THE EFFECTS OF RESISTANCE TRAINING DURING EARLY CARDIAC REHABILITATION (Phase II) ON STRENGTH AND BODY COMPOSITION

By

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ABSTRACT

The effects of combined resistance training (RT)and aerobic exercise were compared to aerobic only (AO) exercise on measures of strength, fat mass (FM), lean mass (LM), and muscle mass (MM). Twenty-seven haemodynamically stable male cardiac patients (age range 39-66 years) performed 3 weeks (6 sessions) of aerobic exercise 2x/week before being randomly assigned to one of three groups: aerobic only (AO; n = 10) early-start resistance training (ESRT; n = 8) and late-start resistance training (LSRT; n =9). All three groups participated in 16 weeks (32 sessions) of aerobic exercise, however, the ESRT and LSRT groups performed 12 and 6 weeks (24 or 12 sessions respectively) of moderate-high intensity (70-79% of 1RM) weight training (7 exercises). There were no haemodynamic complications due to the RT over the course of the study. Body composition was measured using anthropometric girths, sum of skinfolds (SOS), body weight (BW), waist-to-hip ratio (WHR), Near Infrared Photospectometry (NIR) and Dual- Energy X-ray Absorptiometry (DXA), DXA measures were only done for 14 subjects (AO & LSRT, n=4; ESRT, n=6) and due to the small group numbers results were used as supplemental information. MM was calculated from a regression equation based on skinfold-corrected limb girths.

Results: A 3 (Group) X 4 (Time) ANOVA with repeated measures on the last factor, indicated no significant changes for the group effect in BW (p=0.6) and SOS (P=0.9), DXA & NIR LM (both p=0.6); DXA & NIR FM (p=0.4 & p=0.9, respectively) or MM (p=0.2), or individual girths. However, a significant difference occurred for the time factor for WHR ($F_{3,72}$= 5.4, p<.002) and for waist girths ($F_{3,72}$= 4.02, p<.01) with no changes to hip girths (p=0.7) or umbilicus skinfolds (p=0.9) suggesting a decrease in subjects' visceral fat. The group X time factor showed significance for the DXA LM ($F_{2,11}$= 5.7; p<.02), and MM ($F_{6,72}$= 5.1, p<.001) indicating that changes in response to the RT interventions over time were dissimilar between the groups at specific assessment periods. The

AO group lost 2 ± 1.5% DXA $LM_{pre\text{-}to\text{-}post}$ and 3.3 ± 2.1% MM while the ESRT and LSRT groups gained DXA LM_{ESRT} 3.9% ±1% and MM $_{ESRT}$ 4.0 ± 1.4% MM and DXA LM_{LSRT} .8 ± 1.1% and MM_{LSRT} 4.0 ± 1.4%.

Overall pre-to post-training strength changes were significantly different ($F_{2,22}$= 9.5, p<.001) between groups with the greatest changes occurring in the ESRT group (27± 4.2%) followed by the LSRT group (25 ± 3.3%) and then the AO group (7.3 ± 2.6%). A post-hoc Tukey HSD analysis revealed the significant difference to be between the RT and AO groups (p<.05); no significant difference existed between the two RT groups (p=.35). Upper and lower body pre-to post training strength changes were significantly different ($F_{2,22}$ = 5.8, p<.009 and $F_{2,22}$ = 7.4, p<.004, respectively) with the upper body increasing 6.5%$_{AO}$, 17.9% $_{ESRT}$, 18.4% $_{LSRT}$ and lower body increasing 7.5% $_{AO}$, 39.0% $_{ESRT}$, 33.8% $_{LSRT}$.

Conclusions: RT significantly increased strength with the greatest gains occurring in subjects who started RT earlier rather than later in the cardiac rehabilitation program (CRP). However, there were no significant strength differences between the ESRT and the LSRT groups suggesting that RT can begin as late as 10 weeks after starting a CRP and show similar strength gains to those who start RT earlier.

There were no significant changes in body composition between groups, however, the AO group showed a numerical loss in MM and DXA LM while the RT groups showed a numerical increase in these variables. A statistically significant group X time interaction effect for MM (p<.001) and DXA LM ((p<.02) suggests that RT maintains or increases MM and DXA LM, while AO exercise actually caused losses in these variables. WHR for all groups significantly decreased over time regardless of training intervention suggesting that RT may not play a primary function on WHR changes. WHR changes were due to a loss in waist girths suggesting a loss in visceral fat.

The primary goal of a CRP is to return the patient to a normal life as quickly as possible, RT can play a vital role in this process. RT can begin as early as 4 weeks post-cardiac event with minimal risk of haemodynamic complications in selected low-moderate risk cardiac patients. RT has many physiological benefits and by incorporating it earlier in a CRP, cardiac patients have an opportunity to incur these benefits sooner. This may then facilitate a quicker return to work and leisure activities.

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GLOSSARY

1 RM	1 Repetition Maximum
AACVPR	American Association of Cardiovascular and Pulmonary Rehabilitation
ACSM	American College of Sports Medicine
ADL	Active Daily Living activities
AEC	All Exercises Combined (resistance training)
AO	Aerobic Only exercise group
ART	Aerobic and Resistance Training groups
BP	Blood Pressure
CAD	Coronary Artery Disease
CBAG	Coronary Artery Bypass Graph
CHF	Congestive Heart Failure
CRP	Cardiopulmonary Rehabilitation Program
CWT	Circuit Weight Training
DBP	Diastolic Blood Pressure
DXA	Dual Energy X-ray Absorptiometry
DXALM	DXA Lean Mass: does not include bone or fat
ECG	Electrocardiogram
EHR	Exercising Heart Rate
ESRT	Early Start Resistance Training group
FM	Fat Mass
FW	Free Weight training equipment
GXT	Graded Exercise Test
HHP	Healthy Heart Program
HR	Heart Rate
HRR	Heart Rate Reserve
IE	Individual Exercises (resistance training)
LM	Lean mass
LSRT	Late Start Resistance Training group
MAP	Mean Arterial Pressure
MI	Myocardial Infarction
MM	Muscle Mass
MMkg	Muscle Mass in Kilograms
NIR	Near Infrared Photospectometry
NIRLM	NIR Lean Mass: does not include fat
PTCA	Percutaneous Transluminal Coronary Angioplasty (PTCA)
RHR	Resting Heart Rate
RPP	Rate Pressure Product
RT	Resistance Training
SBP	Systolic Blood Pressure
SOS	Sum of Skinfolds
SV	Stroke Volume
WT	Body Weight

INTRODUCTION

Before 1960, physicians had a poor understanding of how to effectively rehabilitate the cardiac subject. The approach of choice was one of caution: cardiac subjects were generally restricted to bed rest for up to 2 months and for some, to minimal activity for up to 1 year after a cardiac event (Froelicher, 1990). Throughout the 1960s, a more active approach was explored and aerobic exercise such as walking and cycling was incorporated into the process. The acute physiological effects of isometric contractions were investigated during the 1970s and were deemed dangerous to the cardiac subject due to the increased blood pressure response. Subsequently, researchers examined the effects of various forms of dynamic resistance training (RT) and brief, non-sustained isometric exercise and concluded that they were safe and effective and should be included in the rehabilitation setting (Verrill and Ribisil, 1996; Fletcher et al., 1992). Today RT has become a well-accepted adjunct therapy and is now considered an acceptable form of training for properly screened subjects by such organizations as the American College of Sports Medicine (ACSM) the American Association of Cardiovascular and Pulmonary Rehabilitation (AACVPR) and the American Heart Association (AHA) .

The 1995 ASCM strength training guidelines for cardiac outpatients suggest that those patients who meet all inclusion criteria can begin as early as four to six weeks after the start of a supervised aerobic program. These recent guidelines are progressive and safe; however, physicians have been slow to incorporate them into the clinical setting. Possible explanations for this may be budget restraints, administrative limitations, lack of space, and shortage of qualified staff. One objective of this study is to demonstrate the importance and value of RT in the cardiac rehabilitation protocol (CRP), which in turn, may influence medical directors and administrators to incorporate it into their CRPs.

Many clinics that do incorporate RT into their CRP, are using outdated 1991 ACSM guidelines which recommend RT begin after 12 weeks of participation in a supervised aerobic program. This delayed start generates several issues for contention. First, the number of RT sessions is relatively small to truly make significant physiological improvements. It is well documented that mild to moderate RT (30%-50% of 1RM) in cardiac rehabilitation increases strength and aerobic capacity with no detrimental haemodynamic responses (Kelemen 1986; Haslam 1988; Wiecek 1990; McCartney, 1991. The average increase in strength performance ranges from 20%-50% in healthy, 9%-227% in seniors and 20%-40% in cardiac patients over a 12-16 week training program (Verrill and Ribisil, 1996). In the first month of RT, the average strength increases for males and females under 30 years of age ranges from 3-6% per week; notably, 80% of the increases are due to neuromuscular adaptations (Westcott, 1993). However, these statistics can be misleading since the rate of strength development is virtually impossible to predict due to the numerous factors that influence it such as age, biomechanics, attitude, physiological adaptations and genetic differences (Westcott, 1989). This prediction becomes more complex when dealing with older cardiac patients (40+ years) with varying conditions and medications. In addition, many CRPs discharge their patients within 4 months of starting the program; this time-span is equivalent to approximately 32 aerobic exercise sessions, of which, the final 8 sessions include RT. Research suggests that the longer one strength trains, the greater will be the benefits and the longer strength levels will be maintained after cessation of the activity (Westcott, 1987; Fleck & Kraemer, 1987). Once discharged, many patients do not have access to the same RT equipment used in the CRP, or any equipment at all and they tend to lack sufficient competency to continue resistance exercise on their own.

The benefits of early RT intervention are undeniable. There have been 4 published studies that have demonstrated the beneficial effects of resistance training on strength, haemodynamics and aerobic capacity during the early part of the phase II period of rehabilitation (approximately 4-6 weeks). Squires et al. (1991), Butler et al. (1992), Stewart et al. (1994) and Daub et al. (1996) have demonstrated that resistance training incorporated earlier in the rehabilitation phase can result in greater gains in strength and aerobic capacity. They suggest that these improvements in upper and lower body strength allow cardiac participants to perform everyday activities at a lower energy cost and with greater efficiency of movement (Verrill and Ribisil, 1996) These researchers found few adverse effects due to this early intervention of resistance training as compared to aerobic exercise and believe that their results will serve to return patients to work and daily activities sooner.

Second, many patients have returned to work by the 4th month of their rehabilitation program, including those whose work duties require heavy lifting; 8 RT sessions is too few to prepare them for the strength demands associated with their jobs. There have been a small number of published studies involving cardiac patients which have incorporated resistance training at relatively high intensities of 70%-80% of 1RM (Ghilarducci et al., 1989; McCartney et al., 1991). Based on these findings it is believed that this intensity of training can be tolerated and can produce optimal gains in strength over the course of the program. However, it is argued that exposing cardiac patients to loads of this nature may be unnecessary since (a) the increase in risk far outweighs the relatively small gains in strength, (b) most cardiac patients have no need for increases in strength beyond those needed for ADL and work activities (c) intense training causes excessive fatigue and potentially increased haemodynamic responses. Another objective of this study is to further investigate the magnitude of change in muscular strength and endurance in patients who engage in resistance exercise after the 4th week of participation in the rehabilitative process. Also, to provide insight regarding the personalization of exercise prescription to match the needs of the patient. These results can then be used to justify the higher RT workloads for some patients who must return to jobs involving strenuous physical lifting, while confirming, the argument of low-moderate intensities for the average patient.

Another area of focus in this study is in the area of body composition. Changes to body composition components such as fat mass (FM), lean mass (LM), and muscle mass (MM) have not been extensively researched in the cardiac patient. Most documentation reveals inconclusive results regarding the magnitude of changes to FM and LM. These discrepancies may be due to one or more of the following possibilities: (a) experimental methodology, (b) measurement techniques and/or (c) late intervention. Studies that have produced insignificant changes in LM may be due to methodological issues such as too long a rest between reps (5-10 seconds) or too low training intensities (30%-50% of 1RM). Another possibility for the lack of change in FM or LM may be due to the techniques used to measure FM and LM. Most cardiac studies that have shown insignificant changes to FM and LM have used skinfold and anthropometric girth measurements. Skinfold measurements have been shown to be inaccurate when determining percentage body fat (Martin et al., 1985, 1991). In addition, studies that have indicated changes to FM and LM in healthy subjects have used more sophisticated assessment techniques such as computed tomography (CT) (Borkan et al., 1983; Frontera et al., 1988; McCartney et al., 1995), magnetic resonance imagery (MRI) (Fowler et al., 1991; de Ridder et al., 1992) Dual Energy Absorptiometry (DXA) (Galea et al., 1990) and ultrasound (Westcott, 1993). These methods appear to offer a clearer estimation of FM and LM than previous methods. Another common error in measurement technique is due to researchers reporting changes in MM when the technique they used i.e. ultrasound, measured LM; these two measures are distinctly different and cannot be treated as one and the same. The third explanation for inconclusive results in FM and LM may be due to late intervention. There appears to be no published research that has measured the body composition, specifically MM of cardiac patients prior to the start of the rehabilitation program. Several researchers suggest that the insignificant changes in FM and LM may be due to the fact that most of these studies were done using low-risk cardiac patients who had already undergone 3 months or more of traditional "usual care" exercise and that any significant body compositional changes had already taken place (Gettman et al., 1978; Ghilarducci et al., 1989; McCartney et al., 1995). Therefore, another objective of this study is to assess the body compositional changes in cardiac patients from time of entrance into CRP to exit.

LITERATURE REVIEW

Chapter 1

Resistance Training: Acute Physiological Responses

When cardiac patients begin physical activity several important areas of physiological response need to be monitored: BP, heart rate (HR) and oxygen (O_2) consumption (Drought, 1995).

Blood Pressure: Isometric Exercise

Previous studies reported that significant increases in systolic and diastolic BPs may occur with heavy RT and isometric exercise (Asmussen, 1981; Macdougall et al., 1985; Mitchell et al., 1981). Other earlier studies have also shown that elevated systolic BPs could increase the rate pressure product (RPP) and mean arterial pressure (MAP) (Jorgensen et al., 1973) and may also increase the likelihood of other cardiac conditions such as dysrhythmias, myocardial ischemia, or left ventricular dysfunction in coronary heart disease (CHD) patients (Stewart et al., 1989). The reasons for this increase in pressure are primarily due to (a) a mild increase in cardiac output (an increase in heart rate without an increase in stroke volume) and (b) little change in peripheral vascular resistance (McCartney et al., 1995). During exercise, the myocardium requires more oxygen due to the increased heart rate, thus a mild increase in cardiac output results in inadequate oxygen supply to the myocardium. As a result, the lack of peripheral vessel dilation, which normally would reduce MAP during physical exertion, does not ensue, and so, the "pressure load" on the heart increases. However, it has been argued that these haemodynamic and myocardial responses to isometric exercise are more prevalent when contractions are sustained; non-sustained isometrics appear to be safer (Franklin et al., 1991; Fletcher et al., 1992). Fleck and Kraemer (1988) and Featherstone et al., (1993), suggest that increased DBP may actually facilitate myocardial perfusion; McCartney et al., (1995) adds that transmural pressure across cerebral vessels may also be reduced during Valsalva manoeuvres, which in turn, may serve as a protective mechanism reducing the risk of vascular damage to the heart and brain (Verrill and Ribisil, 1996). Although little research exists to support these claims, these researchers do propose that brief non-sustained isometric contractions and Valsalva effects may have a functional purpose. Many jobs and daily activities involve manual lifting and pushing invoking isometric contractions and the Valsalva effect, therefore it would make sense to prepare patients in advance. This concept has received support of the AHA in their 1992 position paper on exercise (Verrill and Ribisil, 1996).

Blood Pressure: Dynamic Resistance Exercise

Recent studies have investigated the effects of dynamic resistance weight training on BP. Elevations in BP were noticed but did not exceed 190/106mm Hg during circuit weight training (CWT) using 8-16 reps at 30%-60% of predicted 1RM values in selected and high-risk cardiac patients (Butler et al., 1987; Haennel et al., 1989, Harris and Holly 1987; Kelemen et al., 1986; Sparling and Cantwell, 1989; Squires et al., 1991). This reduction in pressure, compared to that of isometric exercise, may be due to: (a) the dilation of peripheral vessels with an accompanying reduction in peripheral vascular resistance, (b) increased cardiac output or (c) decrease in MAP (Verrill et al., 1992).

Vander et al., (1992) used resistance workloads of 40%-60% of 1RM, and found that coronary artery disease (CAD) patients had lower peak systolic pressures and RPP during CWT than during maximal graded exercise testing (GXT). Further, peak DBPs exceeded those of GXT by 100-136%, however the mean diastolic pressure was only 100mm Hg during the weight training sessions. Studies using higher training intensities have shown SBP to be similar to maximal GXTs and DBP to be significantly higher ($\leq$ 138mm Hg) than GXT values (Haslam et al., 1988; Wiecek, et al., 1990).

Haslam et al., (1988), measured the ECG and arterial blood pressure responses to single-arm, single-leg and double-leg graded exercises in MI patients using intra-arterial catheters. Their findings suggested that single-leg and -arm exercises that used resistance loads less than 80% of 1RM and double-leg exercises less than 60% of 1RM, resulted in clinically acceptable arterial pressures and ECG responses. Wiecek et al., (1990) reported mean peak SBPs and DBPs were greatest in single-arm overhead presses (249 ± 16 and 152 ± 12 torr, respectively) and recommended avoiding over-the-shoulder lifts for CAD patients, if measurement of left ventricular function is not possible. One criticism of both Haslam's and Wiecek's study is that the catheterized arm was inactive during the RT, a factor which may have affected the validity of results. McCartney (personal communication) are presently conducting research that uses a special catheter placed in the working limb. The findings of this study will provide further insight into BP responses during RT.

Wiecek et al., (1990), also investigated the accuracy of the BP measurement techniques used in past studies to determine if these BP results were indeed accurate. They measured intra-arterial pressures directly using indwelling catheters and compared these readings with the armcuff method. Results indicated a 13% lower SBP reading during lifting, with the armcuff. They also observed no differences in DBP between methods. Ellestad (1989) suggested that the underestimation of SBP by the cuff method may be due to the human ear's inability to detect the low frequency of the first Korotkoff sounds. Wiecek et al., (1990), also reported that immediate post-arterial pressures drop rapidly, by as much as 100mm Hg, within the first 1-2 seconds, hardly enough time to inflate the sphygmomanometer cuff. These findings suggest that measurements after lifting, can't be relied on. Armcuff measurements taken during lifting, also need to be scrutinized. Classic research performed by McCartney et al., (1988, 1989, 1991, 1995) has raised the question regarding the validity and accuracy of information derived from the use of this tool. They feel that it is extremely difficult to get distinct accurate readings, since the pressures vary so greatly during a single repetition. They propose the use of intra-arterial techniques, if precise measurements are needed.

ASCM 1995 guidelines outline that RT exercise is permitted for those individuals who meet specific inclusion criteria. Those patients with left ventricular dysfunction (LVD), a condition inhibiting the ejection of blood during ventricular contraction, and in turn, reducing oxygen supply to the tissues, were excluded. Only those patients with ejection fractions (EFs) greater than 40% are included. Research by Squires et al., (1991) and Vander et al., (1986) reported that some LVD patients with EFs less than 40% showed no ischemic responses to CWT and regular RT. This information warrants further investigation focusing on the inclusion of LVD patients in RT.

Implications & Considerations

- Dynamic RT and CWT at intensities between 60%-80% of 1RM is safe and recommended for selected cardiac patients
- To reduce BP increases, sustained isometric contractions such as a tight hand grip or holding of breath should be avoided
- Brief (1 sec) isometric contractions and Valsalva manoeuvres can be safely tolerated during RT
- Double leg presses and Overhead presses should start at lower intensities (50%-60% of 1RM) and increase gradually to ensure safety.
- The accuracy and feasibility of using the sphygmomanometer to measure blood pressure during resistance exercise needs to be considered by the researcher prior to the study

- If precise measurements of arterial pressure are needed, then intra-arterial catheterization may be the most accurate method

Acute Hr, O_2 Consumption And Heart Function

Research on the acute effects of circuit weight training (CWT) on HR and O_2 consumption have produced variable results in both healthy subjects and cardiac patients. The majority of studies agree that HR, myocardial O_2 demand and ventilatory responses are lower and produce less myocardial ischemia than conventional graded aerobic exercise testing (Keleman et al., 1986; Vander et al., 1986; Gettman et al., 1981). HRs during CWT and regular RT range from 60%-83% of HRmax and 30%-50% of VO_2max (Gettman et al., 1981; Haennel et al., 1989; Hurley et al., 1984). Featherstone et al., (1993) reported significantly lower mean peak HR responses (range = 74-92 bpm) during 40-100% of maximal muscular contraction as compared to maximal treadmill exercise (mean = 157 bpm). This lower HR response appears to hold true for patients on beta blockers (Squires et al., 1991). Interestingly, McKelvie et al., (1995) measured the effects of RT on those with congestive heart failure (ejection fraction 27 $\pm$ 2.0%); results showed that RPP and HR were lower than bike ergometer work, and the DBP was higher, a result which may enhance myocardial circulation via collateral perfusion (McCartney et al., 1995).

Fardy et al., (1977) suggested that arm exercises, due to the use of smaller muscle mass, have a greater physiological cost than leg exercises and will produce higher HR responses. However, others believe that this may only be the case during submaximal workloads with higher the number of repetitions, and is the reverse when maximal workloads are used (Macdougall et al., 1985; Haslam et al., 1989; Fry 1990). It has been shown that the greater the repetitions and the longer the set the greater the RPP and demand on the heart (Haslam et al., 1989, Wiecek et al., 1990).

Intensity of the workload, expressed as a percentage of 1 RM, is thought to affect mean peak HR progressively (Haslam et al., 1988). Haslam et al., (1988) found that mean peak HR, in cardiac patients increased as workloads increased from 20%-80% respectively; although at 60% of 1RM, the double-leg press exercise elicited an RPP and MAP product that exceeded values comparable to 85% of maximum power output in cycle ergometer testing. Hurley et al., (1984) noted that higher intensities and shorter rest intervals contributed to higher HRs compared to treadmill walking at the same VO_2 workload. It would appear that the reduced recovery time between sets was of strong influence in the higher HR response. Reasons for increase of HR with the increase in load may be due to (a) greater sympathetic activation and release of norepinephrine and epinephrine hormones (Hurley et al., 1984), (b) the isometric BP response activating the adrenergic system, (Collins 1991 as per Verrill review 1992) (c) the greater recruitment of fast twitch muscle fibers, thereby triggering the pressor response (Collins 1991 as per Verrill review 1992). In general, HR O_2 cost and ventilatory response appear to increase proportionately with:

- volume of work including workload lifted, duration and number of sets, repetitions and exercises
- a decrease in rest between sets
- the speed of movement and joint angle,
- the patient's fatigue level and physiological well-being that day
- type of medication and changes in medication dosages
- fitness level and nature of cardiac impairment
- degree of Valsalva effect and isometric contraction

RT may also produce fewer abnormal myocardial responses than aerobic exercise. Butler et al., (1987) using echocardiography, observed ischemic segmental left ventricular wall abnormalities to be greater (5-61 segments) immediately following graded exercise testing compared to 1 ischemic segmental wall motion abnormality following CWT. Featherstone et al., (1993) noted no ischemic ECG changes when patients weight trained but, 5 of the 12 participants had ST segment depressions greater than or equal to 1 mm during graded exercise. Other studies using post myocardial infarction (MI) patients reported less myocardial ischemia than normally found with exercise testing on a cycle or treadmill (Debusk et al., 1979; Markiewicz et al., 1979) or when carrying loads of up to 40 pounds (Bertagnoli et al., 1990). However, high intensity CWT sessions (greater workloads and decreased rest intervals etc.) and weight loaded walking, have produced similar HR, O_2 and ventilatory costs including episodes of symptomatic hypotension (Kelemen et al., 1986), wide BP fluctuations, premature ventricular contractions (PVCs) or ventricular bigeminy (Sheldahl et al., 1985, 1993).

