3		

Holter Monitor Protocol

Prepare Skin	
Apply electrodes	
Attach leads	
Replace batteries	
Insert cassette	
Set time	
Calibrate	
Check defib monitor	
Explain procedure- arrange next appointment	
Give patient diary sheet	

DATE / /

ID

CDS

(Hare/Davis)

This questionnaire consists of a number of statements about the way you feel *at present*.

Next to each statement there is a rating scale from 1 to 7 for you to indicate how much you agree or disagree with the statement.

Strongly disagree 1 2 3 4 5 6 7 Strongly agree

Please indicate how strongly you agree or disagree with each statement by circling one of the numbers on the scale.

For example, a score of a 4 would indicate that you neither agree nor disagree with the statement, a score of 1 that you strongly disagree, and a score of 7 that you strongly agree.

EXAMPLE

Strongly disagree 1 (2) 3 4 5 6 7 Strongly agree

This indicates that you quite strongly disagree with the statement.

THERE ARE NO RIGHT OR WRONG ANSWERS

PLEASE ENSURE YOU HAVE COMPLETED ALL ITEMS

CDS

CHECK TO MAKE SURE YOU HAVE ANSWERED ALL QUESTIONS	Strongly Disagree	Strongly Agree
1. I have dropped many of my interests and activities...	1 2 3 4 5 None dropped	6 7 All dropped
2. My concentration is as good as it ever was...	1 2 3 4 5 Very Poor concentration	6 7 Excellent concentration
3. I can't be bothered doing anything much...	1 2 3 4 5 Keen to do things	6 7 Can't be bothered
4. I get pleasure from life at present....	1 2 3 4 5 No pleasure	6 7 Great pleasure
5. I am concerned about the uncertainty of my health...	1 2 3 4 5 Not concerned	6 7 Very concerned
6. I may not recover properly...	1 2 3 4 5 Will recover completely	6 7 Will not recover
7. My sleep is restless and disturbed...	1 2 3 4 5 Not restless	6 7 Very restless
8. I am not the person I used to be...	1 2 3 4 5 Just the same	6 7 Completely different

CHECK TO MAKE SURE YOU HAVE ANSWERED ALL QUESTIONS

Strongly Disagree

Strongly Agree

9. I wake up in the early hours of the morning and cannot get back to sleep...

1 2 3 4 5 6 7
Never wake Always wake

10. I feel like I'm living on borrowed time...

1 2 3 4 5 6 7
Unlimited time Very much on borrowed time

11. Dying is the best solution for me...

1 2 3 4 5 6 7
No solution Best solution

12. I feel in good spirits...

1 2 3 4 5 6 7
Very poor spirits Excellent spirits

13. The possibility of sudden death worries me...

1 2 3 4 5 6 7
Not at all Very worried

14. There is only misery in the future for me...

1 2 3 4 5 6 7
No misery Only misery

15. My mind is as fast and alert as always...

1 2 3 4 5 6 7
Slow and inattentive Very fast and alert

16. I get hardly anything done...

1 2 3 4 5 6 7
Everything done Nothing done

17. My problems are not yet over...

1 2 3 4 5 6 7
All problems over Still major problems

CHECK TO MAKE SURE YOU HAVE ANSWERED ALL QUESTIONS	Strongly Disagree							Strongly Agree						
18. Things which I regret about my life are bothering me...	1 Absolutely no regrets	2	3	4	5	6 Great regrets	7							
19. I gain just as much pleasure from my leisure activities as I used to...	1 No pleasure at all	2	3	4	5	6 Very great pleasure	7							
20. My memory is as good as it always was...	1 Very poor memory	2	3	4	5	6 Excellent memory	7							
21. I become tearful more easily than before...	1 Not at all tearful	2	3	4	5	6 Very easily tearful	7							
22. I seem to get more easily irritated by others than before...	1 Never irritated	2	3	4	5	6 Very easily irritated	7							
23. I feel independent and in control of my life...	1 No independence	2	3	4	5	6 Completely independent	7							
24. I lose my temper more easily nowadays...	1 Never lose temper	2	3	4	5	6 Lose it very easily	7							
25. I feel frustrated...	1 Not at all frustrated	2	3	4	5	6 Extremely frustrated	7							
26. I am concerned about my capacity for sexual activity...	1 No concern at all	2	3	4	5	6 Grave concern	7							

SELF-EVALUATION QUESTIONNAIRE

Developed by C. D. Spielberger, R. L. Gorsuch and R. Lushene

STAI FORM X-1

NAME _____ DATE _____

DIRECTIONS: A number of statements which people have used to describe themselves are given below. Read each statement and then blacken in the appropriate circle to the right of the statement to indicate how you *feel* right now, that is, *at this moment*. There are no right or wrong answers. Do not spend too much time on any one statement but give the answer which seems to describe your present feelings best.

	NOT AT ALL	SOMEWHAT	MODERATELY SO	VERY MUCH SO
1. I feel calm	(1)	(2)	(3)	(4)
2. I feel secure	(1)	(2)	(3)	(4)
3. I am tense	(1)	(2)	(3)	(4)
4. I am regretful	(1)	(2)	(3)	(4)
5. I feel at ease	(1)	(2)	(3)	(4)
6. I feel upset	(1)	(2)	(3)	(4)
7. I am presently worrying over possible misfortunes	(1)	(2)	(3)	(4)
8. I feel rested	(1)	(2)	(3)	(4)
9. I feel anxious	(1)	(2)	(3)	(4)
10. I feel comfortable	(1)	(2)	(3)	(4)
11. I feel self-confident	(1)	(2)	(3)	(4)
12. I feel nervous	(1)	(2)	(3)	(4)
13. I am jittery	(1)	(2)	(3)	(4)
14. I feel "high strung"	(1)	(2)	(3)	(4)
15. I am relaxed	(1)	(2)	(3)	(4)
16. I feel content	(1)	(2)	(3)	(4)
17. I am worried	(1)	(2)	(3)	(4)
18. I feel over-excited and "rattled"	(1)	(2)	(3)	(4)
19. I feel joyful	(1)	(2)	(3)	(4)
20. I feel pleasant	(1)	(2)	(3)	(4)

LIVING WITH HEART FAILURE QUESTIONNAIRE

These questions concern how your heart failure (heart condition) has prevented you from living as you wanted during the last month. The items listed below describe different ways some people are affected. If you are sure an item does not apply to you or is not related to your heart failure then circle 0 (No) and go on to the next item. If an item does apply to you, then circle the number rating how much it prevented you from living as you wanted.

Did your heart failure prevent you from living as you wanted during the last month by:

	No	Very little					Very much
1	0	1	2	3	4	5	
2	0	1	2	3	4	5	
3	0	1	2	3	4	5	
4	0	1	2	3	4	5	
5	0	1	2	3	4	5	
6	0	1	2	3	4	5	
7	0	1	2	3	4	5	
8	0	1	2	3	4	5	
9	0	1	2	3	4	5	
10	0	1	2	3	4	5	
11	0	1	2	3	4	5	
12	0	1	2	3	4	5	
13	0	1	2	3	4	5	
14	0	1	2	3	4	5	
15	0	1	2	3	4	5	
16	0	1	2	3	4	5	
17	0	1	2	3	4	5	
18	0	1	2	3	4	5	
19	0	1	2	3	4	5	
20	0	1	2	3	4	5	
21	0	1	2	3	4	5	

Training Protocol

Circuits consist of a combination of three hydraulic resistance stations interspersed with aerobic activities including stationary cycling, walking and upper limb ergometry. The possibility of an order effect will be eliminated by randomising the activities throughout the training program.