Implications and Considerations

- RT 60%-80% of 1RM or less elicits clinically acceptable cardiovascular responses and appears safe for selected cardiac patients (Verrill and Ribisil, 1996; McCartney et al., 1995)
- Resistive exercise HR should not exceed upper-limit thresholds in cardiac patients
- A lower volume of exercises (5-6), sets (1-2) and repetitions (8-12) is recommended
- Rest interval duration should not be so short (less than 30 secs) as to cause HR to exceed upper threshold
- Rest intervals should be extended towards the final 2-3 exercises to allow HRs to drop below threshold
- Monitoring of patients should be performed before, during and after training to Week HR, fatigue levels, and feelings of well-being

Resistance Training: Physiological Long -Term Responses

Blood Pressure

It is uncertain whether RT induces long-term changes in blood pressure (McGarthy, 1990). Many studies have produced conflicting results. Blumenthal et al., (1991) studied the effects of CWT on BP following a 16-week program and found resting SBP and DBP decreased by 7mm Hg and 6mm Hg respectively in borderline hypertensive patients. However, the control group showed similar changes and it was concluded that weight training may not affect BP. Harris and Holly (1987) showed a 7.5mm Hg drop in DBP in borderline hypertensive men after engaging in a 9 week weight training circuit. Similarly, Hurley et al., (1988) detected a drop in resting DBP of 5mm Hg over a 16 week CWT program with no change in resting SBP. Interestingly, Hagberg et al., (1984) observed the reverse, resting SBP dropped while resting DBP did not in adolescent hypertensives following a 20-week RT program. Other studies using normotensive and hypertensive adolescents, have also shown positive decreases in BP (Stone et al., 1983, Fixler and Laird, 1979) and may suggest that adolescents respond more favourably to aerobic and RT than do adults. The mechanisms involved remain a mystery and more research is needed. Finally, the use of isometric exercise to reduce BP is showing some remarkable results. Wiley et al., (1992) had normotensive 20-52 year old men perform isometric handgrip exercise for 8 weeks and showed a significant decrease in mean SBP and DBP of 12.5mm Hg and 14.9mm Hg respectively. This study is promising and paves the way for further progressive research in this area.

However, most studies have shown no significant changes in SBP, DBP and MAP following RT (O'Connor, 1993; Cononie et. al., 1991; Ghilarducci et al., 1989; Kelemen et al., 1989). Perhaps the most convincing evidence supporting the lack of BP change over time comes from Sparling et al., (1990), who showed no significant changes in SBP and DBP in a six month study. BPs at the start=122/77mm Hg, mid=124/78mm Hg, end = 122/76mm Hg were essentially unchanged.

Implications and Considerations

- Research is equivocal and more is needed to assess long-term effects on BP in a variety of populations
- More sophisticated BP measurement tools such as intra-arterial catheters need to be developed and used in future research
- Isometric exercise may have a beneficial effect on heart
- Long-term dynamic RT has no detrimental effects and is considered safe

Long-Term HR, O_2 Consumption And Heart Function Adaptations

It is evident that aerobic exercise can reduce myocardial O_2 demand and resting HR in both healthy and cardiac individuals (Pollock & Schmidt, 1995); however, the long-term effects of RT on these variables remains unclear (McCartney and McKelvie, 1996). Decreases in resting heart rate (RHR) and exercising heart rate (EHR) and increases in peak VO_2 have ranged from 4-15.5% in some studies (Stone et al., 1983; Stewart et al., 1994)) while others show little change following high intensity CWT. Haennel et al., (1990) observed lower RHR, EHR, increased stroke volume (SV), resting and exercising cardiac output (Q) in selected cardiac patients following 8 weeks of hydraulic CWT. However, Hurley et al., (1984) found no changes in submaximal exercise Q in healthy subjects following 16 weeks of high intensity CWT. Most recently, Stewart et al., (1994) using telemetry ECG during training, reported a significant increase (15.5%) in peak VO_2 after a 10-week CWT program. The most notable contribution of this research was the introduction of RT within 4 weeks post MI without provoking adverse cardiac episodes or responses. Reasons for the contrast in research results may be due to differences in experiment methodology. In Verrill and Ribisil's extensive literature review (1996), it is suggested that heart rate and oxygen consumption (VO_2) responses during RT are dependent on the factors listed below and that variations in one or several can produce contrasting results:

- type and amount of resistance
- duration of rest interval between sets and reps
- individual's cardiovascular fitness level
- prescribed medications

Possible explanations for improvements in RHR, EHR and VO_2 may be due to a depressed sympathetic, stimulated parasympathetic influence, and/or increased left ventricular stroke volume (Verrill and Ribisil, 1996). Petersen et al. (1989) suggested that CWT may lower RHRs and EHRs due to an improvement in SV (because of longer diastole and increased venous return), but not involve a change in ventricle size. Derman et al., (1994) observed no significant LV mass changes in aerobically trained cardiac patients following 10 weeks of CWT and appear to support this theory.

Finally, the diversity of results in the literature may be due to ethical limitations. The standard of care and treatment for cardiac rehabilitation involves aerobic exercise; RT is not considered a vital component of this care. As such, it is not possible to withhold aerobic exercise in order to study independent effects of CWT and RT in cardiac patients. Without this information, investigating the effects of RT in cardiac patients, independent of aerobic exercise influences, will remain clouded.

Implications and Considerations

- The implications of these results are yet to be realized, although they may mean earlier return to work for cardiac patients and an increased tolerance and performance of active daily living (ADL) and work activities.
- Intense CWT involving short rest intervals, long work intervals (45-60 sec) and high volumes (sets and reps) can produce adverse haemodynamic responses placing the cardiac patient at risk and is not recommended
- Research is inconclusive regarding long-term changes to SV and cardiac output (Q) as a result of maximal and sub-maximal RT and requires research
- Evidence is inconclusive regarding increases of VO_2max with RT in healthy and borderline hypertensive subjects (<160/104mm Hg)

Maximal Aerobic Capacity (Vo_2max)

Many studies examining the effects of RT on VO_2max demonstrate low to moderate increases (4 to 15%) in healthy subjects (Cononie et. al., 1991; Hurley et al., 1984; Haennel et al., 1989; Blumenthal et al., 1991). Similar effects appear to exist with cardiac patients (McCartney et al., 1995). Arm ergometer VO_2max by as much as 21.1% in borderline hypertensive males following upper and lower body strength training (Harris and Holly, 1987).

Studies that have examined VO_2max following CWT have shown a range of 4-19% improvement. Haennel et al., (1991) reported an 11% increase in VO_2max after 8 weeks of hydraulic RT. Kelemen et al., (1986) found similar improvements. Without measuring VO_2max directly, they reported a 12% increase in peak exercise performance time on the Bruce Treadmill test. McCartney et al., (1991) noted power output on the cycle ergometer increased by 15% and performance time by 109% over a control group. No VO_2max results were reported. More recently, Svedahl et al., (1994), released results indicating a 23% increase in peak VO_2 and 19% increase in VO_2max in 8-12 week post MI patients following a 12 week CWT program that consisted of 6 work stations, 3 days per week, 40 minutes per day. Other recent studies have shown encouraging changes in VO_2max including Wilke et al., (1991) (14% increase), Daub et al.,.(1996) (4.4 -13.4% increase) and Stewart et al., 1994 (13% increase).

Increases in maximal aerobic capacity may be influenced by (Verrill and Ribisil, 1996)

- the low-level demand for oxygen during a workout set
- differences in training protocol including:
- level of experience of the subjects and initial fitness level

Results vary depending on (Butler et al., 1987):

- frequency, load, type and duration of work and rest intervals
- patient initial fitness level and other characteristics
- medications

Implications and Considerations

- A meta-analysis may provide insight regarding the influence of various exercise protocols and equipment in order to determine optimal training protocols
- CWT should be used as an adjunct to the aerobic component of the cardiac rehabilitation process as a means of enhancing training effects
- The effects of weight training on work tolerance, performance and ADL need further study
- More research is needed testing VO_2max as opposed to peak VO_2

Muscular Strength And Endurance

It is well accepted that RT increases significantly the strength of sedentary individuals. The average increase in strength performance ranges from 20%-50% in healthy, 9%-227% in the elderly, and 20%-40% in cardiac patients (Verrill and Ribisil, 1996). One of the original studies assessing strength gains in the cardiac patient was performed by Kelemen et al., (1986) who observed a 24% average increase in overall strength levels over a 10-week period in selected patients who trained at 30%-40% of 1RM. McCartney et al., (1991) reported an average increase of 29% in strength. They also reported that after their 10-week (20-session) study workloads considered to be the cardiac patient's initial 1RM were being lifted, on average, for 14 repetitions. Ghilarducci et al., (1989), using 80% of 1RM showed an average 29% increase in overall strength levels (range was 12%-53%). However, exposing cardiac patients to loads of this nature may be unnecessary since (a) the increase in risk far outweighs the relatively small gains in strength and (b) most cardiac patients have no need for increases in strength beyond those needed for ADL and work activities. In studies investigating seniors and strength performance Fiatarone et al., (1990) and Frontera et al., (1988), showed remarkable mean increases of 174%±31% and 107% respectively. These studies dramatically demonstrated the need and value of RT in this population. Results vary considerably depending on the muscle groups tested; smaller groups demonstrate smaller increases, while large muscle groups show larger changes (Westcott, 1987). Multiple joint exercises such as chest and leg presses, tend to show greater increases than isolation exercises (Pec Deck, Bicep Curls). The number of muscles contributing to a lift is considered the primary reason for the observed differences in strength performance and changes.

The longest follow-up study to date was performed by Stewart et al., (1989) who showed increases in upper- and lower-body strength of 13% and 40% respectively. In the work of Sparling et al., (1990), overall strength was shown to have increased by 22% for 12 common resistance exercises. Training workloads were similar to the Kelemen study (1986) whereby 16 patients performed 1 set of 12 repetitions at 30%-40% of 1RM three days per week. Lack of attendance (an average of 35%-50% of total sessions were not attended), low frequency (2x/week), and low intensities may have hindered greater gains in strength.

The effects of certain medications on performance have not been well explored. Calcium channel blockers and beta blockers appear to have no influence on strength performance (Harris & Holly 1987; Stewart et al., 1989). It is difficult to ascertain the impact of these medications since many cardiac patients are on several medications at once and those who are not, are too few in numbers for research to be conclusive (McCartney, personal communication).

Few studies have examined the effects of RT sooner than phase 3 (approx. 8-12 weeks from MI or coronary artery bypass graft (CABG) of conventional exercise rehabilitation. Squires et al., (1991) showed no detrimental haemodynamic or ischemic ECG responses during training in patients who started training 7-8 weeks post MI. More recently, Stewart et al., (1994) and Daub et al., (1996), using telemetry ECG during testing and/or training, have demonstrated that CWT can begin as soon as 4 weeks post MI with no adverse cardiac events. Average increases in upper- and lower- body strength were 22% and 29% respectively (Stewart et al., 1994) and 10.5% - 13.5% (Daub et al., 1996).

Implications and Considerations

- The early introduction of RT is feasible, is safe and may facilitate earlier return to normal ADL and work activities and should be encouraged in CRPs.
- There is no need to expose cardiac patients to workloads above 70% of 1RM since increasing the risk of injury offers relatively small gains in strength.
- An argument could be made to support high-intensity training (above 60% 1RM) for those patients whose work requires lifting of heavy loads. Future investigations could assess the workloads and risks involved in different occupations and focus on personalizing weight training exercise prescription to meet the patient's work demands.
- More research is needed to provide greater evidence and insight into the long-term effects of RT on BP in cardiac and high-risk populations.

Blood Chemistry

The research on the effects of RT on CAD risk factors such as lipoprotein profiles, glucose metabolism and insulin sensitivity in healthy subjects is controversial. The studies examining these risk factors in cardiac patients are scant and just as contradictory. In healthy subjects, researchers have noted reductions in total cholesterol (TC), LDL-C, and increases in HDL-C levels with RT (Hurley et al., 1988; Goldberg et al., 1984), glucose tolerance and insulin sensitivity (Franklin et al., 1991).

Healthy subjects have shown short-term increases of 11%-12% in HDL-C after high-volume training 24 hours after exercise (Wallace et al., 1991). Studies on cardiac patients show no significant change in blood chemistry (Goldberg et al., 1984; Manning et al., 1991) while others indicate an improved glucose tolerance and insulin sensitivity (Hurley et al., 1988; Miller et al., 1984). Verrill and Ribisil (1996) suggests improving experimental designs and control for methodological limitations such exercise type and intensity, gender, baseline values, age, medication, plasma volumes, dietary regimen in order to gain further insight in this area.

Implications and Considerations

- More research with stricter experimental designs is needed

Body Composition Changes

It is well documented that RT increases lean mass (LM) in healthy individuals (Moritiani and deVries, 1980; Harris & Holly, 1987). Changes in body composition have not been studied in-depth in cardiac patients (Verrill and Ribisil, 1996). Most studies that have been done with this population, have shown little to no changes in subcutaneous fat, body weight or LM. (Sparling et al., 1990 and Ghilarducci et al., 1989). These small changes may be due to the low intensity of exercise common in CRPs, resulting in low energy expenditures. Other explanations may be that the tools used for measurement were not sensitive enough to detect small changes or perhaps the studies were not long enough to show an effect for the tools used. Finally, diet may not have been well controlled during the studies. There have been losses of body fat measured (20.8 $\pm$ 4.4% to 19.4 $\pm$ 3.3%) after a 10-week CWT program with no changes in body weight (Kelemen et al., 1989). Campbell (1996) showed a 1.8 kg FM loss and 1.4 kg LM gain in 8 males and 4 females (age range 56-80 years) engaged in RT only exercise. This study is one of the few that strictly controlled diet; these findings suggest that changes in body composition do occur, but may be masked by confounding variables such as poor diet. It has been documented that maintenance of LM and decreases in body fat occur in those cardiac patients who participate, and more importantly, adhere to the dietary and exercise recommendations of the CRP (Verrill and Ribisil, 1996). Inactive, weak elderly persons, 70-79 years have also shown gains in LM due to (Cononie et al., 1991, Westcott, 1987). However, past longitudinal studies found no significant changes of body fat or body weight in cardiac patients following a 6-month circuit training program using 30%-40% of 1RM (Sparling et al., 1990). In the studies reviewed in this paper, fat mass appears to have been estimated using the skinfold calliper method. This method has been shown to be inaccurate when determining percentage body fat (Martin et al., 1985, 1991).

Recent advancements in technology have produced potentially more accurate methods for body compositional assessment such as dual-energy X-ray absorptiometry (DXA), computed tomography (CT) or magnetic resonance imaging (MRI) and should be considered when investigating body compositional changes in cardiac patients. Trueth et al., (1994) measured changes to LM and FM using DXA, MRI, and hydrostatic weighing (HW) in 60 year old healthy males involved in a 16 week study who trained 3x/week at intensities of 90% of 3RM. They reported an increase in DXA LM and HW of 2 kg, a decrease in DXA FM and HW of almost 2 kg, and an increase in MRI mid-thigh cross sectional area of 11cm^2 and a decrease in mid-thigh subcutaneous fat of 6 cm^2. In another study, Trueth et al., (1995) measured changes to intra-abdominal and subcutaneous fat using computed tomography (CT) in 67 year old healthy females. They found no changes in BW, FM and LM, as measured by HW, but demonstrated a decrease in intra-abdominal fat of 13 cm^2 and subcutaneous fat ratio of .04. These findings suggest that changes do occur when using sophisticated equipment, however, traditional methods such as callipers may not be sensitive enough to detect body compositional changes.

Researchers and practitioners in the field, cannot always afford nor do they have access to sophisticated equipment such as DXA, CT and MRI. The development and use of affordable, but sophisticated assessment tools, has recently found its way into the literature. Unfortunately, these tools have produced conflicting results, which in turn have provoked scepticism. In a recent study, 64 healthy males subjects, age range between 18-35 years, either performed AO exercise, RT only exercise or no exercise (controls) for 12 weeks (Broeder et al., 1997). They had their body composition measured using near infrared photospectometry (NIR), bioelectrical impedance (BIA) and HW. Results from HW showed a decline of fat weight for the AO and RT groups, a gain in fat-free weight in the RT group, no change in fat-free weight in the AO and no change in the controls. However, BIA and NIR did not always track body composition well; NIR underestimated the gain in fat-free weight while BIA underestimated the changes in relative fat. Broeder et al., (1997), concluded that BIA and NIR were not appropriate, reliable tools for tracking body composition.

The measurement of intra-abdominal fat loss in cardiac patients is of special importance to cardiologists and their patients, since it has been well established that large amounts of visceral fat can increase health risks for CAD (ACSM, 1995). The use of sophisticated body composition measurement tools such as DXA could prove helpful in the care and treatment of this population.

Finally, there appears to be no published research that has measured the body composition, specifically MM of cardiac patients prior to the start of the rehabilitation program. Several researchers suggest that the insignificant changes in FM and LM may be due to the fact that most of these studies were done using low-risk cardiac patients who had already undergone 3 months or more of traditional "usual care" exercise and that any significant body compositional changes had already taken place (Gettman et al., 1978; Ghilarducci et al., 1989; McCartney et.al., 1995).

Implications and Conclusion

- Future research using cardiac patients should chart body composition changes using more potentially precise devices of measurement such as DXA, CT, MRI and/or a comparison of these data with that of NIR and BIA.
- If the researcher chooses to rely on skinfold measurements to assess body composition changes, then SOS would be a better variable to use than percentage fat.
- Measure body composition in cardiac patients prior to starting a CRP.
- Include muscle mass in body compositional testing to provide further insight regarding fat-to-muscle changes.
- Stricter controls for diet may prove enlightening when assessing the effects of CRPs on body composition

METHODOLOGY

Chapter 2

Subject Selection

A total of 200 candidates were screened, 34 subjects were recruited (16.5%), 27 of the 34 completed the study (80%). Six of the 7 drop-outs occurred before the exercise program began. All cardiac patients entering the Healthy Heart Cardiac Rehabilitation Program (HHP) at St. Paul's Hospital were first screened for eligibility by the Healthy Heart's medical director and cardiologist Dr. Andrew Ignaszewski during Monday morning intake clinics. Afterwards, Dr. Ignaszewski personally explained the study to each potential candidate and informed him that he would be contacted by the author, André Noël Potvin, who would then set-up an appointment to discuss the details of the study in person. Prior to this meeting, all candidates received a welcome package (Appendix A) that included a letter explaining the study, an informed consent form (approved by the UBC and St. Paul's Hospital Ethics committees), a schedule of exercise sessions (Appendix A) and a visual flow chart (Appendix A)outlining the schedule of events throughout the study. During this initial meeting, The author explained in detail the requirements and responsibilities involved in the research and gave candidates the opportunity to ask questions before signing the consent form. Two subjects quit after 2 weeks due to business demands and being unable to maintain attendance. A third subject found it to difficult to travel to the clinic and dropped-out, even though this issue was addressed during the orientation meeting. The fourth subject quit after the second week due to personal problems (not known). The fifth subject was unable to pass the re-assessment screening process at the 3rd week mark of participation and therefore was dropped from the study, and the sixth subject had a second heart attack one week prior to starting in the study. The seventh became ill with bronchial pneumonia by the 12th week of the study and had to drop-out.

Once the subjects had consented to participate in the study, their doctors were sent a letter explaining the study and their patients' involvement (Appendix B). Next, the subjects' had their body composition assessed (performed by the author within the first 2 weeks of entering the program). The subjects then started the regular Healthy Heart exercise program. After 3 weeks, the candidates were re-assessed by the case manager (supervising nurse) and Dr. Ignaszewski for eligibility for RT. Those patients who were still classified as being high-risk according to the ACSM guidelines (table 1) were excluded (only one did not pass). Those who met the criteria for inclusion into the resistance training program (table 2), were then randomly assigned to either a control (AO) or experimental (ART) group.

The entire recruitment process lasted 7 months, though originally, it had been estimated that this process would take only 3-4 months. Possible reasons for the longer selection process, may have been that (a) the first 2 months were slow summer months (July and August), averaging 1 recruited subject every 2-3 weeks (b) the strict eligibility criteria eliminated 83.5% of all patients screened.

Tracking of patients was done using the forms listed in Appendix C. It involved 3 forms: Subject Information Form; Attendance Form and Schedule of Testing (Appendix C). When a subject completed the study, he received a report of his test results and a certificate of completion (Appendix D). His doctor was sent a letter and the subjects test results (Appendix E).

Table 1:ACSM 1995 Contraindications for Exercise

- Unstable angina
- Resting BP systolic >-220 or 110>-Diastolic
- Resting systolic drop of 20mm Hg from average level that cannot be explained by medications
- Resting ST displacement (> 2mm) horizontal or down-slopping
- Uncontrolled sinus tachycardia (> 120 bpms)
- Ventricular tachycardia (3 or more consecutive PVCs)
- Frequent multifocal PVCs(30% of the complexes)
- Uncompensated congestive heart failure (CHF)
- Exercise-induced left bundle branch block
- Onset of 2nd and/or 3rd degree A-V block
- R on T-wave PVCs
- Recent embolism
- Thrombophlebitis
- Inappropriate bradycardia greater than 10bpms with increase or a change in workload
- Uncontrolled diabetes (resting blood glucose >400mg/dl
- Severe orthopedic problems that would prohibit exercise
- Other medical or metabolic problems that would be aggravated by exercise

Table 2: ACSM Inclusion Criteria for RT for Cardiac Patients

- Sedentary for 3-6 months
- Resting diastolic blood pressure < 105mm Hg
- 4-6 weeks after MI or CABG
- 1-2 weeks after PTCA or other revascularization procedure (except MI, CABG)
- 4-6 weeks involvement in supervised aerobic program
- peak exercise capacity of >5 METS
- not compromised by CHF, unstable symptoms, arryhthmias, or severe valvular disease

Subjects

- 39-66 years (mean = 52.3 years) of age cardiac post-surgery and non-surgery heart disease male patients who met the ACSM criteria for inclusion to resistance training. Fourteen of the 27 original subjects had experienced an MI (52%), 2 CABG (7%) and 11 PTCA (41%). Twelve of these 27 subjects(44%) experienced their cardiac event within 8-12 weeks of the study, 10 (37%), 12 -52 weeks pre-study and 5 (19%) between 2-4 weeks (all PTCAs).-

- subjects must have had a myocardial infarction (MI) coronary bypass graph (CABG) or percutaneous transluminal coronary angioplasty (PTCA)
- all subjects have had a sedentary lifestyle for 6 months or more prior to entering the cardiac rehabilitation program and are new to weight training
- all control-group subjects were randomly selected
- patients were evenly distributed across the 3 groups (n=10), however, with drop-outs, the final group distribution was uneven (ESRT=8, LSRT=9, AO=10)

Grouping Of Subjects (N = 27)

No documented studies to date have measured the body composition of cardiac patients prior to the start of the rehabilitation program. It would appear that all previous studies had intervened at the third month. Gettman et al., (1978), Ghilarducci et al., (1989) and McCartney et al., (1996) suggested that previous insignificant findings in the literature regarding the loss or gain of FM and LM may be due to the fact that most studies were done using low-risk cardiac patients who had already undergone 3 months or more of traditional "usual care" exercise and that any significant body compositional changes had already taken place. In an attempt to investigate this suggestion, a third group (called the late-start resistance training group - LSRT) was created from the 18 remaining subjects engaging in aerobic exercise only. This new LSRT group started resistance training at the 10 week landmark (n = 9). This information would serve to provide further insight regarding the magnitude of FM loss prior to and following the 10th week.