- Warm up (stretch and aerobic movements) for 5 minutes
- Cycle (aerobic activity)
- Upper Body Cycling (aerobic activity)
- Shoulder Press (resistance activity)
- Leg Flexion / Extension (resistance activity)
- Chest press (aerobic activity)
- Stationary Cycle (aerobic activity)
- Walk (Cool Down)

Detailed Procedure

1. Resting blood pressure
2. Resting heart rate : check current patient symptoms.
3. Application of ECG electrodes
4. Cycle
5. Upper Body Cycle
6. Application of ECG monitor
7. Resistance Training
8. Removal of ECG leads
9. Cycle
10. Walk
11. 2 minutes rest
12. Resting blood pressure
12. Resting heart rate

At the completion of the test the Beckman Print out is marked and stored for analysis.

Changes in predicted VO_{2peak} will be evaluated and statistically analysed at the completion of the eleven week program.

Indications for stopping the E.T.T

General Signs and Symptoms

- Severe Chest Pain suggestive of angina
- Severe Dyspnoea
- Marked apprehension, mental confusion or lack of co-ordination
- Sudden onset of pallor and sweating
- Onset of cyanosis
- SaO₂ falling below 80%

Electrocardiographic Signs

- Frequent ventricular premature beats, particularly when showing the R on T wave, frequent runs of 3 or more, and paroxysmal ventricular tachycardia
- Second or third degree heart block
- Ischaemic changes, marked S-T depression
- T wave inversion, or the appearance of a Q wave
- Appearance of bundle branch block pattern

Blood Pressure Signs

- Any fall in systolic pressure below the resting value
- A fall of more than 20mmHg in systolic pressure occurring after the normal exercise rise
- Systolic BP in excess of 300 mmHg or a diastolic in excess of 140mmHg

MEDICAL PROTOCOLS**ARREST PROTOCOLS**

In C.C.U. it is the trained graduate's responsibility to initiate advanced life support.

- Viz:
- C.P.R.
 - Maintain airway.
 - Drug therapy.
 - Defibrillation as indicated.

N.B. These protocols follow traditional methods and are open to review as indicated.

ARREST PROCEDURE

* Document arrhythmias - always check Serum Potassium stat.

* Basic Life Support

1. Establish unresponsiveness.
2. Call for assistance, call Code 0.
3. Position patient:
 - supine
 - remove head of bed.
4. Clear airway, insert airway.
5. Establish breathing via air viva. Maintain until patient intubated by anaesthetist.
6. Commence C.P.R. 4 breaths initially then
Ratio - 1.5
1 breath : 5 chest compressions.

MEDICAL PROTOCOLS

Arrest Protocols (Continued)

Ventricular fibrillation)	
Ventricular tachycardia)	requires emergency
Tachycardia with L.O.C.)	D.C. Reversion

- Document arrhythmias.
- Basic life support (Steps 1 - 4)
- Defibrillation - immediate defibrillation is priority treatment.
- i) Ventricular fibrillation and ventricular tachycardia
 - defibrillate with maximum 300 joules (asynchronous) increase to 400 joules if 1st D.C. reversion is unsuccessful.
- ii) If tachyarrhythmia with L.O.C. e.g. S.V.T., patient may require synchronised D.C. @ 150 joules initially, then increase by 50 joules as necessary.

Post reversion from ventricular fibrillation and ventricular tachycardia:-

- Give I.V. Lignocaine 1.5mg/kg bolus then a Lignocaine infusion rate as per protocol. The sequence of use for antiarrhythmic drugs is as follows:-

(If no reversion - a repeat bolus dose of Lignocaine 0.5mg/kg can be given).

For Ventricular Fibrillation:

- 1st choice:-
1. Lignocaine
 2. Bretylium 5-10mg/kg
 3. Procainamide) Refer appropriate
 4. Mexilitine) protocols

For Ventricular Tachycardia:

1. Lignocaine
2. Procainamide
3. Consult attending cardiologist

* (Check Potassium and magnesium level and treat accordingly).

Arrest Protocols (Continued)**Method of defibrillation (In emergency)**

1. Maintain continuous monitoring.
2. Position gel-pads or apply gel to paddles.
Place gel pads just to right of the sternum below the clavicle and at the left ventricular apex near the anterior axillary line to the left of the nipple.
3. Charge defibrillator 300 joules (as per Austin Hospital's Coronary Care Protocol for Post Cardiac Surgical Patients).

Theoretically D.C. reversion above 400 joules may cause some myocardial damage. Reversion at this level is adequate to revert most patients.

If a second D.C. reversion is required, charge increased to maximum joules.

4. Place sternal and apical paddles over the gel pads firmly.
5. Announce shock is to be delivered - ensure all personnel clear of both patient and bed. The safety of all persons in the immediate area is the responsibility of the person discharging the fibrillator.
6. Apply firm pressure and deliver shock - if possible deliver shock during expiration when transthoracic resistance is lowest.
7. Wait and check for return of pulse or rhythm after each defibrillation.
Record rhythm strips.
8. If first shock is unsuccessful, increase energy to maximum joules and repeat shock immediately. Make sure the gel-pads are not dry.

If recurrent VF, defibrillate 3 times in succession, then give drug therapy.

9. If burns occur - apply SILVAZINE cream.

MEDICAL PROTOCOLS

Arrest Protocols (Continued)**Ventricular Fibrillation**

Immediate D.C. reversion (300 joules)

Sinus Rhythm treat as per post V.F. protocol	V.F. Increase to 300 joules and repeat D.C. shock immediately	Asystole treat as per asystole protocol	Other rhythm treat as per appropriate protocol
---	--	--	---

1. Maintain adequate ventilation, intubate.
2. Between defibrillation attempts, maintain CPR. Some patients may require 2-3 D.C. shocks in succession before reversion.
3. I.V. line - D5W. Administer Lignocaine bolus 1.5mg/kg and commence Lignocaine infusion.
4. If V.F. refractory, Adrenaline may be used. Will coarsen V.F. to ventricular flutter therefore making myocardium more responsive to further D.C. reversions.
Adrenaline 1:10,000 in 10 mls. over 10-15 seconds.
5. D.C. reversion @ maximum joules.
6. Change of antiarrhythmic drug as per protocol.
7. Check serum K⁺ levels as soon as possible.
8. Sodium Bicarb. may be given upon return of a stable rhythm after ABG's have been recorded and artificial ventilation is inadequate to restore acid base. Bicarb. is more clearly indicated during an arrest associated with a tricyclic overdose or in a patient with a pre-existing acidosis which is responsive to bicarb.

N.B. ABG's not appropriate during an arrest.

Arrest Protocols (Continued)**Ventricular tachycardia**

No L.O.C.

Adequate perfusion

1. Monitor & observe patient

2. Check Serum Potassium
stat with machine in ICU
If potassium level is
low, correct immediately
as per "Potassium
Replacement Protocol".3. Attempt to revert
arrhythmia with bolus
Lignocaine I.V. 1.5mg/kg
Repeat in 2 minutes
if no reversion.If successful
reversion, commence
Lignocaine infusion
as per protocol

Poorly Perfused

1. Prepare for elective
D.C. reversion2. Administer
as per protocolIf no reversion
repeat another bolus of
0.5mg Lignocaine
- Notify RMO
- Consider change of
antiarrhythmic drug as
per protocol

L.O.C.

Emergency
D.C.reversion
300 joules
followed by
antiarrhythmic
drugs - a bolus
& then infusion**Other tachyarrhythmias:-**Example:- S.V.T.
S.V.T. with aberration.
Rapid atrial fibrillation/flutter.

If adequate perfusion:-

Do ECG to confirm type of tachyarrhythmia.
Notify RMO.
Treatment specific to rhythm as ordered by medical officer.

If inadequate perfusion:-

- prepare for emergency D.C. reversion (if unconscious).
- Elective D.C. reversion (if conscious).