Control group: aerobic only (AO)

10 cardiac-rehabilitation 43- to 66-year-old (mean = 53.3 years)male patients who participated in the HHP's aerobic training protocol without resistance training

Experimental group 1: aerobic/resistance (early-start resistance training - ESRT)

8 Cardiac-rehabilitation 42- to 66-year-old (mean = 50.5 years) male patients participated in the HHP's aerobic training protocol and engaged in an organized resistance training program that started at the 4th week.

Experimental group 2: aerobic/resistance (LSRT - 10 weeks in aerobic cardiac program before starting RT))

9 Cardiac-rehabilitation 39- to 61-year-old (mean = 53.1years) male patients participated in the HHP's regular aerobic training protocol as well as engaged in an organized resistance training program that started after 10 weeks of aerobic only training.

Measurements: Body Composition

Three approaches were used to assess body composition anthropometry, Near Infrared Photospectrometry (NIR-Futrex 5000A - Futrex Inc, Gaithersburg, MD 20879), Dual-energy X-ray Absorptiometry (DXA Norlund XR26 Mark II - Norlund Medical Services, Fort Atkinson, Wisconson). All measurements and repeat measurements were taken by the author, except DXA, which was performed by a qualified technician. Measurements were taken on 4 occasions (see figure

1) except for DXA; it was taken twice, pre- and post-study; financial and administrative constraints limited its use for this study.

Height and Weight

Height and weight were taken on a Detecto Medical balance weight scale (Detecto Scales Inc. Brooklyn, NY). Height was measured to the nearest millimeter (using the scale's height ruler). Weight was recorded to the nearest 0.1 kilograms. The subjects were weighed while in their street clothes (without shoes or jackets) and then had their clothing weighed separately; the weight of the clothing was then subtracted from the clothed weight. The purpose of this was two-fold (a) for accuracy and (b) convenience - it was not possible to weigh the subjects in their underwear since the scale was located in the reception area of the Lipid Clinic.

Sum of Skinfolds (SOS)

Subjects had their skinfolds measured on the right side of the body at 7 different sites: triceps, biceps, subscapular, suprailiac, umbilicus, front thigh and medial calf (see appendix). Skinfolds were measured in duplicate to the nearest millimeter with a third reading taken if there was a discrepancy between the first and second measurement of 6 mm or more. SOS were used as the gauge for change in fat mass over the 16 week study. Harpenden calipers were used.

Girths

Circumference measurements were taken at the chest (4 cm above nipple area), the waist (most narrow point), the hips (gluteal protrusion), the arm (midway between acromiale and radiale), forearm (at maximum girth), thigh (midway between the inguinal crease and the superior border of the patella), and calf (at maximum girth). Limb muscle girths were estimated by correcting limb girths for skinfold thickness using the circular model of limb cross-section described by Martin et al., (1991). These particular circumference measurements were the identical measurements used by Martin et al., (1990) to create the cadaver-validated skinfold regression equation used in this study to estimate muscle mass (MM):

$$MM = Height\,(0.0553CTG^2 + 0.0987FG + .0331CTG) - 2445$$

(CTG = Corrected Thigh Girth; FG = Uncorrected Forearm Girth; CCG = Corrected Calf Girth)

(SEE = 1.53kg, r = 0.97)

NIR

Using the Futrex 5000A and procedures recommended by the manufacturer, measurements were performed at the same 7 skinfold sites: triceps, biceps, subscapular, suprailiac, umbilicus, front thigh and medial calf, to derive relative body fat distribution. All sites were taken twice with a third measurement taken when the range between the first two was greater than 6 and then averaged. The sum of these measurements (FutSOS) was then used as an indicator of change in fat. The biceps site was also used as the single predictor of total percentage body fat (Elia, 1990). The physical parameters of age, sex, height (inches) weight (pounds), body frame (manufacturer's standards) and activity frequency, intensity and time were entered into the instrument prior to the initial biceps recording to derive percentage body fat, FM and LM. This body fat calculation was performed by the instrument.

The light wand was placed on each site with firm pressure, enough to make a brief indentation in the skin (manufacturer recommendation).

DXA

Fourteen subjects underwent a pre- and a post-study body DXA scan. Each subject rested supine on a Norland bed for approximately 25-30 minutes while the machine scanned the body cross-sectionally. The DXA computer then calculated percentage body fat, FM, LM and bone mineral content (BMC). The same technician performed all 28 scans and ensured that each subject's body position, pre- and post-study scan, was similar.

Body composition (except DXA) was assessed as each patient reached the following stages:

0 Wk	Week 4	Week 10	Week 16
I	I	I	I
Assessment 1	Assessment 2	Assessment 3	Assessment 4

I. Within the first 2 weeks of starting the Phase 1 Healthy Heart Program
II. 4 weeks after the start of the program (ESRT group, assessed prior to starting resistance training)
III. 10 weeks after the start of the program (LSRT group, assessed prior to starting resistance training)
IV. At the completion of the study (week 16)

Figure 1: Body Composition Assessment Schedule

Testing: Haemodynamics and Aerobic Capacity

Aerobic Capacity Testing:

All patients performed a graded exercise treadmill stress test (GXT) prior to beginning and exiting the HHP. Testing protocol was determined by Dr. Ignaszewski based on the nature of the patients' conditions. The same GXT was performed pre and post study. Haemodynamics were recorded and analyzed.

Haemodynamics

Each patient was monitored using a 12 lead electrocardiogram (ECG) both during the GXT and throughout the first 4 weeks of aerobic training. The case manager made the final decision whether ECG telemetry would be discontinued after the 4^{th} week. This decision had no bearing on the study results. During the RT sessions, heart rate was monitored via ECG and Polar Heart Rate Monitor. BP was monitored pre-, during and post-GXT, as well as, before and after every 1RM strength test.

Testing: Determining Resistance Training Workloads

There were 5 separate workloads calculated for 5 different types of work sets: Practice, Warm-Up, Starting, Training and 1 RM. Only the practice session workload was calculated prior to the 1RM testing, all others were calculated afterwards as percentages of the 1 RM test results.

Practice Workload

This weight was generally, 20-50% of the subject's body weight (up-to 175 pounds) and performed for 1 set of 5-10 repetitions (Table 3). It was meant to teach subjects how to perform the exercise and ensure that they were familiar with it prior to the 1RM testing; no strength training effect was to be incurred. This workload differed for each muscle group worked.

Warm-up Workload

A Warm-up set consisted of 5 repetitions with a workload that was generally 50%-60% of the subject's 1RM. It always preceded the Starting or Training set. Its purpose was to prepare the subjects mentally and physically for the harder set to follow.

Starting Workload

This weight was used in the first 1-2 weeks of training after the 1RM test. It was approximately 60%-65% of the subject's 1RM. Its purpose was to safely stimulate neuro-muscular motor unit recruitment and synchronization, as well as develop muscular endurance. Subjects completed 1 set of 13-15 repetitions per exercise. A warm-up set al.,ways preceded the starting set.

Training Workload

This workload was 70-79% of the subject's 1 RM (Poliquin, 1989; Hoeger, 1990). Its purpose was to stimulate a change in muscle physiology and incur a muscular strength training effect. The subject began training at this intensity by the 3rd week of RT. The subjects completed 1 set of 8-12 repetitions. Workloads were increased every 1-3 weeks as patients were able to complete 12 repetitions during two consecutive workout sessions per exercise. A warm-up set of 5 repetitions always preceded this set.

To determine the different practice workloads, a method recommended by Baechle and Groves (1992) was used. It involved calculating practice "warm-up" workloads by using the subject's body weight and multiplying it by a percentage coefficient established for the exercise to be performed (table 3). Calculated weights were rounded-off to the nearest 5 pounds.

Table 3: RT Coefficients for Determining Practice Weights (Baechle and Groves, 1994)

Exercise	Practice Coefficient		Body Weight (pounds)		Practice Workload (pounds)
Chest Press	.25	x		=	
Split Squat	no load body wt .only	x		=	
Seated Row	.25	x		=	
Overhead Shoulder Press	.15	x		=	
Leg Press	.7	x		=	
Biceps Arm Curl	.15	x		=	
Triceps Pushdown	.15	x		=	

Subjects had two separate practice sessions (minimum 48 hours rest) during the week prior to their test session (Figure 2). The idea was to learn the proper technique and execution of each exercise while reducing the influence of "the learning effect" on strength performance. These practice sessions were with workloads that were 20-70% of body weight up-to and including a body weight of 175 pounds[1] depending on the exercise. These practice sessions were not designed to induce an increase in strength prior to the 1RM test, but instead, to reduce the amount of interference on strength performance due to the subjects lack of understanding of the exercises and proper technique.

[1] **Weight Training Instruction: Steps to Success**, Baechle & Groves: Human Kinetics 1994, p.12

These practice sessions occurred during the 3rd week of participation in the Healthy Heart Clinic's CRP; and each was tested for muscular strength during the 4th, 10th and 16th week. Since the AO group did not engage in RT, but were tested for 1 RM strength, the AO group performed two practice sessions during the 3rd, 9th and 15th week. Again, the purpose of this procedure was to reduce any error that may exist in strength performances due to a subjet's lack of practice and familiarization with the exercise.

TEST WEEK

Monday	Wednesday	Monday
I	I	I
Practice 1	Practice 2	Test Day

Figure 2: Strength Practice and Test Day Schedule

On test day, the subjects performed a warm-up set of 5 repetitions followed by progressive sets of 3 repetitions per set. Patients rested 1-3 minutes or as needed, while the load increased by 1-3 plates (5-60 lbs) and then the lift was repeated. This process was repeated until the subject could lift the new weight for no more than 1-3 repetitions. This final weight was then considered to be the patients 1 RM or within 10% of it.. This testing approach appears to be safe and reliable and does not affect haemodynamic responses negatively (McCartney et al., 1996). However, it did cause a great deal of delayed-onset muscular soreness (DOM). This technique was used in this study merely to align the methodology and results with that of other RT studies. However, it is the position of this investigator that this method be used with caution and patients be intensely screened for orthopaedic problems that could be exacerbated during testing or training. The use of a less intense 3-5 RM strength test may be more appropriate for safety. Several studies have reported injuries due to this method (Pollock et al., (1991); Wilke et al., (1991), although mostly to those subjects who already had preexisting chronic or latent injuries; their recommendations are to use a 3- 5 RM method to reduce the mechanical stress on the skeletal system.

Table 4: Summary of 1 RM Testing Procedures

- subjects reported a feeling of health and well-being of 5 on a scale of 1(lousy) - 10(ecstasy) prior to being tested in order for the test session to continue (see table 15)
- a pre-calculated warm-up set was performed for 5 repetitions (rest 1-3 minutes or as needed)
- a set of 3 repetitions was performed with the pre-calculated starting weight (rest 1-3 minutes or as needed)
- if successful, the load was increased by 1-3 plates (3-20 pounds) prior to the next lift
- the process repeated itself until the subject could no longer lift the new weight without forfeiting technique, holding breath or pausing during the rep
- this final weight was considered to be subject's actual 1 RM
- ESRT and LSRT subjects started training at 60% of 1RM test results
- workloads were then adjusted weekly to accommodate strength increases
- workloads were increased by 3-20 pounds when subject completed 15 reps (first 2 weeks), and then 12 reps by 3rd week on 2 consecutive workouts

Adjustment Of Workloads

Workloads were adjusted weekly based upon the subject's ability to surpass the target zone of "reps completed" (see Table 5). If the target zone for that week is 8-12 reps to fatigue and the subject completes a 12th repetition at two consecutive sessions, then the load was increased by approximately 2-10% or 3-20 pounds. All weights were increased by the start of the third week to fatigue the subject in 8-12 reps (70-79% of 1 RM).

Table 5: Adjustment of Workloads (Baechle and Groves, 1994)

Subject's Actual Reps Completed	Adjustment (add or subtract)[2]
< 7reps 8-9	- 15 pounds - 10

[2] adjustment workloads varied from lighter to heavier than poundage shown above depending on the exercise and/or the reason for the performance

10-11	- 5
12-15 (suggested target zone)	0 (suggested target zone)
16-17	+ 5
18-19	+ 10
20	+ 15

Table 6: Workload Increases per Muscle Group (Pauletto, 1990, 1991)

Exercise	Poundage Increase
Arm Curls	3-5lbs*
Triceps Pushdowns	3-5
Overhead Press	5-10
Seated Row	5-10
Chest Press	5-10
Leg Press	10-20
Split Squat	10-20
	* varied from subject to subject depending on each ones ability to handle the increase

RT Exercises

The exercises used in this study, for both testing and training, of the cardiac subjects were the Vertical Bench Press, Seated Cable Row, Leg Press, Split Squat, Overhead Shoulder Press, Triceps Pushdown and Biceps Arm Curl (figures 3-10). These exercises were chosen for one or more of the following reasons: for their capacity to challenge the subject's major muscles groups; their capacity to work several joints and muscles groups at the same time; and/ortheir functional application regarding common work and leisure activities (pushing, pulling, lifting, squating etc).

Vertical Bench

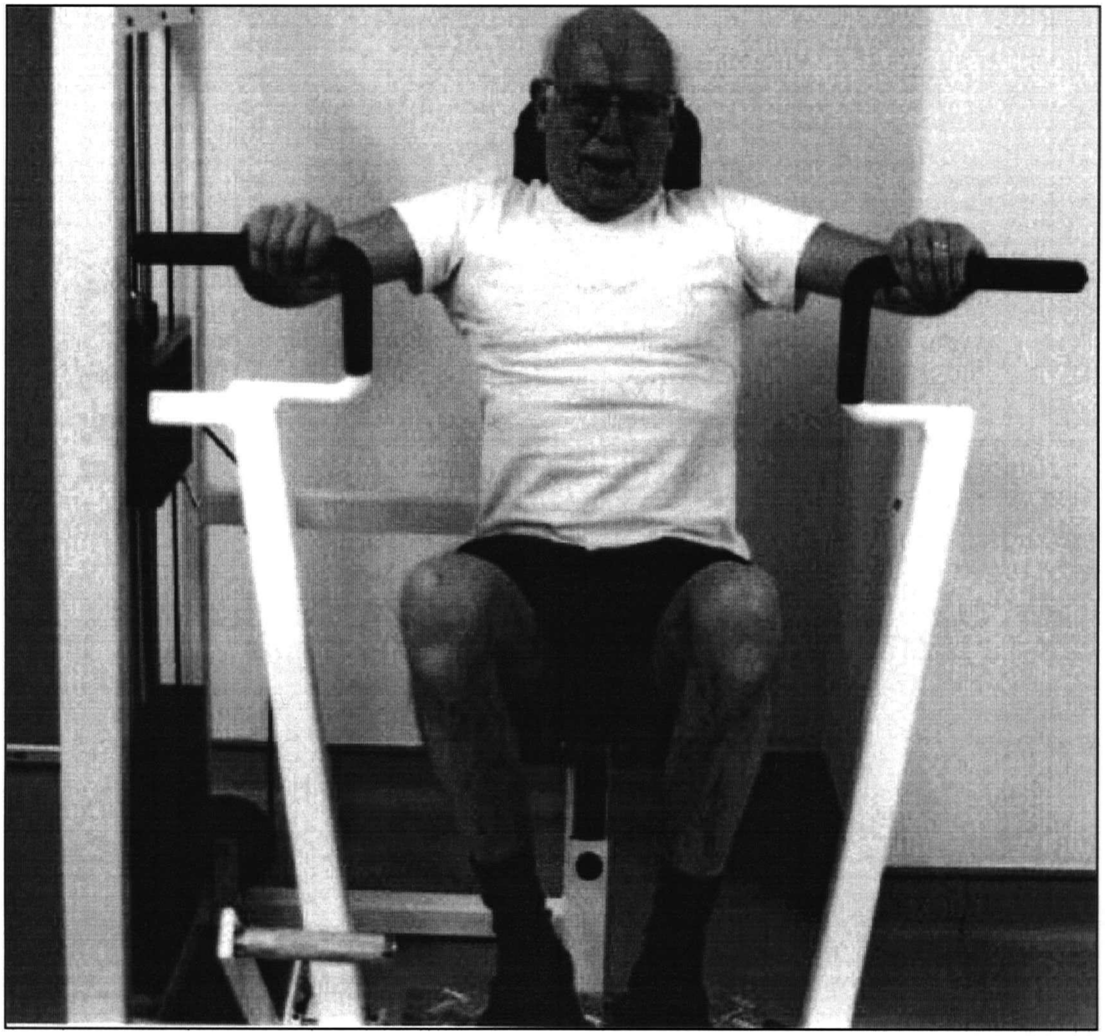

Figure 3: Vertical Bench exercise is a pressing movement designed to work the chest. In a seated position (Apex Equipment - Victoria, B.C. Canada)

Leg Press

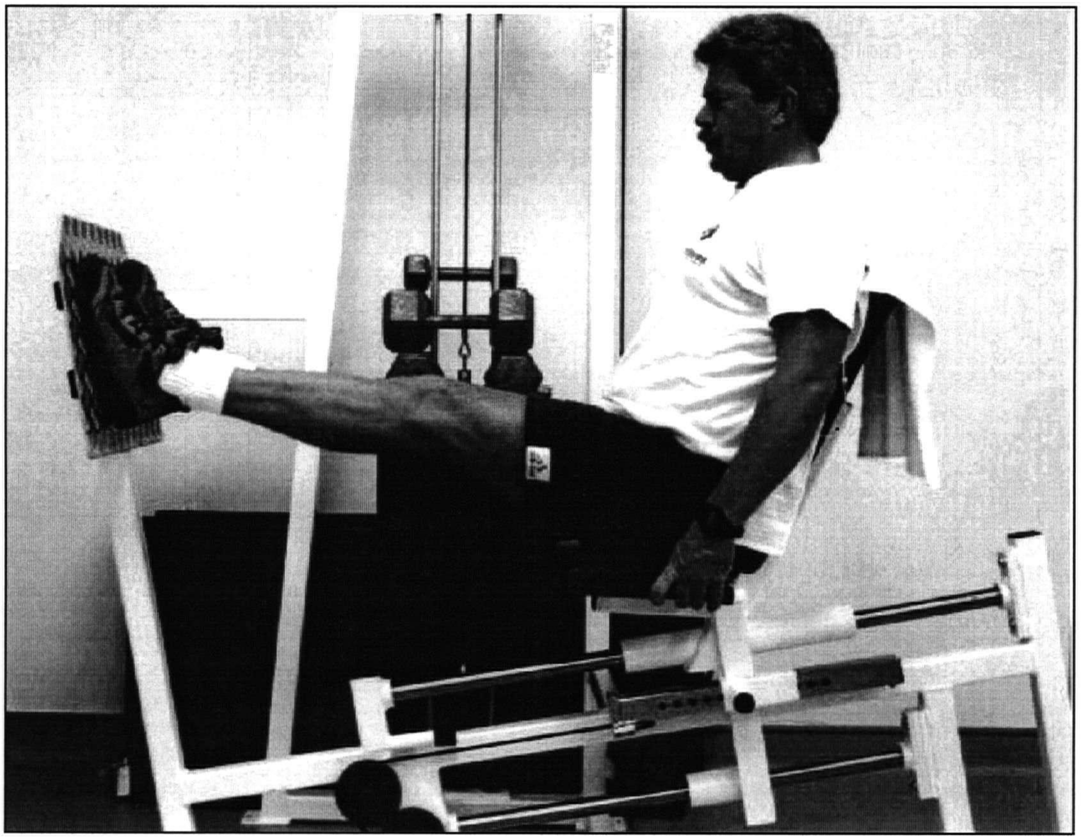

Figure 4: Leg Press exercise is used to develop the legs in a seated position; dumbbell weights had to be stacked on top of the machines regular weight stack as subjects became stronger and needed to lift more than the machine's maximum weight.

Seated Row

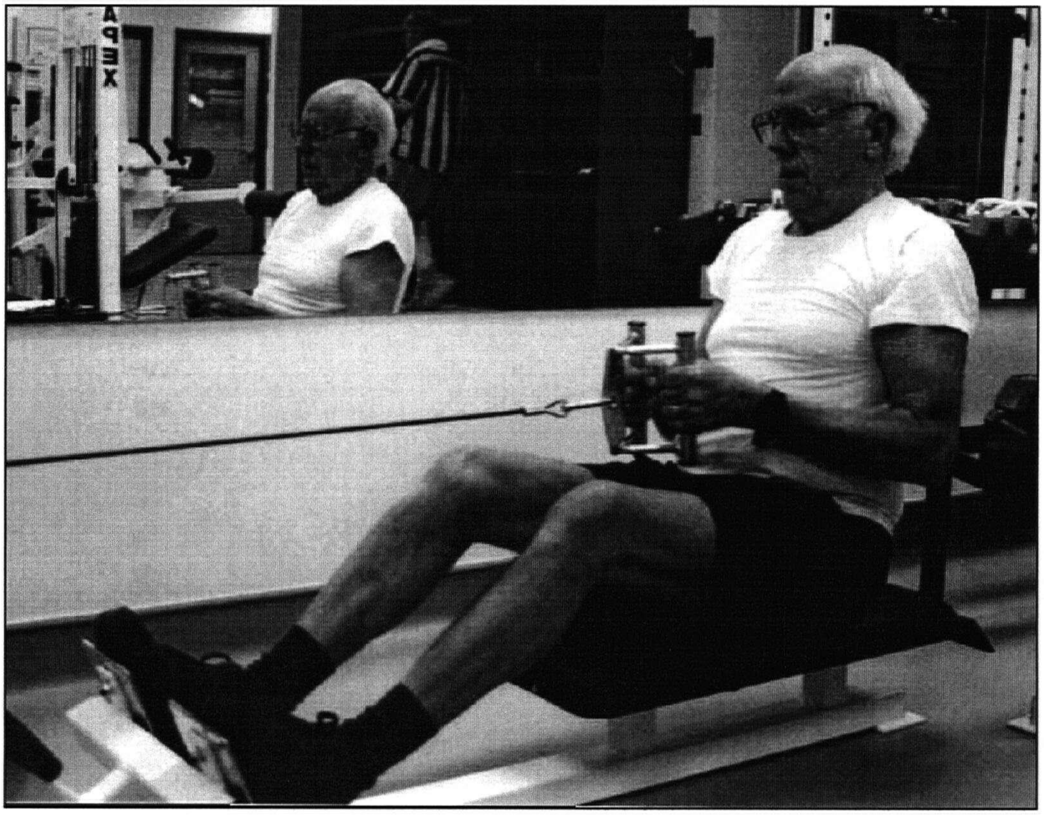

Figure 5: Seated Row develops strength in the back musculature necessary for pulling objects towards the body while having to stabilize the trunk.

Split Squat

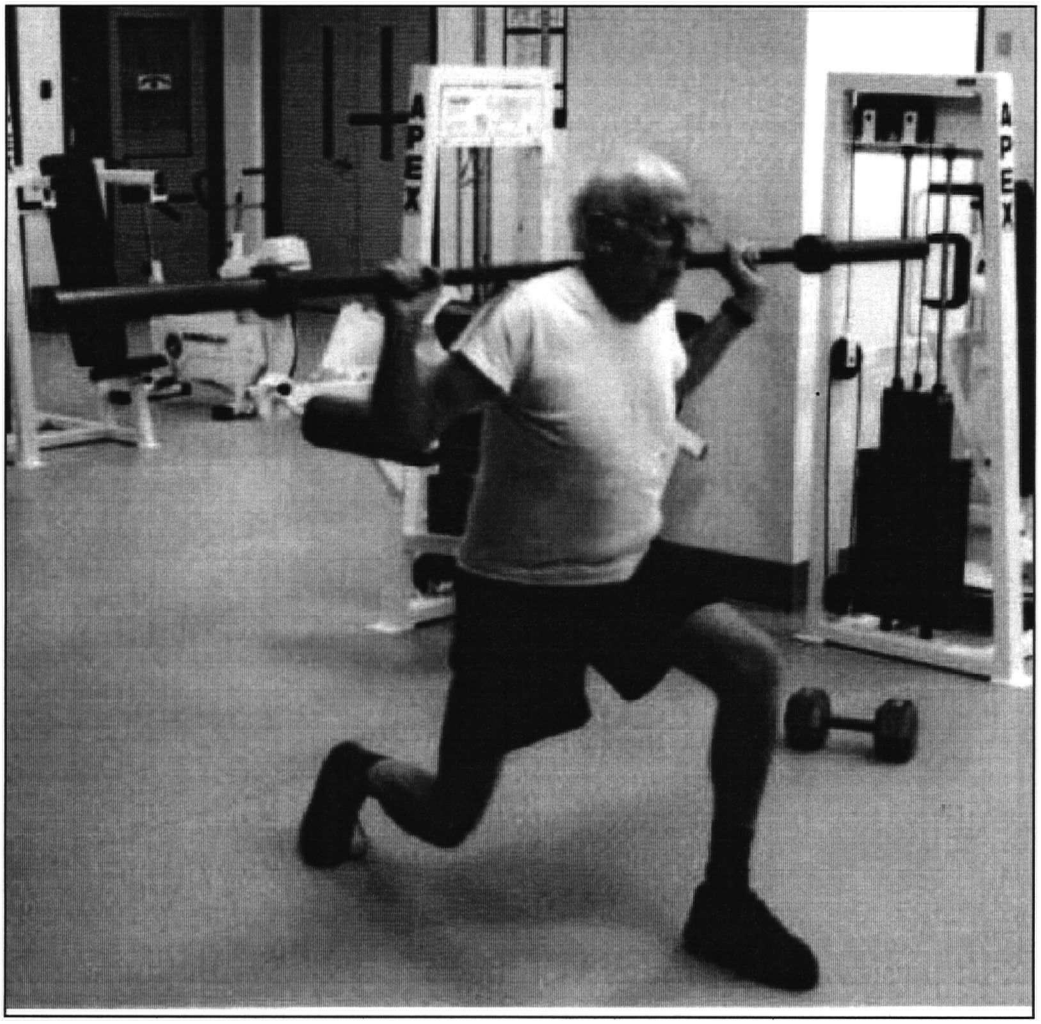

Figure 6: The Split Squat is designed to work the muscles of the lower body in unison, while stabilizing the upper body and maintaining balance. This is quite a functional exercise since many lifting of objects from the floor require the same biomechanical patterns.

Split Squat

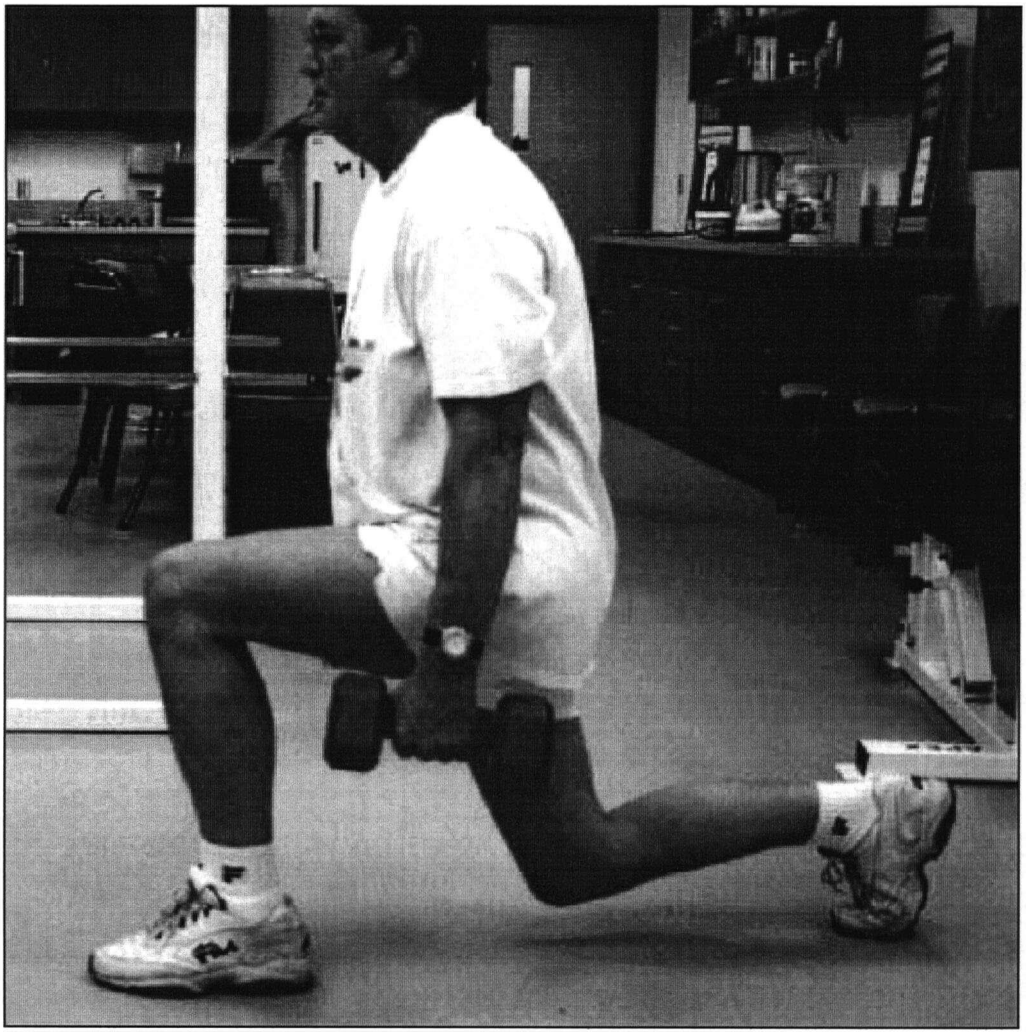

Figure 7: The Split Squat performed with dumbbells. They subjects all started with their bodyweight and gradually increased workloads.

Shoulder Press

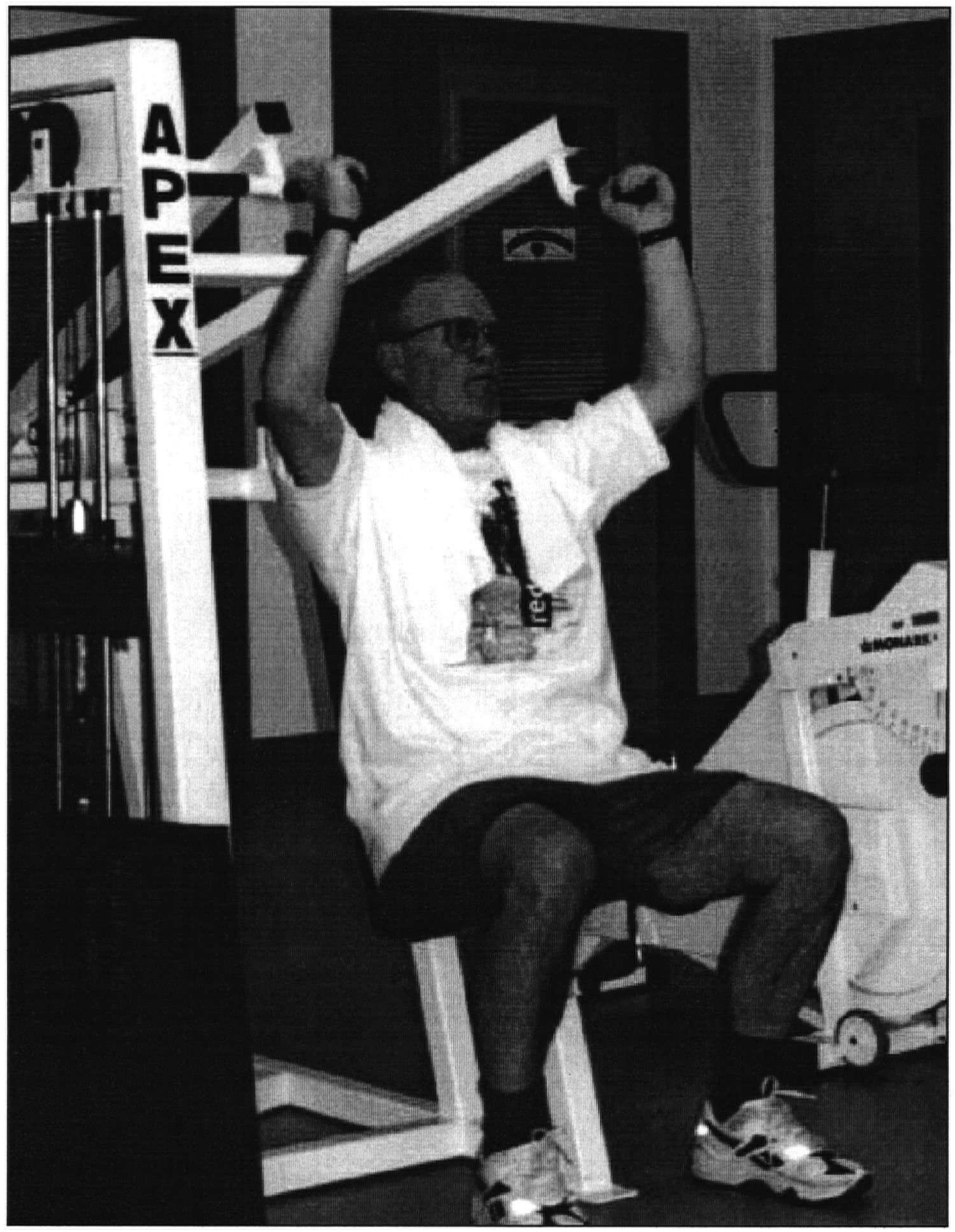

Figure 8: The Overhead Shoulder Press is an excellent functional exercise for developing strength in the shoulders. The hand position in this picture places the shoulder and elbows in a more realistic lifting position than when they are out to the side.

Biceps Arm Curl

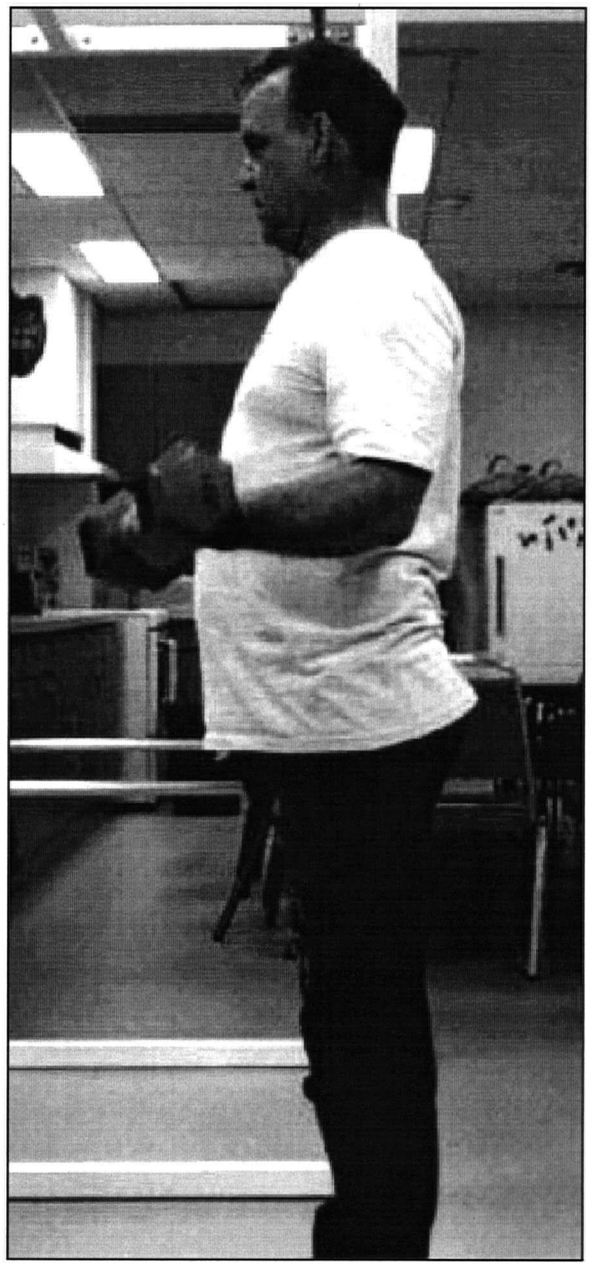

Figure 9: The Biceps Arm curl

Triceps Pushdown

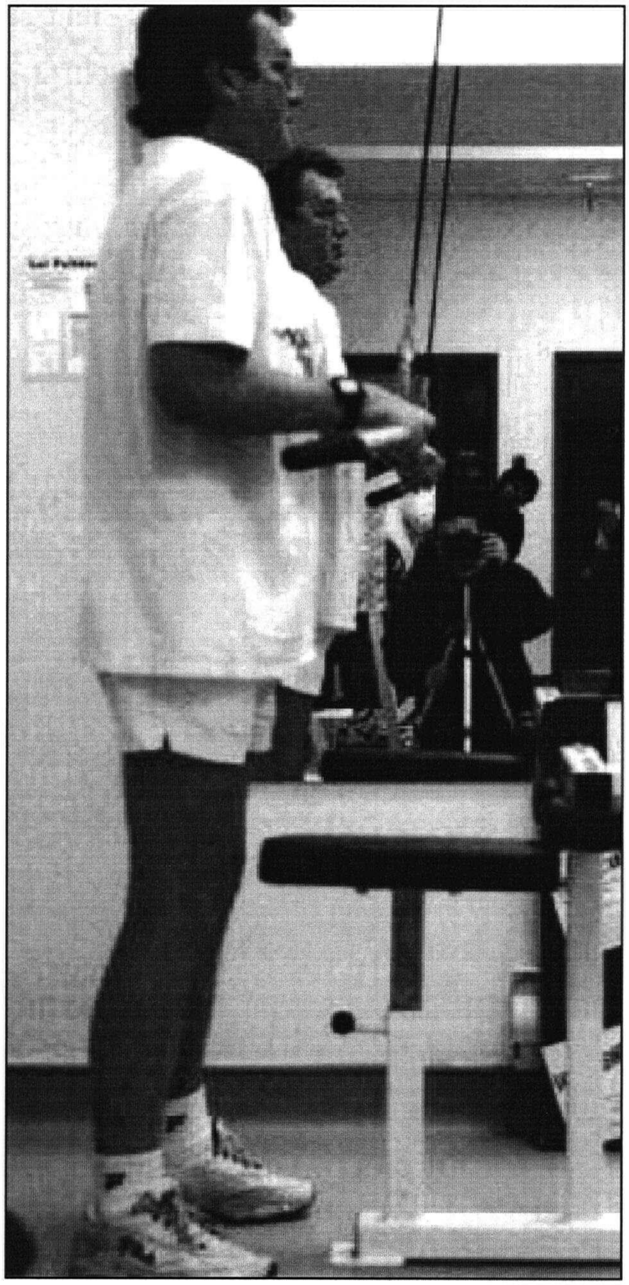

Figure 10: The Triceps Pushdown

Exercise Protocol

Subjects from all groups trained at the HHP and followed its standard aerobic training protocol.

They performed aerobic exercise as follows:

Basic Exercise Session

AO

- 10 minutes aerobic warm-up (cycling, treadmill etc.)
- Aerobic Component: 3, 10 minute stations in target training zone (based on stress test results)
- 10 minute mild muscular strength exercise (2-5 pound weights)
- 10 minutes stretch and relaxation

ESRT & ESRT

- Warm-up: 10 minutes (cycling, treadmill etc.)
- Aerobic Component: 20 minutes (divided into 2,10 minute sections)
- Resistance Training: 25-30 minutes (using machines)
- Cool down: 10 minutes stretching and relaxation

Controlling for Work Volume

In order to reduce the interference effect on body composition from one group expending more Kilocalories (Kcal) than another, the volumes of training in the aerobic exercise group and the RT groups were made similar. The metabolic cost of each training section (warm-up, aerobic and RT) was calculated using established regression equations and formulas listed on the following page and in Table 11 . It was estimated that 10 minutes of aerobic exercise (at 60-70% HRR) for the average male cardiac subject, in this study, equaled 25-30 minutes of RT consisting of 1 warm-up set (5 reps) and 1 training set at 70-79% of 1RM (8-12 reps). The actual time spent performing weight training, lifts was only 7-10 minutes, the remaining 15-20 minutes was used for rest between sets and exercises. The length of time of the aerobic section was reduced from 30 minutes to 20 minutes for those subjects engaging in RT. This meant that the AO group performed 40 minutes of aerobic exercise[3] per session while the RT groups did only 30 minutes (table 16)

Work volume, expressed as caloric expenditure, was estimated and equated between aerobic exercise and weight training as follows:

Step 1

Estimated caloric expenditure for each aerobic exercise and then totaled the training sections (see formulas below)

Step 2

Estimated caloric expenditure for each weight training exercise (see formulas table 11)

Step 3

Equated caloric expenditure by reducing aerobic exercise by 10 minutes and increasing weight training to 25-30 minutes for the RT groups. The AO group training time remained unchanged.

The following formulas were used to estimate METs and energy cost for each aerobic activity based on intensity and duration (Howley, 1992):

Treadmill Walking (no Incline)[4]

1) VO_2 ml/kg^{-1}/min^{-1} = [.1 ml/kg^{-1}/min^{-1} (horizontal velocity in meters/min) + 3.5 ml/kg^{-1}/min^{-1}] (ASCM 1995, p. 278-9)

2) METs = (VO_2 ml/kg^{-1}/min$^{-1)}$ ÷ (3.5 ml/kg^{-1}/min)

3) Kcal/min = METs x (3.5 ml/kg^{-1}/min$^{-1)}$ x (body weight in kg) x (.001L/min) x (5 kcal/LO_2/min)[5]

[3] includes a 10 minute warm-up period at 50-60% HRR

[4] majority of subjects trained on the treadmill without an incline between speeds of 2-4mph; those who did train on an incline did not surpass an 8% grade and had speed reduced to maintain target training intensities

[5] 5 kcal represents the constant value used as the conversion factor to estimate the caloric equivalence per liter of oxygen uptake (Howley and Franks, 1992).

4) Kcal/10 minute = (Kcal/min) x (10 min)

Table 7: Energy Cost in METS and Kcal for 10 minutes of Treadmill Walking

Body Weight (kg)	Miles/hour & Kcal/10 min (no incline)									
	2	Kcal	2.5	Kcal	3	Kcal	3.5	Kcal	4	Kcal
67	2.5	29.7	2.9	34.2	3.3	38.7	3.7	43.1	4.1	47.6
80	2.9	41.1	3.2	45.2	3.5	49.3	3.8	53.4	4.1	57.6
90	3.2	51.2	3.5	54.7	3.7	58.3	3.9	61.8	4.1	65.3
100	3.5	61.0	3.7	64.1	3.8	67.1	4.0	70.1	4.2	73.1

Bike Ergometer (Hagerman, 1988)

1) VO_2 (ml/min) = work rate (kpm.min^{-1}) (2ml O^2 x kpm^{-1}) + (3.5 ml/kg^{-1}/min^{-1} x body weight in kg) (ACSM, 1995 p. 278-9)

2) METs = (VO_2 ml/min^{-1}) ÷ (body weight in kg) ÷ (3.5 ml/kg^{-1}/min^{-1})

3) Kcal/min = METs x (3.5 ml/kg^{-1}/min) x (body weight in kg) x (.001L/min) x (5 kcal/LO_2/min)[6]

4) Kcal/10 minute = (Kcal/min) x (10 min)

Table 8: Energy Cost in METS and Kcal for 10 minutes of Bike Ergometry (legs)

Body Weight (kg)	Work Rate (kpm/min^{-1}) & Kcal/10min					
	300	Kcal	450	Kcal	600	Kcal
67	3.7	43.4	4.9	57.5	6.1	71.5
80	3.2	44.8	4.3	60.2	5.4	75.6
90	2.9	45.7	3.8	59.9	4.8	75.6
100	2.6	45.5	3.4	59.5	4.3	75.3

6

StairMaster 4000 PT Step Machine (Butts et al., 1993; Thomas, 1989))

1) METs = (2.675) + .(935) x (Step rate on console)

2) Kcal/min = METs x (3.5 ml/kg^{-1}/min x body weight in kg) x (.001L/min) x (5 kcal/LO_2/min)

3) Kcal/10 minute = (Kcal/min) x (10 min)

Table 9: Energy Cost in METS and Kcal for 10 minutes of Stairclimber

			Step Rate and Caloric Expenditure			
Body Weight (kg)	5 (60/min)	Kcal/10 min	7 (77/min)	Kcal/10 min	9 (95/min)	Kcal/10 min
67	7.35	86.2	9.22	108.1	11.1	130.0
80	7.35	102.9	9.22	129.1	11.1	155.3
90	7.35	115.8	9.22	11.9	11.1	174.7
100	7.35	128.6	9.22	11.9	11.1	194.1

Subjects exercising on the StairMaster worked at or below a step rate of 5 on the machine console which equaled 60 steps per minute. This rate was used when caloric energy cost for a 10 minute exercise bout was estimated (table 9).

Rowing Ergometer

Research by Bassett et al., (1984) and (Carey, 1974) provided the mean estimates of METs, needed to approximate energy expenditure for rowing (table 10).