Use of antiarrhythmics in Coronary Care Unit1. **Lignocaine (Xylocard)**

Bolus Dose of 100 mgm given I.V. or 1.5mg/kg

Lignocaine Infusion:-

Preparation:

2 gms Lignocaine in 500 mls 5% Dextrose

4 gms Lignocaine in 1 litre 5% Dextrose

Infusion rate:

4 mgm/min. = 60 mls/hour 1st hour

3 mgm/min. = 45 mls/hour for 2nd hour

2 mgm/min. = 30 mls/hour thereafter usually 12 hours

Maintenance:

- if arrhythmia still persists after 5 minutes or if arrhythmia recurs a further bolus of 0.5mg/kg may be given.
- recommence timing of 1st hour of Lignocaine from this point.

If arrhythmia still remains uncontrolled 5 minutes after second stat dose of Lignocaine, change to procainamide for V.T.

2. **Procainamide Hydrochloride:**

Initial doses: I.V. 50 mgm repeated each minute until-- the rhythm is controlled

- the QRS widens (50% of original width)
- the B/P falls below 85mm.Hg systolic
- To maximum dose 1,000mgm.

***Note**

If arrhythmia is controlled early in administration of procainamide, continue initial doses as above until patient is given 400mgm/I.V.

Procainamide Infusion:

Preparation: 2 gms Procainamide in 500 mls 5% Dextrose

Maintenance: 3mgm/minute = 45 mls for 1st hour
2mgm/minute = 30 mls thereafter

Duration: -12 hours

MEDICAL PROTOCOLS

Use of antiarrhythmics in Coronary Care Unit (Continued)

3. **Bretylium:** (Refer to information on Bretylium)

- for refractory ventricular tachycardia and ventricular fibrillation

Bolus dose (undiluted) for ventricular fibrillation or ventricular tachycardia with L.O.C.

Bolus dose I.V. 300mgm - 500mgm stat followed by immediate defibrillation.

Ventricular tachycardia if conscious:-

1. I.V. Maxolon 10mgm for nausea STAT.
- Give I.V. 50mgm/minute (Total 300mgm-500mgm over 10-15 minutes).

Dilution: 500mgm Bretylium in 10 mls
Add 10 mls 5% Dextrose = Total 20 mls solution.
25 mgm Bretylium = 1 ml.

Bretylium Infusion

Preparation:

400mgm Bretylium in 100 mls 5% Dextrose.

Maintenance:

2mgm/minute = 30mls/hour for 1st hour
1mgm/minute = 15mls/hour thereafter

A second bolus dose (5mgm per kilo weight) i.e. approximately 300mgm may be given after 1st hour of arrhythmia persists. (Refer information).

4. **Mexilitine Infusion:**

Bolus dose of 200mgm I.V. slowly prior to commencing infusion over 10 mins.

2nd bolus dose of 100mgm 15 minutes later.

- if arrhythmia still present or recurs, a further 50-100mgm bolus may be given.

Dosage dependant on patient's weight and response. (Duration of infusion usually 12 hours).

Preparation

1 gram Mexilitine in 1 litre 5% Dextrose.

Use of antiarrhythmics in Coronary Care Unit (Continued)**Infusion rate:-**

1mgm/minute = 60 mls/hour for 1st hour then

0.5mgm/minute = 30mls/hour thereafter.

Drugs for Use in the event of

- (a) Asystole
 - (b) Ventricular standstill
 - (c) Bradyarrhythmia with poor perfusion/L.O.C.
 - (d) Complete heart block with poor perfusion/L.O.C.
1. Document arrhythmia
 2. Basic life support - steps 1 - 6 (on page ***)
 3. Drugs used in sequence:-
 - i) I.V. Atropine
 - ii) I.V. Isuprel for complete heart block
 - iii) I.V. Adrenaline (1:10,000)
 - iv) I.V. calcium
 4. Maintain C.P.R. throughout.
Allow for absorption of drug approximately 30 - 60 second between consecutive and/or change of drug.
 - i) Atropine:

Initial dose

I.V. Atropine 0.3mgm - 0.6mgm (Minijet) if necessary, increments of 0.3mgm may be given at 1 to 2 minute intervals to a maximum of 1.8mgm or until pulse rate of 90/minute results.

ii) Isuprel**Preparation:**

- i) 0.2mgms/10 mls mini set
- ii) 0.3mgms isuprel (1 ml)
diluted to 10 mls with 9 mls of normal saline

i & ii) each 1 ml of solution contains 0.02mgms of Isuprel.

MEDICAL PROTOCOLS

Initial dose

I.V. Isuprel 0.02mgm = 1 ml.

Increments of 0.02mgm (1 ml) I.V. to be given at 1 minute intervals until adequate perfusion is obtained, pulse rate of 90/minute results of arrhythmias develop.

If effective or partially effective with no side effects, maintain perfusion state with infusion.

Isuprel Infusion:-

Use 5 ml ampoules.

Preparation

4mgm Isuprel in 500mls 5% Dextrose

1mcg/minute = 7.5mls/hour

2mcg/minute = 15mls/hour

4mcg/minute = 30mls/hour

Appendix D

Data Collection

Demographic Assessment

***Convert for SPSS**

Patients Name _____ **S. No.** _____ **UR No.** _____

Address _____

Name of Doctor _____ **Tel** _____

Date of ETT ____/____/____ **Review** ____/____/____ **RNVG** _____

Reason for Exclusion

Death	Disability/other illness
Distance, geography, transport	Financial, social, language
Refusal or anticipated non-compliance	Already in randomised exercise trial
MRSA	Other (Specify)

Early Withdrawal

Death	Disability /Other illness
Distance, Geography, transport refusal	Financial, social
Other	MRSA

Country of Origin _____ **Marital Status** _____

Employment status _____ **Occupation** _____

Cigarette Smoking History _____

D.O.B ____/____/____ **Age** _____

Current Physical Status _____ **Angina on Effort (Grade 0-4)** _____

Grade	Description of symptoms
0	None
1	Ordinary physical activity(walking, climbing stairs) does not cause angina. Angina with strenuous or rapid or prolonged exertion at work or recreation.
2	Slight limitation of ordinary activity. Walking or climbing stairs rapidly, walking uphill, walking or stair climbing after meals, or in cold, or in wind, or under emotional stress, or only during the few hours after awakening. walking more than 2 blocks on the level and climbing more than one flight of ordinary stairs at a normal pace in normal conditions.
3	Marked limitation of ordinary activity. Walking one to two blocks on the level and climbing one flight of stairs in normal conditions at a normal pace.
4	Inability to carry on any normal physical activity without discomfort-anginal syndrome may be present at rest.

Current Grade of Dyspnoea (1-4) _____ **NYHA 1964**

Grade	Description of symptoms
1	No limitation of physical activity. Ordinary physical activity causes no undue dyspnoea
2	Slight limitation of physical activity. comfortable at rest with mild exertion, with symptoms only with the more strenuous grades of physical activity.
3	Marked limitation of physical activity, comfortable at rest but experiences symptoms even with the mildest forms of ordinary activity.
4	Inability to carry out any physical activity without discomfort. Symptoms of cardiac insufficiency... may be present at rest and are intensified by activity.

Pre-operative Findings

Cardiac Failure

- i. Yes
- ii. No

Heart Size

- i. Normal
- ii. Borderline enlarged (50-60%)
- iii. Enlarged (>60%)

Lungfields

- i. Normal
- ii. Congested
- iii. Interstitial oedema
- iv. Pulmonary oedema

E.C.G

- i. No
- ii. Yes

ECG

- i. Normal
- ii. ST/T abnormality
- Old MI : Pathological Q waves
- Fresh MI : Pathological Q waves and ST elevation, plus history

L.B.B.B ?