1) Cal/hr = 300 + 4 x (watts) ÷ (1.1639 cal/watt/hr)[7]

2) Weight-adjusted cal/hr = (cal/hr) - 300 + (1.714 x weight in pounds)[8]

3) METS = (weight adjusted cal/hr) ÷ (5 kcal/$L0_2$/min basal rate of calorie burn)

[7] 1.1639 is a units conversion factor from watts to calories

[8] corrects for the effect of moving a heavier or lighter weight than 175 pounds body back and forth during rowing

Table 10: Energy Expenditure for Rowing Ergometer (Bassett, 1984)

	10mph/16kph	15 mph/25kph	20mph/33kph
Stroke rate/min	16.4 ± 3.2	20.0 ± 2.7	24.3 ± 3.4
VO_2 ml/kg^{-1}/min^{-1}	11.0 ± 1.1	16.7 ± 4.6	21.0 ± 3.5
METS	3.1 ± .3	4.8 ± 1.3	24.3 ± 3.4
Kcal/min^{-1}	4.7 ± .5	6.1 ± 0.7	8.6 ± 0.8
Kcal/10 min	47.0 ± 5.0	61.0 ± 7.0	86.0 ± 8.0

Subjects' average speed when rowing was 10 mph or 16.4 pulls/min. This equated to a kcal expenditure of 4.7 kcal/min^{-1} which was then multiplied by 10 minutes to derive the energy cost of rowing for the average subject in a 10 minute training bout.

RT Formulas for Estimating Energy Cost

Research determining the energy cost of weight training is sparse. Most research done in this area has measured the overall energy cost of performing circuit weight training (Wilmore, 1978); few researchers (McArdle and Foglia 1969), (Pratley, 1992) and (Keuhl, 1990) have looked at the oxygen demands of individual exercises. This information would prove invaluable when trying to ascertain the effects of one form of RT over another on energy cost, metabolism and body composition. There is such a wide variety of RT exercises and systems of training, each placing considerably different demands on the system, that assuming the effects to be relatively equal from circuit training, to powerlifting and bodybuilding, would be a mistake.

In regards to this study, this factor plays a significant role in its influence on energy cost. The subjects in this study did not engage in a circuit style of RT, but rather were allowed to move randomly from exercise to exercise at their own pace. In addition, the intensity was considerably higher (70-79% of 1RM) than most circuit training studies (40-60% of 1RM), again possibly affecting final energy cost.

Wilmore et al., (1978) reported an average caloric expenditure of 9 kcal/min when performing a 10-station weight training circuit for 3 laps at 40% of 1RM with 30 seconds work to 15 seconds rest. This 9 kcal/min overestimates the caloric expenditure for our study since subjects' rest periods were longer and work periods were shorter than in the Wilmore (1978) study. The subjects in this study rested for as long as was needed and did not start the next exercise bout until their heart rates dropped below their lower limit training zone. Their total actual exercise lifting time averaged approximately 7-10 minutes, while their total rest time averaged 15-20 minutes. This large inverse work-to-rest ratio difference, compared with the Wilmore et al., (1978) study, is why the regression formulas created by Keuhl et al., 1990 were used in the present study. They were considered to be more appropriate, since they provided the opportunity to calculate work performed per exercise.

Table 11: Prediction Formulas for Energy Cost during RT (Keuhl, 1990; Brown, 1994)

Exercise	Equations	SEE (kcals)	R	P<
Bench Press	.56 + .006 (wt)[9]	2.2	0.7	0.0001
Leg Press	.78 + .002 (wt)	0.9	0.7	0.0001
Seated Row	.62 + .008 (wt)	0.7	0.8	0.0001
Shoulder Press	.05 + .008 (wt)	1.4	0.5	0.005
Split Squat	no formula available			
Biceps	no formula available			
Triceps Pushdowns	no formula available			

No regression formulas could be found for the biceps arm curl, triceps pushdown or the split squat; therefore, a rough estimate of kcal/min was made for each based on the final kcal results of the previous 4 exercises.

[9] Wt represents the weight lifted (pounds) x the repetitions performed

Table 12: Energy Cost of Resistance Training Exercises

	Average Caloric Cost based on all subjects (79% 1RM)		
	1RM	**70% of 1RM x 12reps (pounds)**	**Kcal**
Bench Press	152.6	1446.8	9.4
Leg Press	393.8	3733.4	8.3
Seated Row	152.6	1446.6	12.2
Shoulder Press	115	1090.2	8.8
Split Squat	105.7	1002.1	8.0[10]
Biceps Curl	33.8	320.6	3.0[10]
Triceps Pushdown	76.2	722.2	3.0[10]
Total per session			49.6

Total Volume of Work

The total volume of work, expressed in kcal, is listed below for each exercise activity (table 13).

Table 13: Overview of Caloric Cost per Activity

Group	Average Caloric Expenditure of Each Activity (Kcal)					
	RT	Bike	Treadmill	Rower	Stairmaster	Total Kcal/Session
AO		59.5	43.4	47	102.9	252.8
RT[11] Combo 1	49.5	59.5	43.4		102.9	255.3
RT Combo 2	49.5	59.5		47	102.9	258.9
RT Combo 3	49.5		43.4	47	102.9	242.8

Table 13 illustrates the effect of removing one 10 minute aerobic exercise bout from the RT groups session and replacing it with 25-30 minutes of resistance training. This procedure was sufficient at equating the caloric expenditure for all subjects in this study. Table 13 also outlines the possible exercise combinations for the RT groups during a single session.

[10] No regression formulas could be found therefore, a rough estimate of Kcal/min was made based on the 4 other exercises listed in table 12.

[11] Expenditure varied depending on what aerobic exercise the subject performed on the day

Table 14: Overview of Exercise Protocol

Aerobic:	• Healthy Heart Program protocol 50-60%HRR Warm-up and 60-70%HRR Training
Subject Instruction:	• One-on-one on first 4 visits; semi-supervised by 5th workout
Schedule of Training	• Weights and aerobic class in separate locations
Subject Monitoring:	• HR monitors; 3-6 RPE; BP (see Monitoring next page)
Day of Week	• 2/wk
Type of Equip	• Apex machines; free weights (dumbbells and barbells)
Intensity	• 60% of initial 1RM • 60%-70% of corrected 1RM by wk 2 • 70%-79% of corrected 1 RM by wk 3 • 3-6 RPE (subject stoped when fatigue/strain reached a 6)
Reps	13-15 to start during weeks 1 & 2; and 8-12 by week 3
Sets	1 set to volitional fatigue (for 1st 3 weeks); then to momentary fatigue all remaining sessions
Rest (sets)	self-paced and as needed; they were encouraged to start when ready
Rest (days)	48 hours minimum
Speed of Rep	2 secs up; 2 secs down; no rest between reps; continuous movement
Warm-up System	treadmill/rower/cycle for 10 minutes (50-60%HRR)
Workout System	large to small muscle group sequence; random selection
Length of Program	16 weeks (RT was 6 weeks to 12 weeks for the LSRT and ESRT respectively)
Exercises	1 chest press, 1 seated row, 1 shoulder press, 1 biceps curl, 1 triceps pushdown, 1 leg press, 1 split squat (7 exercises)
Rate of Progression	completion of 15 reps (first 2 weeks), and then 12 reps by 3rd week on 2 consecutive workouts
Adjustment of Workloads	increased by approximately 2-10% or 3-20 pounds.

Monitoring of Subjects

Prior to beginning a weight training session, the subjects were asked to report on their state of well-being. They used an informal rating of perceived well-being scale (developed by the author) of 1 (feeling horrible) to 10 (ecstasy).

A reported reading of 5 or better was required in order for them to participate in weight training for that day (see Table 15).

Table 15: André's Rating of Perceived Well-Being

1	Horrible (I'd rather be taken out and shot)
3	Not Okay today
5	Okay to weight train
6	Good
7	Very Good
8	Great
9	Really Great
10	Ecstasy (better than sex)

Monitoring of Subjects: Procedures

- Resting heart rate and BP were recorded pre/post the 1 RM test.
- BP exercise parameters were based on research by Haslam et al., 1988 and Wiecek et al., 1990 indicating mean peak systolic and diastolic pressure for double leg-press exercise at 80% 1RM at 15 repetitions to be 199 ± 7mmHg and 124 ± 6mmHg respectively. BP readings never surpassed these levels.
- RPE was taken and recorded by the subject or researcher immediately after completing each set.

- Heart rate was monitored and recorded by the subject or researcher during the set and within 10 seconds post-exercise set using a Polar Heart Rate Monitor; the highest reading was the one recorded
- The heart rate was not to exceed the upper threshold established by the exercise specialist, although at times, it surpassed this threshold momentarily by 1-10 beats per minute with no abnormal responses.

Termination Of Resistance Exercise

No subject ever needed to withdraw from RT during a RT session. However, on a few occasions subjects were asked not to RT when their haemodynamic responses appeared unstable or if not feeling well. On these days, these subjects either went home or participated in AO exercise. Below is a synopsis of other occurrences during the study:

- at times temporary dizziness or fatigue was experienced by subjects immediately following a workout set, however, it always dissipated within 30 seconds to 2 minutes (dizziness and fatigue respectively) following the set.
- no subjects experienced confusion, pallor, or cyanosis, although many showed signs of mild dyspnea, which dissipated within first 2 minutes following the termination of the set.
- there were no cases of angina pectoris during the sessions, although, one subject reported tightness in his chest without demonstrating any abnormal haemodynamic responses (ECG, BP, HR)

Orientation to Weight Room: Instructions

All subjects were introduced to the weight room on the 6th session of the HHP program. Instructions included the following:

- adjustment of equipment to match body size/height
- correct body alignment and technique
- correct speed of rep and range of motion
- correct breathing rhythm (as is comfortable for subject or exhale on exertion)
- to avoid gripping handles or any other isometric contractions
- explanation of inappropriate physical sensations, pains and muscle soreness
- explanation of right to stop at any point in time
- explanation of importance of reporting any inappropriate feelings, sensations etc.
- correct starting workload for each exercise
- correct training protocol
- rating of perceived exertion (Borg 1982, revised method 0-10)
- use of heart rate monitors

Schedule of Training

Originally, the order of aerobic and weight training exercise was alternated back and forth as a way of controlling for a potential interference effect of one exercise type over the other. This approach was discontinued since it disrupted the HHP program, staff and flow of class. Therefore, training sessions were as follows:

10 minutes of warm-up
20 minutes of aerobic exercise
25-30 minutes of weight training (ESRT and LSRT only)
5-10 minutes of stretching

Table 16: Schedule of Training Sessions

Time	Mon	Tues	Wed	Thurs
6:45 am	Arrive and Set-up	Arrive and Set-up	Arrive and Set-up	Arrive and Set-up
7:00 am	Warm-up (10 min) 20 minutes of Aerobic Training	Warm-up (10 min) 20 minutes of Aerobic Training	Warm-up (10 min) 20 minutes of Aerobic Training	Warm-up (10 min) 20 minutes of Aerobic Training
7:30	Weight Training (20-25 minutes)	Weight Training (20-25 minutes)	Weight Training (20-25 minutes)	Weight Training (20-25 minutes)
8:00 am	Weights Finished	Weights Finished	Weights Finished	Weights Finished
8-8:15	Stretching	Stretching	Stretching	Stretching
5:15 PM		Arrive and Set-up		Arrive and Set-up
5:30		Warm-up (10 min) 20 minutes of Aerobic Training	Warm-up (10 min) 20 minutes of Aerobic Training	Warm-up (10 min) 20 minutes of Aerobic Training
6:00 PM		Weight Training (20-25 minutes)	Weight Training (20-25 minutes)	Weight Training (20-25 minutes)
6:30 PM		Weights Finished	Weights Finished	Weights Finished
6:30-6:45 PM		Stretching (André)		Stretching (André)

While the RT groups weight trained, the AO group performed 1 additional aerobic activity for 10 minutes and then 15 minutes of mild strength exercise using tubing or light weight consisting of 1-5 pounds. These mild RT workloads represented 10-20% of AO subjects' 1RM and were considered so light that they were no confounding influence.

Table 17: Overview of Study: 16 weeks (32 exercise sessions)

Weeks 1 and 2
- HHP medical director assesses and screens subject
- Subject asked to participate in study
- (medical director, highlights name on intake sign-up list)
- André contacts subject and sets-up appointment
- Informed consent signed and returned (first 2 weeks)
- Body composition assessment 1 (within first 2 weeks)
- Subject begins HHP exercise program (7 am or 5:30pm classes)

Week 3 (6 sessions aerobic exercise completed)
- Subject re-assessed for eligibility into study (file reviewed)
- If eligible subject continues in study
- Orientation to equipment and training protocol

Week 4 (8 sessions of aerobic exercise completed)
- Body comp assessment 2 (done before 7 am & 5:30 pm class)
- Muscular Strength (1RM) measured
- ESRT group begins resistance training

Week 9
- AO and LSRT re-oriented to equipment
- They receive 2 separate practice sessions

Week 10 (20 sessions of exercise completed)
- Body composition assessment 3 (done before class)
- Re-test muscular strength
- LSRT start resistance training (week 11)

Week 15
- AO re-oriented to equipment
- AO and LSRT re-oriented to equipment
- They receive 2 separate practice sessions

Week 16 (32 sessions of exercise completed)
- Body composition assessment 4
- Re-test muscular strength and endurance
- Pre and Post Stress Test aerobic capacity recorded

Statistical Analysis

A 3 (Group) X 4 (Time) ANOVA with repeated measures on the second factor was used to test for differences among the dependent variables. The level of statistical significance was set at $p \leq .05$. All main effects (group, time) and group X time interaction effects between the group factor (AO and RT), were investigated.

Research Question 1:

> **What is the magnitude of change in overall muscular strength in male cardiac rehabilitation subjects participating in aerobic only (AO) and aerobic and resistance training (ART) exercise?**

Research Statement 1:

> **The ESRT group will demonstrate overall pre- to post-training strength increases that are greater than the LSRT and AO groups' increases. The LSRT group will demonstrate pre- to post-training overall strength increases that are greater than the AO group's increases (group effect).**

Hypothesis

Strength: $ESRT_{diff} > LSRT_{diff} > AO_{diff}$

Diff = the difference between the pre and post-training 1RM workloads

Anticipated Results

- an increase in overall strength ranging from 30%-50% for those in ESRT group following a 12-week RT program
- an increase in strength of 20%-30% for both the LSRT and ESRT during each group's initial 6-week weight training period
- minor increase in overall strength ranging from 0%-10% for those in AO group

Research Question 2:

What is the magnitude of body composition changes in body weight (BW), sum-of-skinfolds (SOS), lean mass (LM), muscle mass (MM), fat mass (FM), waist-to-hip (WHR) ratio in male cardiac rehabilitation subjects participating in AO and ART?

Research Statement 2:

The ART groups will demonstrate pre- to post-training increases in LM and MM, that will be greater than those of the AO group. There will be no pre- to post-training changes in BW, SOS and WHR. All three groups will experience an equal drop in FM.

Hypotheses:

BW: $ART_{diff} = AO_{diff}$

SOS: $ART_{diff} = AO_{diff}$

LM: $ART_{diff} > AO_{diff}$

MM: $ART_{diff} > AO_{diff}$

FM: $ART_{diff} = AO_{diff}$

WHR $ART_{diff} = AO_{diff}$

Diff = the difference between the pre and post-training body composition measurements

Anticipated Results

- a decrease in FM of 4%-6% (1.6 - 1.8 kg) for both the AO and ART groups over 16 weeks
- increase of post-LM and -MM measures of 2%-5% (1-1.4 kg) for ART subjects participating in the initial 6 and 12 week resistance training program
- no change in pre- and post-LM and -MM measures for AO

RESULTS

Chapter 3

The dependent variables that were of primary interest were BW, SOS, WHR, MM, FM , LM and 1 RM strength performance. There were no statistically significant differences between groups for the baseline values of all these variables. A table (Table 20, page 85) has been provided for quick reference of the results and hypotheses.

Compliance and Dropout

A total of 34 subjects were recruited , 27 of these 34 completed the study (80%). Two subjects quit after 2 weeks due to business demands and being unable to maintain attendance. A third subject found it to difficult to travel to the clinic and dropped-out, even though this issue was addressed during the orientation meeting. The fourth subject quit due to personal problems (not known). The fifth subject was unable to pass the re-assessment screening process at the 3rd week mark of participation and therefore was dropped from the study. The sixth subject had a second heart attack one week prior to starting in the study. The seventh subject became ill with bronchial pneumonia and had to drop-out after the 12th week. Six of these seven drop-outs, occurred prior to the third week of the HHP; the RT intervention did not begin until the fourth week.

No subject ever needed to withdraw from RT during a RT session. However, on a few occasions over the 11 month study period, subjects were asked not to RT when their haemodynamic responses appeared unstable or if they were not feeling well. On these days, these subjects either went home or participated in AO exercise. Below is a synopsis of other occurrences during the study:

- at times temporary dizziness or fatigue was experienced by subjects immediately following a workout set, however, it always dissipated within 30 seconds to 2 minutes (dizziness and fatigue respectively) following the set.
- no subjects experienced confusion, pallor, or cyanosis, although many showed signs of mild dyspnea, which dissipated within first 2 minutes following the termination of the set.
- there were no cases of angina pectoris during the sessions, although, one subject reported tightness in his chest without demonstrating any abnormal haemodynamic responses (ECG, BP, HR)

The average number of exercise sessions attended, when averaged over all groups was 28.3 (89%) out of a possible 32 sessions. The ESRT group had the best attendance 29.1 sessions (91%), the AO group and the LSRT attendance were 28.4 (89.1%) and 27.4 (85.8%) respectively. This 89% attendance rate for this study is consistent with other studies (McCartney et al., 1995, Daub et al., 1996).

Body Composition

The dependent variables that were of primary interest were BW, SOS, WHR, MM, FM , and LM. When interpreting the data, emphasis was be placed on the anthropometry measures, since these measures offered the more statistically dependable data due to their larger sample sizes (AO, n = 10; ESRT, n = 8; LSRT, n = 9; N = 27) and support in the literature.

DXA, although a good method for measuring FM and LM, had a relatively small sample size (AO, n = 4; ESRT, n = 6; LSRT, n = 4; N = 14) and was not used as a primary method for assessing body composition changes. Its results were used to gain additional insight regarding the body composition changes as well as lend support to the other assessment methods' findings. The author did attempt to increase sample sizes in order to increase the power of the DXA findings, however the high cost per session and limited access to its use, made it difficult to acquire enough scans.

The NIR LM and FM groups were equal in size to that of the anthropometry measures, however, the results provoked skepticism, since repeated (same day) measurements produced large unexplainable fluctuations. This fact, coupled with the strong controversy surrounding NIR's (specifically, the Futrex 5000A) validity and reliability (Broeder, 1997), resulted in a lack of confidence findings. In addition, contradictions between the DXA and NIR results added to the skepticism. These contradictions may be due to (a) the different set of subjects used for each method, (b) the small DXA sample size and (c) the statistical validity and reliability of both techniques. Therefore, the NIR LM and FM variables were not the primary criteria used to assess body composition changes, but as with DXA, used for providing additional insight.

The reader should bear these points in mind regarding the methods of assessment when reviewing the study's results.

Table 18: Body Composition Characteristics and Pre- to Post-Training Results

	AO				ESRT				LSRT			
Measures	**Pre**	**Post**	**Diff**	**% Δ**	**Pre**	**Post**	**Diff**	**% Δ**	**Pre**	**Post**	**Diff**	**% Δ**
Age	53.3[1] ± 2.24	--------	---------	--------	50.5[2] ± 2.9	--------	--------	--------	53.1[2] ± 2.7	--------	--------	--------
Height (cm)	174.8[1] ± 2.7	--------	--------	--------	175.3[2] ± 1.6	--------	--------	--------	170.7[2] ± 3.2	--------	--------	--------
Weight (kg)***	92.2[1] ± 5.6	91.5 ± 5.6	-0.7 ± 0.8	-0.8	90.2[2] ± 6.0	89.6 ± 6.7	-0.6 ± 1.5	-0.7	84.3[2] ± 3.5	84.6 ± 3.6	0.3 ± 0.6	0.3
WHR**	0.97[1] ±.02	0.96 ±.02	0.01 ± .01	0.8	0.95[2] ± .02	0.93 ± .02	0.02 ± .01	2.1	0.97[2] ± .02	0.96 ± .02	-.01 ± .01	-0.1
SOS 7 (mm)	127.7[1] ± 8.9	126.2 ± 10.0	-1.5 ± 4.4	-1.1	125.0[2] ± 8.8	122.6 ± 15.3	-2.4 ± 7.5	-1.9	134.4[2] ± 16.1	133.6 ± 14	-0.8 ± 6.4	-0.6
Muscle Mass ** (kg)	45.4[1] ± 2.0	45.0 ± 2.2	-0.4 ± 0.3	-0.9	45.0[2] ± 3.0	44.9 ± 2.7	-0.1 ± 0.4	-.02	39.6[2] ± 1.8	41.0 ± 1.6	1.4 ± .5	3.5
NIR FM (kg)	25.2[2] ± 3.1	26.1 ± 3.3	0.9 ± .05	1.5	25.0[2] ± 2.9	25.1 ± 3.9	0.1 ± 1.4	0.4	22.4[2] ± 1.4	22.5 ± 1.7	0.1 ± 0.5	.4
NIR LM (kg)	65.8[2] ± 3.1	64.1 ± 3.1	1.7 ± .06	1.1	64.8[2] ± 3.1	64.9 ± 3.0	0.1 ± 0.7	0.1	61.3[2] ± 2.8	62.1 ± 2.9	0.8 ± 0.7	0.1
DXAFM (kg)	22.0[4] ± 2.9	20.9 ± 2.9	-1.1 ±.53	-5.2	27.7[6] ± 3.0	25.8 ± 3.6	-1.9 ± 1.3	-7.9	27.9[4] ± 3.4	28.0 ± 4.6	.1 ± 1.4	0.3
DXALM** (kg)	56.8[4] ± 3.0	55.6 ± 3.2	-1.2 ± .82	-2.1	61.4[6] ± 4.8	63.8 ± 5.4	2.4 ± 0.8	3.9	60.6[4] ± 3.7	61.0 ± 3.5	0.4 ± 0.6	0.7
DXATBMC (g)	2651[4] ± 241	2658 ± 712	7 ± 9	0.3	3225[6] ± 62	3222 ± 48.4	-3.0 ± 17	-0.1	2819[4] ± 101.8	2832 ± 160	12.5 ± 27.2	0.4

± = SEM
1 = (n = 10)
2 = (n = 9)
3 = (n = 8)
4 = (n = 4)
5 = (n = 6)

** There were no significant differences between any of the variables listed, for the group factor. WHR was significant ($p<.002$) for all subjects pre- to post-training (time factor). The group X time factor for MM and DXA LM was significant ($p<.001_{MM}$; p. $<.02_{DXA}$, respectively).

*** Body weight scale values (e.g., AO group = 92.2 kg) vary from DXA LM and FM summed mass values (e.g. AO = 78.7 kg), due to different sets of subjects.

Body Weight

There were no statistically significant differences in body weight ($p= .56$) between mean group pre- and post test scores for the AO (92.2 ± 5.6 kg_{pre}; 91.5 ± 5.6 kg_{post}), ESRT (90.2 ± 6 kg_{pre}, 89.6 ± 6.7 kg_{post}) or LSRT(84.3 ± 3.5 kg_{pre}; 84.6 ± 3.6 kg_{post}). Exercise training interventions did not significantly affect mean body weight scores (see table 18).

There was no significant time effect when averaged over groups ($p=.09$) . The subjects' mean body weight values did not differ significantly over the 4 months of training ($Week_0 = 89 \pm 2.91$ kg, $Week_4 = 88 \pm 2.86$ kg, $Week_{10} = 88.06 \pm 3$ kg, $Week_{16} = 88.6 \pm 3$ kg) suggesting that subjects' mean scores did not change over time.

There were also no significant findings for the group X time effect ($p=.7$). All groups showed similar increases and decreases in BW over time regardless of the training intervention.

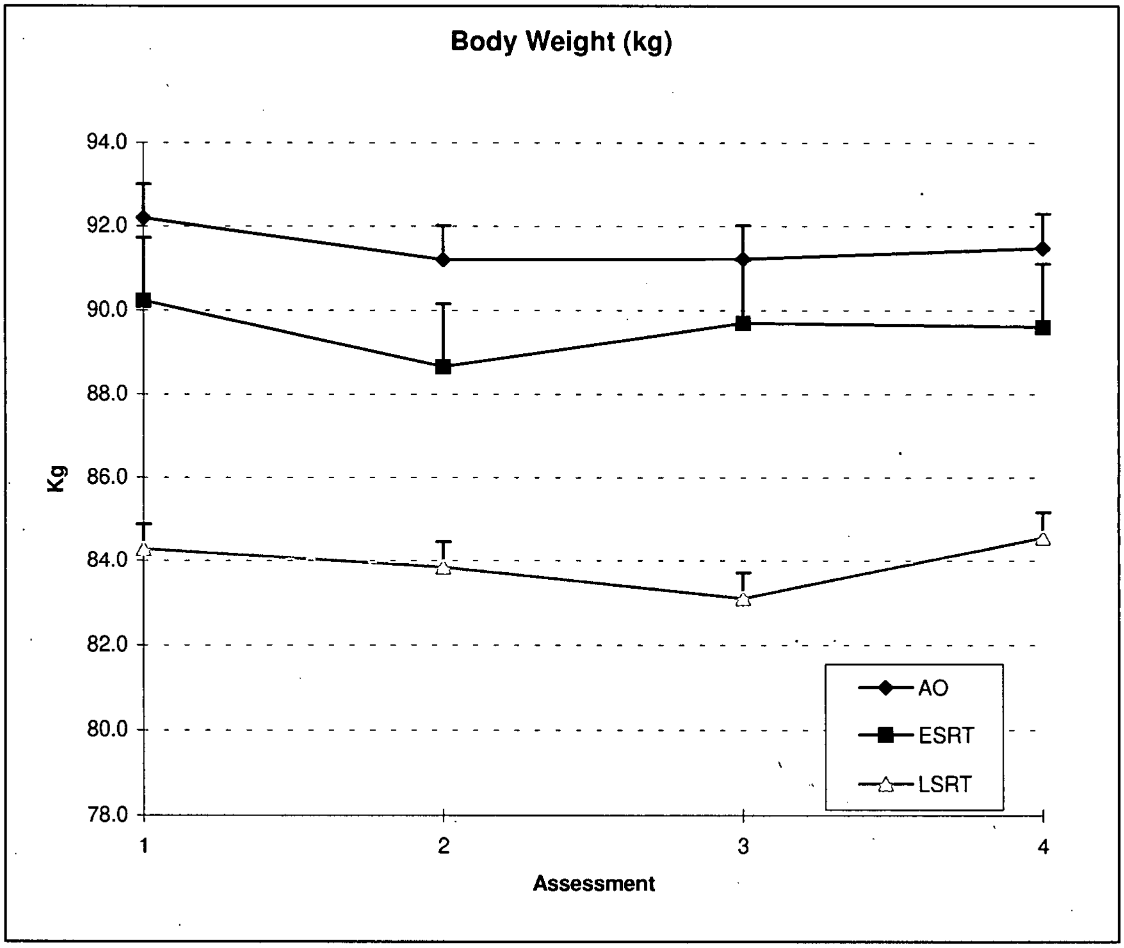

Figure 11: Body weight changes at assessment periods Week 0, Week 4, Week 10 and Week 16. AO group (diamond), ESRT (square) and LSRT (triangle). Values are group means ± SEM.

Lean mass (LM)

The pre- and post-LM changes, as measured by both DXA (n = 6_{ESRT}, n = $4_{LSRT\ \&\ AO}$) NIR (n = 8_{ESRT}; n = $9_{LSRT\ \&\ AO}$), were not significantly different between groups when averaged over time (DXA & NIR, p= .6, respectively). Both DXA and NIR methods were in agreement regarding the direction of changes to LM for the AO and LSRT groups, yet, disagreed regarding the ESRT group. DXA and NIR revealed a decrease for the AO group (-2.1$\%_{DXA}$; -1.1$\%_{NIR}$) and an increase for the LSRT group (.7 $\%_{DXA}$; .1 $\%_{NIR}$) in LM. However, DXA detected a LM gain in the ESRT group of 3.9% while NIR detected no change. In absolute values, the AO group lost -1.2± .8kg_{DXA} and -1.7 ± .06 kg_{NIR}; the LSRT gained .4 ± .6kg_{DXA} or 0.8 ± 0.7 kg_{NIR} and the ESRT gained 2.4 ± .8 kg_{DXA}; NIR showed no changes in LM.

There were no significant differences for the time factor, as measured by DXA (p= .24) and NIR (p=.23). Changes to LM did not differ significantly enough over time ($Week_0$ = 63.9 ± 1.7 kg, $Week_4$ = 63.4 ± 1.7 kg, $Week_{10}$ = 63.3 ± 1.6 kg, $Week_{16}$ = 63.7 ± 1.7 kg), when averaged over the group factor (AO and RT).

There was a significant group X time effect for LM ($F_{2,11}$ = 5.7; p<.02), as measured by DXA; NIR was non-significant (p=.08). Figures 12 and 13 show the difference in LM changes pre- and post-study between groups. DXA revealed a loss in the AO group of -1.2 ± .8 kg, while the ESRT and the LSRT gained 2.4± .8 kg and .4 ± .6 kg, respectively. These differences in LM response to the training intervention suggests a possible negative effect for the cardiac subjects who performed AO exercise and a positive effect for those who engaged in RT.

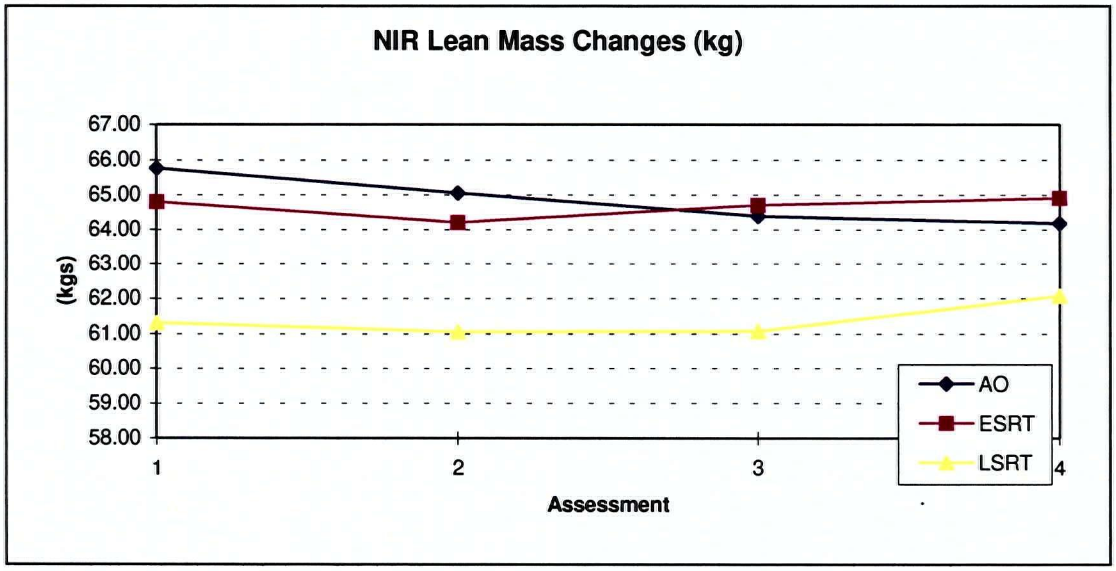

Figure 12: NIR LM changes at Week 0, Week 4, Week 10 and Week 16. Non-significant ($p>.05$). Values are group means ± SEM.

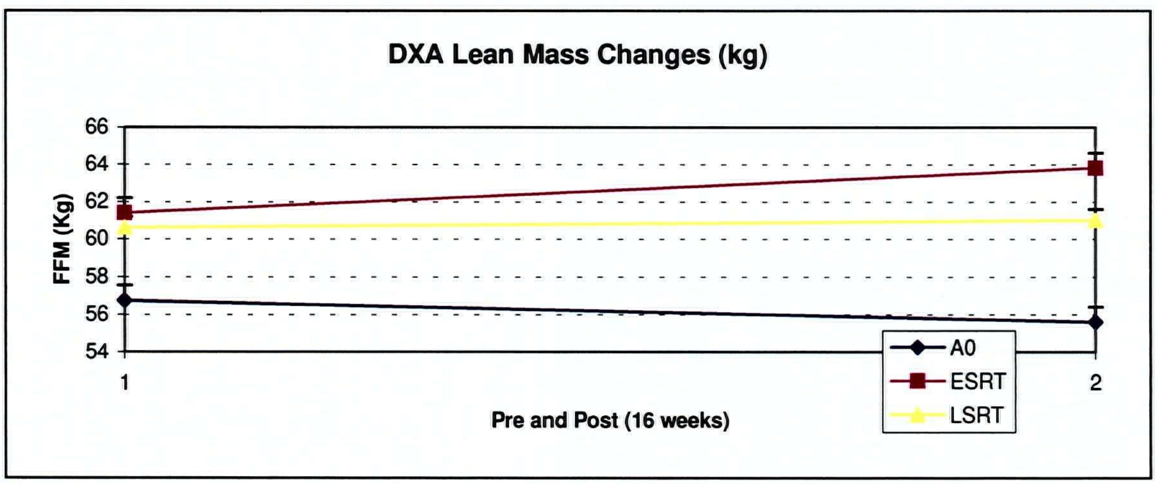

Figure 13: DXA LM changes at Week 0 and Week 16. Values are group means ± SEM. The group X time effect was significant, $p<.02$, as measured by DXA.

Fat Mass (FM)

The mean group pre- and post-FM changes, as measured by both DXA and NIR (Futrex 5000A), were not significantly different between groups (p=.4). DXA revealed decreases in FM over time for AO group (-5.2% or -1.1 ± 0.5 kg), ESRT (-7.9 ± 4.3% or -1.9 ± 1.3 kg) and minor change in the LSRT group (.3% .or .1 ± 1.4 kg). Conversely, the NIR revealed increases in FM for all groups over time: AO = 1.5% (0.9 ± 0.5 kg); ESRT = 0.4% (.1 ± 1.4 kg) and LSRT =0.4% (0.1 ± 0.5 kg). The reason for this contradiction of results between DXA and NIR is not known, however, one possible explanation may be due to human error when using the Futrex 5000A equipment. At times during an assessment, a simple 1cm displacement from the landmark site, resulted in rather large differences between the first to the second reading (as high as 9 units above or below). Another reason for the differences between DXA and NIR, could be due to the different sets of subjects used for each method and sample sizes.

No statistical differences were found for the 4 Time trials (DXA, p=.2; NIR, p=.6) or group X time Effect (DXA, p=.6; NIR, p=.5). These findings show that mean FM changes did not differ significantly between assessment dates when averaged over the group factor (RT and AO exercise), nor did they differ enough from each other regarding the direction and magnitude of change at any assessment interval (group X time effect).

Sum of Skinfolds (SOS)

There were no significant differences between the three groups' pre- and post-SOS scores (p=.9), as measured by Harpenden skinfold calipers, (AO_{pres} = 127.7 ± 8.9mm, AO_{post} = 126.2 ± 10mm; $ESRT_{pres}$ 125.0 ± 8.8mm, $ESRT_{post}$ 122.6 ± 15.3mm; $LSRT_{pres}$ 134.4 ± 16.1mm, $LSRT_{post}$ 133.6 ± 14mm). These results show that SOS did not differ between the AO, the ESRT and the LSRT groups, regardless of the training intervention.

When averaged over the three groups (time factor), subjects' SOS's, did not differ significantly (p=.3) between Week 0-16 (Wk_0 = 129.1 ± 6.6mm; Wk_4= 125.94 ± 6.7mm; Wk_{10}25.3 ± 7.1mm; Wk_{16} 128.7 ± 7.2mm). Subject's did not differ in SOS's over the course of the study (p= .3).

The group X time factor was not statistically significant (p=.99). All groups showed similar changes in direction and magnitude of mean SOS changes between the groups at each assessment period (figure 14).

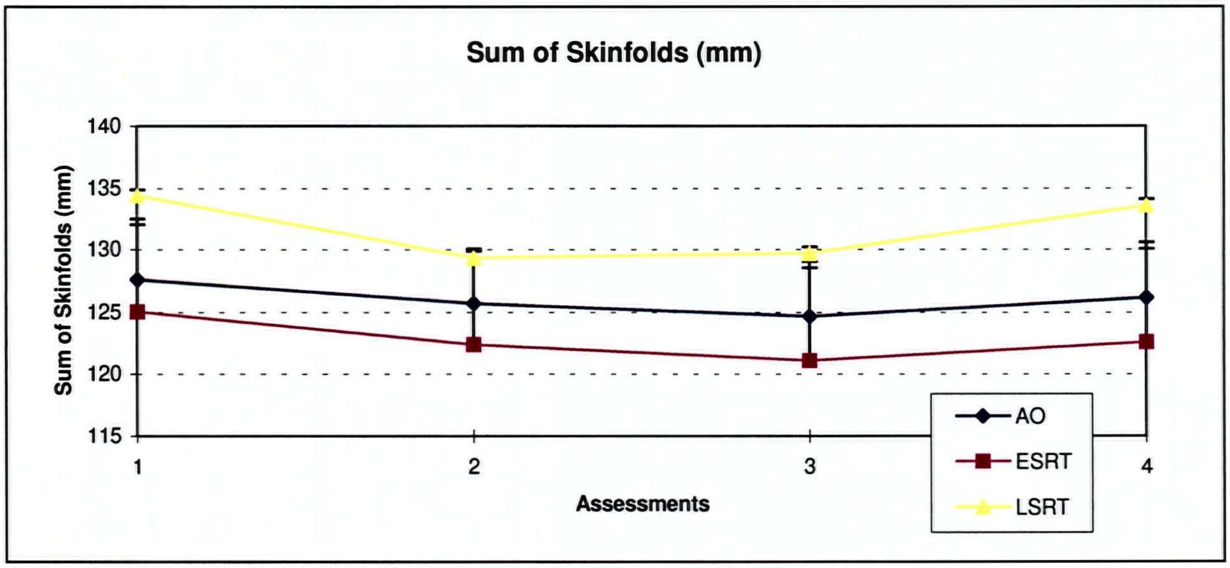

Figure 14: Sum of Skinfold changes from Week 0, Week 4, Week 10 and Week 16. Values are group means ± SEM. Non-significant, p>.05.

Muscle Mass

There was no significant group effect ($p= .19$), as measured by anthropometry, indicating that muscle mass scores , when averaged over the 4 Week periods, did not differ between AO, ESRT and LSRT subjects ($AO_{pres} = 45.4 \pm 2$kg, $ESRT_{pres}$ 45 ± 3kg, $LSRT_{pres}$ 39.6 ± 1.8kg) and post-test mean scores ($AO_{post} = 45 \pm 2.2$kg, $ESRT_{post}$ 44.9 ± 2.7kg, $LSRT_{post}$ 41 ± 1.6kg). There was also no significant pre, mid and post Time effect ($p=.07$) indicating that muscle mass scores, when averaged over the group factor (RT and AO exercise), did not differ within subjects pre-test and post-test values. However, a significant difference was found for the interaction group X time effect ($F_{6,72} = 5.1$, $p<.001$). The AO, ESRT and LSRT groups exhibited different responses in both the direction and magnitude of muscle mass change at each time interval. Figure 15 shows the ESRT group's change in mean muscle mass was inverse to that of the AO group throughout the study. The ESRT group lost 2.7% (1.4 ± 0.8 kg) of muscle mass by the 4th week or 2nd Week while the AO group gained .9% (.4 ± 0.1 kg). The ESRT group then showed an abrupt increase of 2.5% (1.2 ± 0.6 kg) from the 4th to the 10 week while the AO group showed a slight decrease of 0.7% (.24 ± .23kg). Both groups continued to show increases (ESRT 4.0% or .18 ± 2.7kg) and decreases (AO 3.3% or .33 ± 0.3 kg) for the 10th to the 16th week although the change was more gradual. The LSRT group and the AO group showed a strong difference in muscle mass response at the 10th to 16th week. The LSRT gained 4.0% of muscle mass over this period of time (1.4kg) while the AO group lost 3.3 % (.33 ± 0.3 kg). This group X time interaction effect demonstrates the influence RT had on the muscle mass changes. In addition, this interaction pattern of change is similar to that of the DXA (figure 13).

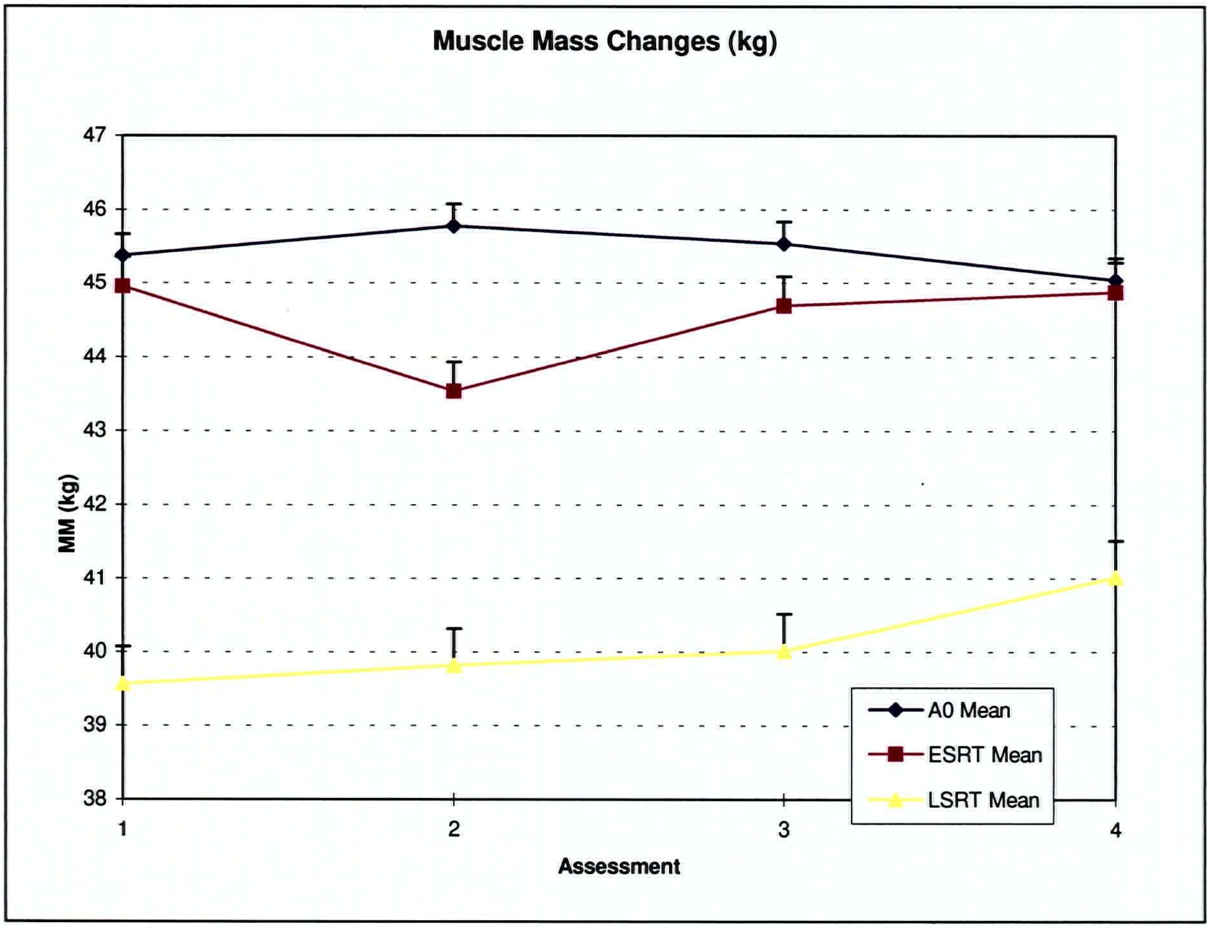

Figure 15: MM changes from Week 0, Week 4, Week 10 and Week 16. Values are group means ± SEM. The group X time effect was significant. p<.001.

Waist-to-Hip Ratio

WHR measurements were not significantly different between groups (p=.6). This finding indicates that mean WHR measurements did not differ regardless of exercise intervention. However, there was a statistically significant time effect ($F_{3,72}$= 5.42, p<.002). WHR values decreased by 1.3% from $Week_0$

(mean = 1.02) to Week4 (mean = .98). A 3 (Group) X 4 (Time) ANOVA with repeated measures on the time factor was also performed on waist and hip girths as well as umbilicus skinfolds; findings revealed a significant pre- to post-waist girth difference ($F_{3,72}$=4.02; p<01) with no changes to hip girths (p=0.7) or umbilicus skinfolds (p=0.9) suggesting a decrease in subjects' visceral fat(girths and individual SOS are not included in Table 18). This drop in waist girths, is likely to be the reason for a drop in WHR (see discussion section). Finally, there was no significant group X WHR interaction effect (p=.47) indicating that all groups exhibited similar changes in both direction and magnitude of WHR scores over time.

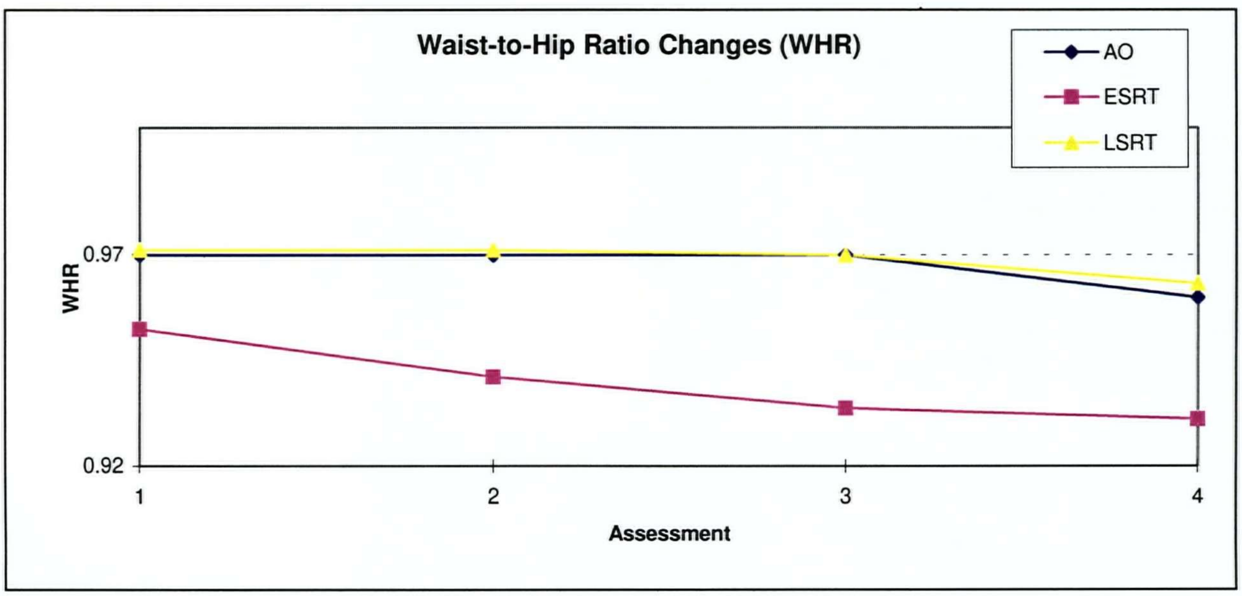

Figure 16: WHR changes from Week 0, Week 4, Week 10 and Week 16.
Values are group means ± SEM. Non-significant, p>.05.