RNVG Ejection Fraction
_____ %

LVEDP

- <12
- 12-15
- 16-20
- >20

Surgery Data

Number of grafts

From Catheter report

Desirable _____

From conference report

Intended _____

From operation report

Applied _____

Aneurysmectomy (from operation report) Yes / No

Valve surgery (from operation report) Yes / No

Post-Surgery complications

Yes / No

Requiring re-operation

Haemorrhage

Clinical/microbiological

Sternotomy infection

Clinical /microbiological

Leg infection

Clinical

Venous thrombosis (leg)

New Q waves in E.C.G

Myocardial infarction

**Persisting moist sounds
or oedema and raised J.V.P)**

Cardiac Failure

**Resulting in hospital stay
longer than 10 days post-
operatively or disability after
discharge.**

Other significant _____

Current Medications

Drug Classification	Drug	Daily Dose
Diuretic		
Potassium		
Digoxin		
Beta Blocker		
Calcium Antagonist		
Hypotensive		
S/L Nitroglycerin		
Nitrate		
Antiarrhythmic		
Sedative/ Hypnotic psychotropic		
Other		
Smoking		

ETT (Modified Naughton)

Age _____ **Resting Heart Rate (Standing)** _____ **b.p.m**

H.R end of stage 2 on test _____ **b.p.m** **H.R. Maximum** _____ **b.p.m**

Resting B.P Standing Syst _____ **mmHg** **B.P End Stage 2 Syst** _____ **mmHg**

B.P Max. Syst _____ **mmHg**

Double Product : **End of Stage 2** _____ **Maximum** _____

Predicted physical working capacity (Mets) _____ **Time on Test** _____ **min.**

Reasons for stopping

	Yes	No		Yes	No
Chest Pain			Dyspnoea		
Fatigue			Leg Weakness		
Leg Pain			Giddiness		
Confusion			Arrhythmia		
Fall in B.P>/ 20mmHg			Other(specify)		

S-T Depression (from leads V4,V6 or V6) 0.08 sec after R wave increment.

S-T elevation (from leads V4,V6 or V6) 0.08 sec after R wave increment.

S-T shape (at time of 60,61 above).

Angina

- i. No
- ii. Definite
- iii. Probable (likely clinical)
- iv. Possible (Unlikely clinical)

Diastolic Response

- i. Fall >20mmHg
- ii. Fall 11 - 20 mmHg
- iii. mmHg >/ stable </ 10 mmHg
- iv. Rise 11 -20 mmHg
- v. Rise 21- 30 mmHg
- vi. Rise 31 - 40 mmHg
- vii. Rise > 40 mmHg

R on T ectopics

- i. No
- ii. Yes

Successive ectopics (take highest)

- i. nil
- ii. pairs
- iii. salvos of 3
- iv. V.T (>3 beats)
- v. V.Flutter
- vi. V.Fibrillation

Conduction Block**A-V Block**

- i. Long RR interval
- ii. Wenckebach
- iii. Other/Partial
- iv. Complete

Recovery (Monitored to 5 minutes)

- i. Standing/sitting
- ii. Recumbent

Systolic B.P fall (during test)

- i. nil <10mmHg
- ii. mmHg
- iii. mmHg
- iv. mmHg
- v. >/40 mmHg

Peak Diastolic Pressure :**Ventricular arrhythmias****Isolated ectopics**

- i. Nil
- ii. VES<1 in 10
- iii. VES >/ 1 in 10
- iv. Bigeminy

Focus of ectopics

- i. Nil
- ii. Unifocal
- iii. Multifocal

Supraventricular arrhythmia

- i. No
- ii. Nodal tachycardia
- iii. atrial tachycardia
- iv. atrial flutter
- v. atrial fibrillation

I-V Block

- i. No
- ii. Partial L.B.B.B or R.B.B.B
- iii. L.B.B.B or R.B.B.B

E.C.G (S-T -T Abnormality)

- i. No change
- ii. Lessening Abnormality
- iii. Increasing Abnormality

Specify :

Angina

- i. No angina
 - ii. Less angina
 - iii. No change
 - iv. More angina
 - v. Appearance of angina
- Specify

Arrhythmia

- i. No Arrhythmia
- ii. Less Arrhythmia
- iii. No change
- iv. More arrhythmia
- v. Specify

Blood Pressure

- i. B.P Fall
- ii. No Change
- iii. B.P Rise
- iv. Specify