Strength Performance

Strength performance was assessed using a One-Way ANOVA on the difference between pre- and post-study group means (table 19) for all RT exercises combined (RTEC) and individual RT exercises

(IE). The overall strength increase for RTEC (table 19 & figure 17) was significantly different ($F_{2,22}$ = 9.5, p<.001) between groups. The ESRT group showed the greatest strength increases (27.9 ± 4.2% or 57.3 ± 9.9 kg) followed by the LSRT group (25.5 ± 3.3% or 46.4 ± 6.8 kg) and finally, the AO group (7.1 ± 2.6% or 14.0 ± 4.7 kg). A Tukey HSD post-hoc analysis revealed the significant difference to be between the RT and AO groups (P<.05); no significant difference existed between the two RT groups. The IE group mean changes (table 19) were significantly different between groups for the Vertical Bench ($F_{2,24}$= 5.3, p<.01), Seated Row ($F_{2,24}$= 3.5, p<. 04), Leg Press ($F_{2,22}$= 3.9, p<04), Split Squat ($F_{2,22}$ = 15.2, p<.0001), but not for the Shoulder Press (p=.12) , Biceps Arm Curl (p=.06) and the Triceps Pushdown (p=.06). Again, it was the ESRT group that showed the greatest increases (see table 19).

Overall lower and upper body pre-to post-training strength increases (table 19 and figures 18-19) were significantly different ($F_{2,22}$= 5.8, p<.009 and $F_{2,22}$= 7.4, p<.004, respectively) with the upper body increasing 6.5 ± 1.3%$_{AO}$,17.9 ± 1.6%$_{ESRT}$, 18.4 ± 1.2% $_{LSRT}$ and lower body increasing 7.5 ± 6.6% $_{AO}$, 39.0 ± 6.4% $_{ESRT}$, 33.8 ± 8.3% $_{LSRT}$. A post-hoc Tukey HSD analysis revealed the significant difference to be between the AO and RT groups (P<.05); the RT groups were not significant different from each other (upper body, p= .8 and lower body, p=.25).

The exercise with the largest relative strength increase was the Split Squat (102.2 ± 25.6% or 35.7 ± 5.3 kg) followed by the Leg Press (26.8 ± 5.3% or 35.7 ± 5.3 kg) and then the Vertical Bench (22.7 ± 4.5% or 15.3 ± 3.5 kg) for the ESRT group. This order remained the same for the LSRT (see table 19). However, the order was different for the AO group. The AO group's Split Squat showed the largest increases (see table 19) followed by the Shoulder Press and finally the Vertical Bench; the AO

Leg Press showed the second least amount of change (4.8 ± 4.9% or 8.2 ± 11.4). These findings suggest that strength improves the most in the legs for those cardiac subjects who RT, but is unpredictable in those cardiac subjects that participate in only aerobic exercise.

Table 18: Strength Performance Formulas for RTEC and IE changes

RTEC Strength Change =	(Mean Sum of RTEC Post-Study 1RM workloads)-(Mean Sum of RTEC Pre-Study 1RM workloads)
IE Strength Change =	(Mean Sum of IE Post-Study 1RM workloads)-(Mean Sum of IE Pre-Study 1RM workloads)

A 3 (Group) X 4 (Time) ANOVA with repeated measures on the time factor, was performed to assess the group X time effect for each RT exercise. All but one exercise, the Shoulder Press ($p=.14$), showed a significant group X time interaction effect. The ESRT group's Split Squat mean scores showed the most dramatic group X time interaction (figure 23) between the three groups ($F_{4,44}= 10.3$ $p<.0001$). The ESRT had the lowest pre-intervention mean score of all three groups (35.0 ± 3.7 kg), and increased strength above the mean values of the other groups by 14.0 ± 4.2 kg by Week 2. The LSRT and AO groups did not differ in direction or magnitude of change from Week 1 to Week 2. However, from Week 2 to Week 3, the LSRT group increased strength abruptly (14.3 ± 3 kg) and similarly to the ESRT group's initial strength surge, while the AO showed minor changes (6.9 ± 2.3 kg). This group X time interaction pattern was similar for 6 of the 7 exercises (see figures 20-26), although the magnitude of change was not as great as in the Split Squat.

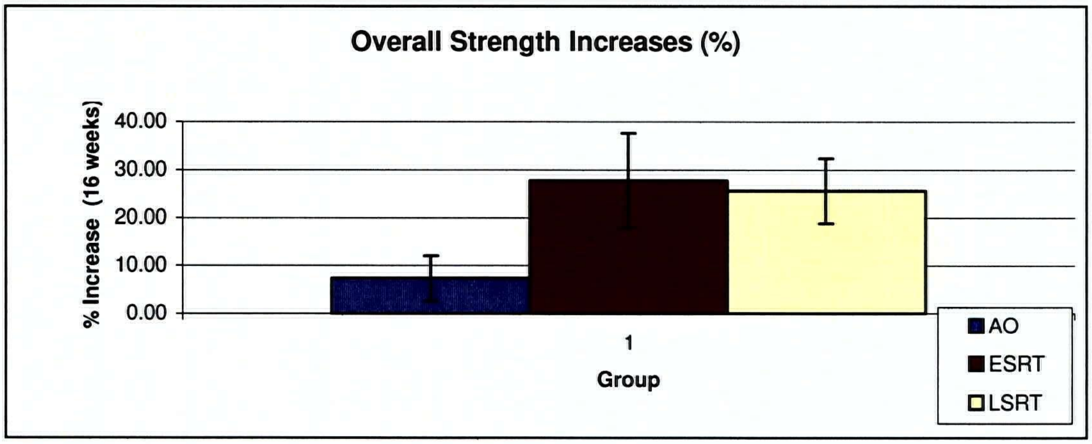

Figure 17: Overall strength increases pre- to post-training. Values are pre- and post-training mean differences ± SEM. Significantly different between RT groups and AO group, p<.001.

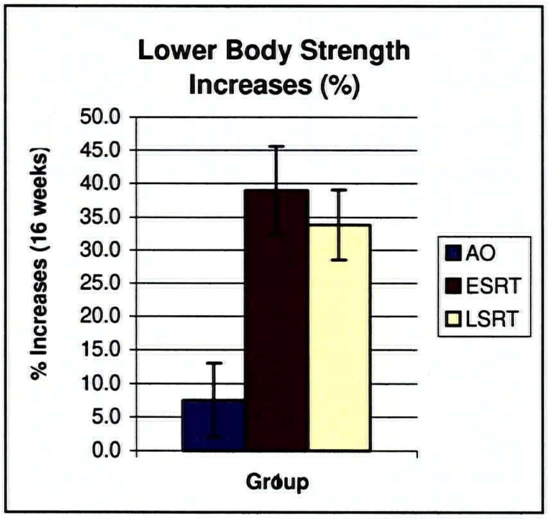

Figure 18: Lower body strength increases. Values are pre- to post-training mean differences ± SEM. Significantly different between RT and AO groups, p<.004.

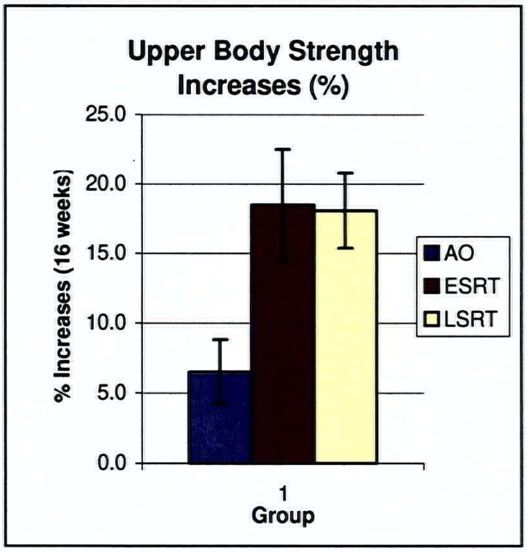

Figure 19: Upper body strength increases. Values are pre- to post-training mean differences ± SEM. Significantly different between RT and AO groups, p<.001.

Table 19: Strength Increases (kg)

Exercise	AO				ESRT				LSRT			
	Pre	Post	Diff	% Δ	Pre	Post	Diff	% Δ	Pre	Post	Diff	% Δ
Vertical Bench	$65.4^1 \pm 5.2$	69.6 ± 4.6	4.2 ± 2.3	6.4 ± 2.1	$67.4^3 \pm 4.0$	82.7 ± 6.2	15.3 ± 3.5**	22.7 ± 4.5	$61.4^2 \pm 4.3$	74.7 ± 5.6	13.3 ± 2.4**	21.7 ± 3.8
Seated Row	$65.5^1 \pm 2.6$	68.5 ± 3.2	3.0 ± 2.1	4.6 ± 3.1	$68.7^3 \pm 3.7$	78.9 ± 4.8	10.2 ± 2.2**	14.8 ± 2.9	$63.1^2 \pm 3.7$	71.4 ± 4.5	8.3 ± 1.7**	13.2 ± 2.9
Shoulder Press	$49.0^1 \pm 2.3$	53.2 ± 3.2	4.3 ± 1.7	8.7 ± 3.5	$54.8^3 \pm 3.9$	63.5 ± 4.9	8.7 ± 1.6	15.9 ± 2.3	$47.8^2 \pm 2.7$	57.9 ± 4.8	10.1 ± 2.7	21.1 ± 5.0
Leg Press	$170^3 \pm 15.6$	178 ± 15.1	8.2 ± 11.4	4.8 ± 4.9	$180^3 \pm 9.8$	228.8 ± 15.8	48.4 ± 9.7**	26.8 ± 5.3	$146^2 \pm 16.7$	190 ± 17.8	43.0 ± 11.3**	29.3 ±10.3
Split Squat	$36.8^3 \pm 4.6$	43.7 ± 3.3	6.9 ± 2.3	18.6 ± 5.6	$35.0^3 \pm 3.7$	70.7 ± 4.7	35.7 ± 5.3**	102.1 ± 25.6	$36.9^2 \pm 4.3$	56 ± 5.2	19.1 ± 2.9**	51.8 ± 8.9
Biceps Arm Curl	$14^1 \pm 0.5$	14.9 ± 0.6	0.9 ± .43	6.5 ± .43	$14.1^3 \pm 0.8$	17.1 ± 1.1	3.0 ± .8	21.3 ± 5.7	$13.7^2 \pm 0.8$	15.7 ± 1.9	2.0 ± 0.6	14.2 ± 4.2
Triceps Pushdown	$30.5^1 \pm 1.4$	32.9 ± 1.6	2.5 ± 0.6	8.1 ± 3.5	$34^3 \pm 2.3$	39.6 ± 2.7	5.6 ± 1.6	16.3 ± 4.7	$30.5^2 \pm 1.5$	36.7 ± 2.2	6.2 ± 1.3	20.4 ± 3.4
Overall Strength Increase	$196^3 \pm 14.3$	210 ± 13.9	14.0 ± 4.7	7.1 ± 2.6	$206^3 \pm 10.8$	264 ± 17.4	57.3± 9.9**	27.9 ± 4.2	$182^2 \pm 13.8$	228 ± 17.6	46.4± 6.8**	25.5 ± 3.3
Lower Body Overall Increase	$94.1^3 \pm 8.7$	101 ± 8.1	6.9 ± 5.5	7.5 ± 6.6	$97.9^3 \pm 4.7$	136 ± 9.1	38.2 ± 6.6**	39.0 ± 6.4	$83.2^2 \pm 9.1$	111 ± 10.3	28.0 ± 25.3**	33.8 ± 8.3
Upper Body Overall Increase	$102^1 \pm 5.0$	109 ± 5.0	6.7 ± 2.3	6.5 ± 1.3	$108^3 \pm 6.2$	128 ± 8.6	20.5 ± 4.0**	18.5 ± 1.6	$98.2^2 \pm 5.6$	116 ± 7.5	18.0 ± 2.7**	18.4 ± 1.2

± represents SEM
** Significant (p<.05)
1 = (n = 10)
2 = (n = 9)
3 = (n = 8)

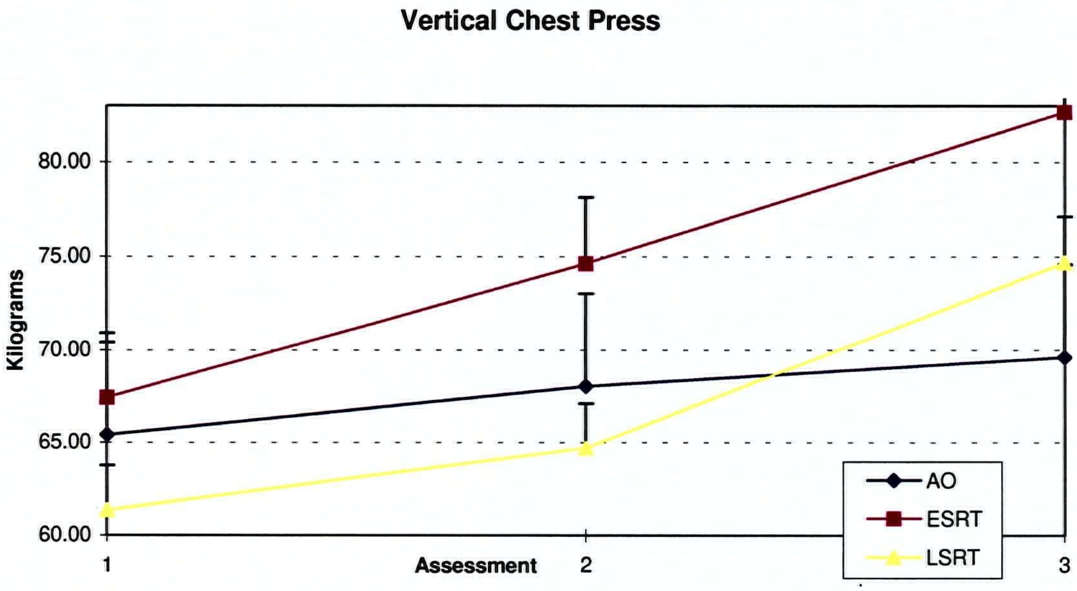

Figure 20: Strength changes from Week 4, Week 10 and Week 16. Values are group means ± SEM. Significantly different between RT and AO groups, p<.01.

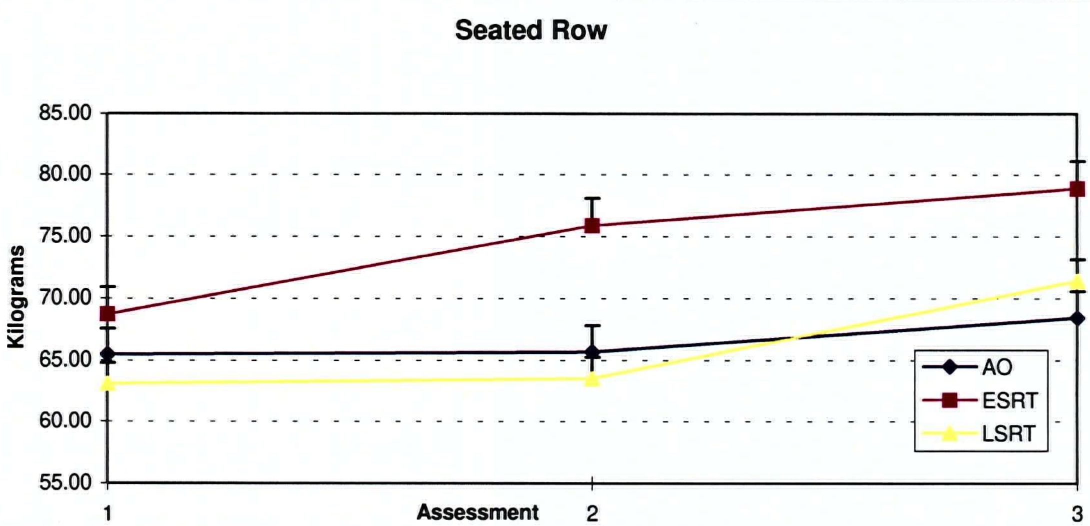

Figure 21: Strength changes from Week 4, Week 10 and Week 16. Values are group means ± SEM. Significantly different between RT and AO groups, p<.04.

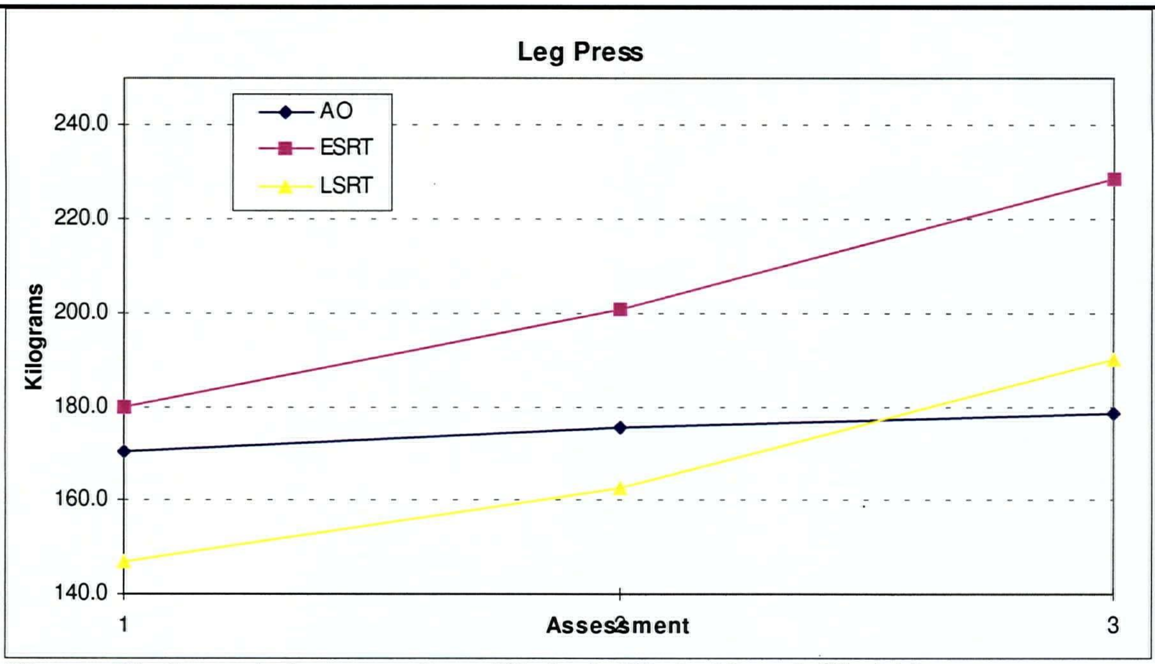

Figure 22: Strength increases from Week 4, Week 10 and Week16. Values are group means ± SEM. Significantly different,p<.04.

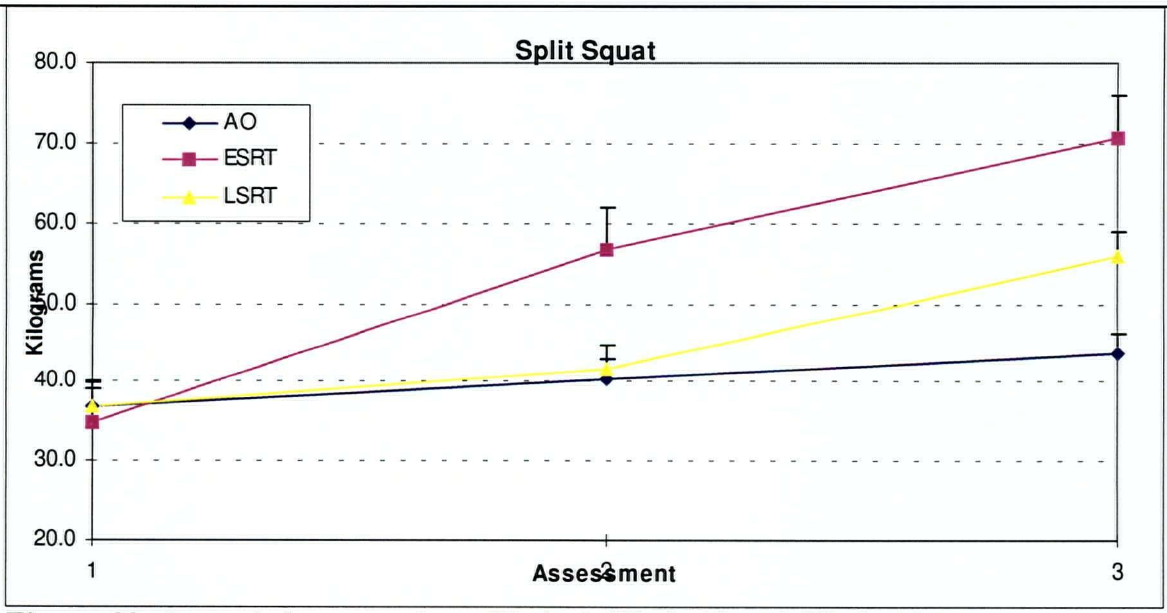

Figure 23: Strength increases from Week 4, Week 10 and Week 16. Values are group means ± SEM. Significantly different, p<.0001

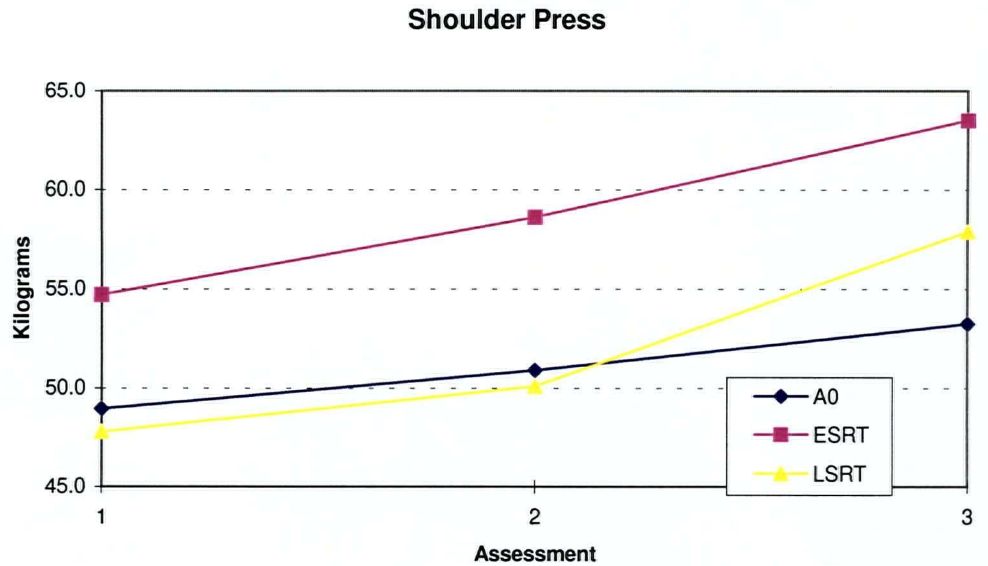

Figure 24: Strength increases from Week 4, Week 10 and Week 16. Values are groups means ± SEM.

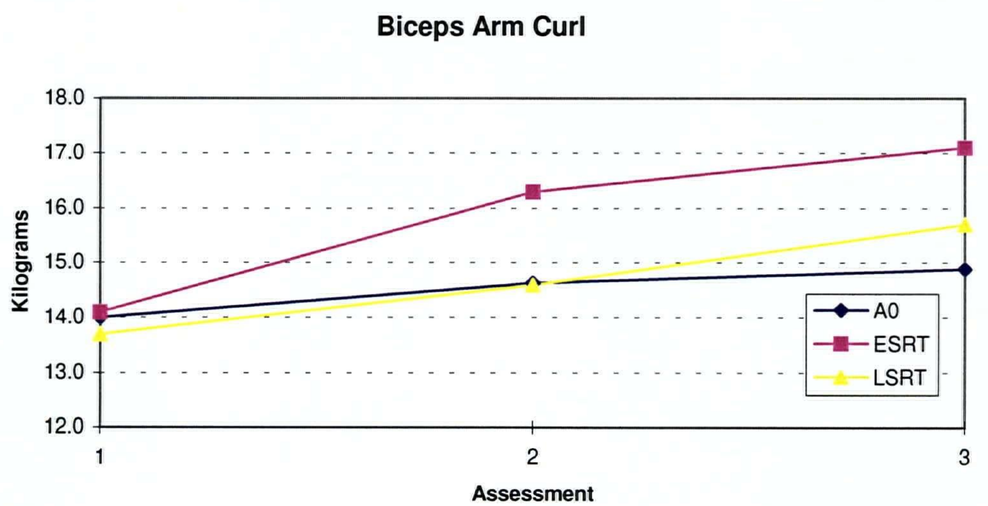

Figure 25: Strength increases from Week 4, Week 10 and Week 16. Values are group means ± SEM..

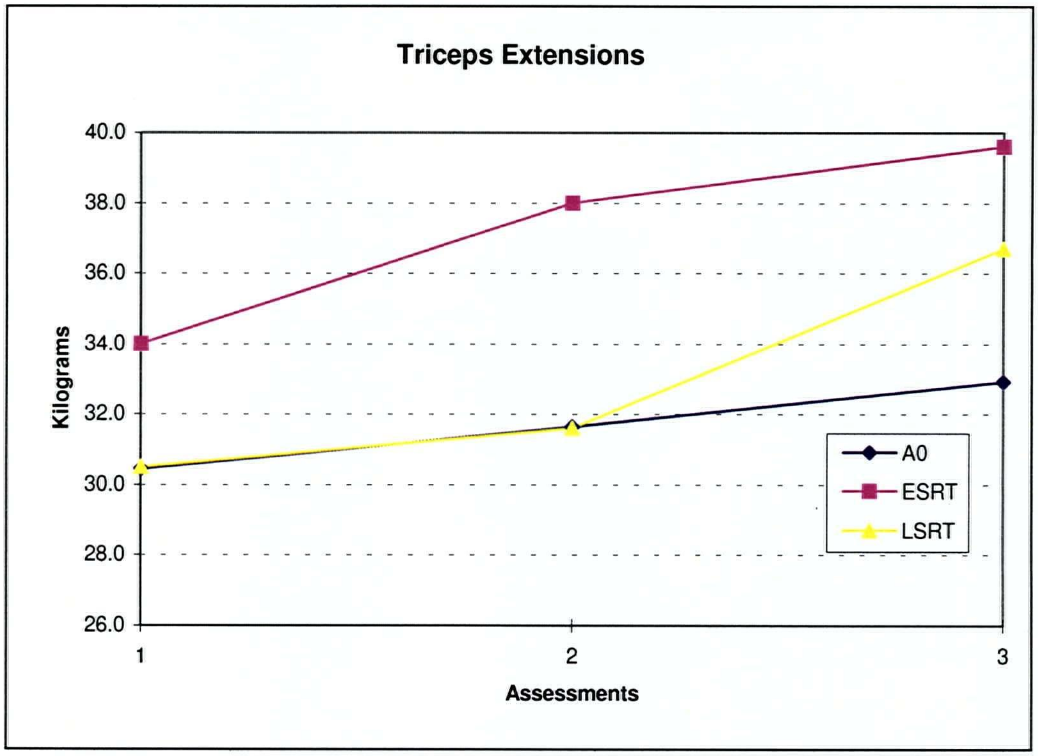

Figure 26: Strength increases from Week 4, Week 10 and Week 16. Values are group means ± SEM.

Table 20 outlines briefly the final results and statistical decisions made for each dependent variable regarding the group (G), time (T) and group X time factors (G XT).

Table 20: Summary of Hypotheses and Results

Hypothesis	Result	P Value	Accept/ Reject Hypothesis
BW: $ART_{diff} = AO_{diff}$	No sig diff. all effects.	G (p=.56) T (p=.09) GT (p=0.7)	Accept Hypothesis
SOS: $ART_{diff} = AO_{diff}$	No sig diff. all effects.	G (p=0.9) T (p=0.3) GT (p=.99)	Accept Hypothesis
LM: $ART_{diff} > AO_{diff}$ DXA	DXA: Sig diff. in G X T AO lost LM and ART groups gained	G (p=0.6) T(p=.24) GT(p<.02)	Accept Hypothesis (G X T) Reject Hypothesis (group & time)
LM: $ART_{diff} > AO_{diff}$ NIR	NIR: no sig diff all effects	G (p=0.6) T (p=.23) GT (p=.08)	Reject Hypothesis
MM: $ART_{diff} > AO_{diff}$	Sig diff. in G X AO lost MM and RT groups gained	G(p=.19) T (p=0.7) GT (p=.001)	Accept Hypothesis (G X T) Reject Hypothesis (group & time)
FM: $ART_{diff} = AO_{diff}$ DXA	DXA: No sig diff. all effects	G (p=0.4) T (p=0.2) GT (p=0.6)	Accept Hypothesis (G X T)
FM: $ART_{diff} = AO_{diff}$ NIR	NIR: No sig diff. all effects	G (p=0.4) T (p=0.6) GT (p=0.5)	Accept Hypothesis (G X T)
WHR $ART_{diff} = AO_{diff}$	Sig. Diff pre- to post training WHR for all subjects.	G (p=0.6) T (p=.002) GT (p=.47)	Accept Hypothesis (time) Reject Hypothesis (group & G X T)
Overall Strength: $ESRT_{diff} > LSRT_{diff} > AO_{diff}$	One Way ANOVA Sig. Diff b/w ART groups and AO. No Sig. diff b/w ART groups.	G (p=.001)	Accept Hypothesis (ART > AO) Reject Hypothesis (ESRT > LSRT)
Upper Body Strength: $ESRT_{diff} > LSRT_{diff} > AO_{diff}$	One Way ANOVA Sig. Diff b/w ART groups and AO. No Sig. diff b/w ART groups	G (p=.009)	Accept Hypothesis (ART > AO) Reject Hypothesis (ESRT > LSRT)
Lower Body Strength: $ESRT_{diff} > LSRT_{diff} > AO_{diff}$	One Way ANOVA Sig. Diff b/w ART groups and AO. No Sig. diff b/w ART groups.	G (p=.004)	Accept Hypothesis (ART > AO) Reject Hypothesis (ESRT > LSRT)

DISCUSSION

Chapter 4

The purpose of this study was to show that RT can be safe and effective as early as 4 weeks post cardiac event and in combination with the regular cardiac rehab programs have a positive effect on body composition (gain LM and lose FM)

Compliance and Dropout

Starting RT as early as 4 weeks post-cardiac event did not appear to have a negative impact on adherence rate or drop-out during the 11 month study. Twenty-seven of the 34 recruited subjects completed the study. This represents an 80% completion rate which is comparable to previous similar studies (McCartney et al., 1995, Daub et. al 1996). All drop-outs were the result of external factors such as business obligations, illness or personal reasons and not due to the research study. However, it should be noted that 6 of the 7 drop-outs occurred before the start of the program, the 7th subject became ill with bronchial pneumonia at the 12th week and had to be dropped. If the 5 pre-start drop-outs are excluded, adherence was extremely high (96%). Attendance was also high (89%). These encouraging statistics suggest that RT started early in the cardiac rehabilitation program is well tolerated and non-detrimental to long term adherence and participation. This result and the fact that their were no injuries or adverse reactions during the study, supports the hypothesis that RT is safe and can begin as early as 4 weeks post-cardiac event in selected cardiac subjects.

Body Weight

Body weight was not expected to change significantly over time. This expectation was based on previous research reporting little to no changes in body weight in similar studies of this duration (Stewart et. al. 1994; Ghilarducci et. al. 1989; Cononie et. al. 1991). In addition, body weight is considered to be a poor indicator for body composition assessment since changes that do occur do not indicate what tissue components are primarily. As anticipated, there was no statistically different changes in weight. The trend although not significant showed a loss of body weight for all groups within the early stages of program (before RT) and then an almost abrupt increase within the first 6 weeks of RT for both RT groups. The ESRT group gained 1.04 kg and the LSRT group gained 1.19 kg while the AO group lost 1kg by the 4th week and gained .6 kg by the end of the study. This pattern, although non-significant ($p>.05$), was helpful to see the changes to LM, FM and MM. When comparing this body weight trend with that of NIR, DXA, and MM methods, we see that the trends are similar (figures 4, 5 & 7). This is encouraging in that it suggests that a difference may exist between training interventions, however statistical significance could not be detected. One such factor may lie in the size of the sample population (AO n= 10, ESRT = 8; LSRT N = 9).

Muscle Mass Changes

The MM data did not show a strong enough difference between groups or between time trials to support the hypothesis that the MM of the ESRT group would show the greatest pre- to post-training increase of the three groups followed by the LSRT and no change in AO. This suggests that 12 weeks of RT training had no significant hypertrophic effect on the muscle. However, the group X time interaction clearly indicated that the AO group was losing MM while the RT groups were gaining MM. The LSRT group surpassed initial MM levels with only 6 weeks of RT. This result is more indicative of other research (Broeder, 1997; Frontera, 1988). The ESRT group showed no pre- to post-training changes to MM, but this statistic was deceiving since, this change only took into account the difference between the first and last measurements, thereby masking MM changes over the RT period alone. From figure 7 it can be seen that the ESRT group's MM dropped 1.4 kg from week 0 to week 4 (not RT yet). The reason for this initial drop is unknown, but after revisiting the data for this group, 3 of the 8 subjects in this group showed strong MM losses of 2.2, 2.1 and 6.3 kg, and with such a small sample size these data may have affected the mean individual change over this time period. The impact of this drop in MM on the ESRT group's pre- and post-training measures was profound. It took 12 weeks of RT for the ESRT group to regain this lost MM and by completion was .01 kg of MM less than initial values. This provokes the question of what the consequences of this initial loss would be on MM if this group had not engaged in RT. Although this is difficult to determine, other research suggests that this loss in MM would not be recovered without some form of resistance overload greater than aerobic exercise can provide (Westcott, 1993). This point is further supported by the AO group's MM data. This group lost a mean of .4 kg (non-significant) from week 4 to the end of the study. The consequences of this loss may or may not have immediate effects on subjects, however, over time and coupled with the negative effects on MM associated with aging and a decline in activity may prove costly in terms of quality of life and functional independence.

This interaction trend showing numerical losses in MM and LM in AO subjects and increases in MM in the RT groups was detected by DXA, NIR and weighing methods employed in this study. This interaction pattern is encouraging and offers compelling evidence supporting the study's hypothesis that RT can improve MM in cardiac subjects early in the cardiac rehabilitation program.

FM

It was hypothesized that no differences in FM would exist between the AO and RT groups. This hypothesis was based on the fact that there is an abundance of conflicting results in the literature regarding FM changes (Fiatarone 1990; Haennel 1989; Sparling 1990) with mild to moderate exercise intensities employed in cardiac rehabilitation programs. Our non-significant changes in FM have supported this hypothesis and have added to the on going research debate. Conflicting results from NIR, DXA and SOS, made it difficult to determine the impact of the training interventions on FM.

All methods used for FM assessments showed insignificant changes suggesting that the total volume of work performed may not have been sufficient to affect FM in these subjects. However, FM changes may also have been affected by subjects' ability to adhere to dietary and lifestyle recommendations. Those subjects who reported adhering to the HHP's recommendations showed DXA FM drops ranging between 1.7 - 7.4 kg. Those who did not adhere showed smaller, if any, FM loss. This observation demonstrates the value and effectiveness a multi-disciplined cardiac rehabilitation program can have on physiological parameters.

SOS

No change in mean SOS scores was anticipated, regardless of grouping. This was based on previous research (Campbell, 1994) reporting a 1.8 kg drop in FM following a rigid 12 week RT study that strictly controlled for diet, but no changes in SOS. Sparling (1990) showed no changes in SOS after a 6-month cardiac circuit weight training program. As anticipated, SOS did not significantly change.

Some researchers (Gettman, 1978; Ghilarducci, 1989; McCartney, 1995) have suggested that insignificant findings in body composition may be due to the fact that most studies performed initial body composition readings approximately 12 weeks after participation in a cardiac rehabilitation program. In this study, body composition measurements were taken from the start, and data showed no significant changes between groups ($p=.9$), between time trials ($p=.3$) or between groups X time ($p= .99$); the late-start theory does not seem likely.

Verrill and Ribisil (1996) suggested that the low total volume of work performed in a standard cardiac rehabilitation program may not cause a high enough caloric expenditure to affect body composition significantly. This may indeed be true as many of the subjects performed aerobic exercise for 30 minutes at an intensity of 5-10 METs. Further, many subjects report an increase in their fear of re-injury and therefore may avoid engaging in certain rigorous daily activities such as housework or laundry. Research by Campbell (1994) showed increases in BMR and daily caloric requirements of 7% and 15%, respectively, including an increase in LM of 1.4 kg and a decrease in FM of 1.8 kg. These subjects performed 3 sets of 8-12 reps of high-intensity RT (80% of 1RM); there was no aerobic exercise (other than for warming-up) and diet was strictly regulated and controlled. These intriguing results may mean that in cardiac rehabilitation programs low volume of training may not be the reason for insignificant changes in body composition, but that poor adherence to dietary guidelines may instead be the major confounding variable.

Individual pre- to post-training SOS scores were quite diverse. Upon further investigation of the overall trend in SOS changes, it was observed that there were no significant differences ($p=.99$) and the pattern of change for all groups was almost identical. Interestingly, between the first 10 weeks, all subjects, when averaged over groups, experienced a drop in SOS of 3.8 mm ± 2.7 (3.4 ± 1.9%). But, all showed small increases in these values over the final 10-16 week period. Reasons for this loss/gain pattern of change are unclear, however, it may be due to several confounding factors by themselves or in combination with others including cessation of smoking during the study, medications, poor adherence to dietary recommendations and/or the Christmas holidays (the study spanned Christmas holidays).

An observation worth noting, is that 17 of the 27 subjects had their exercise programs interrupted by the Christmas holidays, 10 of these 17 subjects gained a total of 113.5 mm in SOS's. This increase was the greatest SOS gain of all the time trials and accounted for 40% of the mean SOS gains. This statistic reflects the strong influence the Christmas holidays and adherence to dietary guidelines had on subjects' mean SOS scores and final results. Although the number of subjects for calculating this statistic was small, it does suggest that the greater the adherence to all modalities of the rehab protocol the greater the changes in body composition.

WHR

The pre- to post-WHR values significantly changed over time for all subjects mean scores ($p<.002$). Since waist girths decreased ($p.<002$), while hip girths and umbilicus skinfolds did not significantly change for all subjects (hip, $p=0.7$; and umbilicus skinfold $p=.99$), the WHR drop suggests a loss in intra-abdominal visceral fat. High levels of visceral fat are associated with increased risk for CAD (ACSM, 1995). The implication of this finding is that cardiac subjects CAD risk level is lowered when participating in a standard CRP. Adding RT early or late in the program does not appear to significantly affect WHR and may not play a primary role on WHR changes.

Strength

Strength increases were predicted to be greatest in the ESRT group, followed by the LSRT with little changes occurring in the AO group.

As predicted, a significant change occurred between the RT groups and the AO group. The ESRT showed the greatest overall pre- to post-training change (27± 4.2%) followed by the LSRT group (25 ± 3.3%) and then the AO group (7.3 ± 2.6%). This finding was expected and in support of other related research (Stewart et al., 1988; Ghilarducci, 1990; McCartney, 1991). There was no significant difference between the two RT groups. The ESRT group was only 2% stronger than the LSRT group who started RT 6 weeks later. The rates of improvement in the initial 6 weeks of RT were similar for both the ESRT and the LSRT. These findings suggest that the majority of increases in strength performance occurred in the legs and within the first 6 weeks and then continued at a more gradual rate. This finding is in line with other research on both normal and cardiac populations of the same age range (Butler et al., 1992; Svedahl et al., 1994). Westcott (1993) demonstrated that over an 8 week period of RT, 76% of all strength gains occur in the first 4 weeks and another 13% in the latter 4 weeks; 80% of these initial increases(first 4 weeks) are due to neurological factors and 20% due to actual physiological adaptations (hypertrophy). Moritiani and deVries (1980) demonstrated that once the initial strength increases of the first 4 weeks occurred, older males (mean = 69 years) then increased strength primarily through neural factors, while younger males (mean = 22 years) increased strength because of hypertrophic changes in muscle. This finding may also be partly responsible for masking body composition changes.

The RT groups showed significant overall upper and lower body pre-to post-training strength increases compared to the AO group; upper body increases were less than lower body increases. The average increases in upper and lower body strength range from 20-50% in healthy populations, 9-227% in older populations and 20-40% in cardiac populations depending on the exercise performed (Verrill and Ribisil, 1996). This study's findings are similar to other research (Stewart et al., 1994; Wilke et al., 1991; Stewart et al., 1988). However, researchers have also demonstrated upper body increases to be greater than lower body increases (Haennel et al., 1991; McCartney et al., 1991; Svedahl et al., 1994). This conflict of upper and lower body increases may be due in part to differences in training protocols, lower absolute starting strengths, exercise sequencing and/or type of exercises selected. Regardless of whether the upper body shows greater or lesser gains than the lower body, the most important fact still remains: strength improves.

Strength increases per exercise, for both groups were statistically significant for the Split Squat, Leg Press, Vertical Bench and Seated Row , but not for the Biceps Arm Curl, Triceps Pushdown and Overhead Shoulder Press. These results indicate that the greatest increases in strength performance are in the exercises that include large muscle groups working together over several joints. The Overhead Shoulder Press although considered a multi-joint exercise, is predominantly using smaller muscle groups (Triceps Brachii and Deltoid) and therefore may explain why it did not show a significant strength increase (Purvis, 1996). This information can be useful to cardiac program administrators and exercise specialists when setting-up or revising their programs; it may prove wise to select RT exercises that require multiple joint involvement and also serve a functional purpose.

Of all the exercises in this study the Split Squat showed the greatest increases, required the most body stabilization, muscle mass and neural synchronization. This exercise can be physically challenging to learn and perform, and requires proper instruction and attention during a lift. However, the benefits of this exercise and other similar ones, in terms of functional application and strength gains, are great.

The inclusion of multi-joint exercises could prove useful to patients in their daily activities (i.e. picking up grandchildren, moving the couch to vacuum around it). Ewart (1989) suggests that this form of exercise also enhances patients' self-perceptions of their ability to perform these daily exercises. This exercise and most other exercises need to be assessed in terms of their potential to aggravate precipitating musculoskeletal conditions or injuries. No negative complications or haemodynamic responses were observed for any of the lifts. The Split Squat however, because of its physiological demand on the body, requires more rest between lifts, greater warm-up sets and constant supervision.

No complications arose from the use of workloads of 70-79% 1RM. The overall strength increases of 25-27% are of the same magnitude to those found in other studies using 40-70% of 1RM (Wilke, 1991; Daub, 1996). Since comfort is compromised (McCartney, 1996) and blood pressure responses increase at higher workloads (Haslam, 1988; Wiecek, 1990), it is considered unnecessary to train at such intense loads. Adequate gains in strength and functional ability are easily achievable at lower intensities (60-70% of 1RM) and with greater comfort.

The use of only 1 workout set was effective in improving overall strength significantly. This finding confirms past research purporting that 1 set workouts (plus a warm-up set), can have significant affects on strength performance in normal, aging, and cardiac populations (Wescott, 1993; Frontera, 1989; Fiatarone, 1990; Verrill and Ribisil, 1996; NSCA, 1995). The implications of these findings are useful for the cardiac population specifically. Accomplishing 2-3 sets of RT, as suggested in most literature, doubles and triples the volume and length of work performed during a single workout. For most cardiac patients this increased volume of work becomes a strong physiological and psychological burden (Ewart, 1989; Milani, 1996). Patients tend to fatigue more easily than the normal population and would benefit from shorter and effective workouts such as 1 set workouts with 50-70% of 1RM.

Summary

The impact of RT exercise early in the standard CRP, on FM, LM, muscle mass and SOS remains inconclusive, however, cardiac patients who stick to all program recommendations demonstrate the greatest changes to FF, FM MM and SOS. Early incorporation of RT in cardiac rehabilitation is safe and appropriate, but does not offer patients a dramatic strength improvement over those patients who start 10 weeks later. This information may be encouraging to specific cardiac patients who, due to the instability of their conditions, may not be able to begin RT early. Also, it may prove helpful to CRP staff when prescribing exercise for these same patients.

Practical Application of This Study

When rehabilitating cardiac patients, RT can be safely performed by selected patients as early as 4 weeks post-cardiac event. Medical screening by a qualified cardiologist and supervision by qualified exercise staff is essential in the early stages to facilitate a faster return to normal daily activities. Although shown to be relatively safe for stable cardiac patients, it is not necessary to RT at intensities of 70-80% of the 1RM, nor is it essential to perform more than 1 workout set (must include a warm-up set) in order to receive significant physiological and psychological benefits. Performing only 1 set and training with workloads of 60-70% of 1RM can be an extremely effective and efficient rehabilitation approach. Monitoring of heart rate and patients' feelings of well-being are encouraged as a means of gaining insight regarding their responses to RT exercise on the day. Incorporating exercises that strengthen patients' functional strength capacities is encouraged; however musculoskeletal limitations need to be taken into account. Increasing workloads should be based on whether patients can complete 1 repetition more than the upper limit (12 reps) for 2 consecutive sessions and should not increase more than 1-5 pounds for the upper body and 5-20 pounds for the lower body for each increase. The patients' inability to perform 8-12 reps comfortably is an indication that the increase was too large or too soon.

Author's Final Thoughts

Initially, my interest in cardiac rehabilitation was sparked by my mother's cardiac condition and her need for rehabilitation; she was the catalyst of my research. It was my goal to investigate ways for optimizing the rehabilitation process; it is my sincere hope that this research and the recommendations put forth in this thesis, may be used by cardiac rehabilitation administrators, case managers, exercise specialists and leaders in their quest to develop their own optimal rehabilitation programs. Happy training!

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Purpose of the Study
I understand that the purpose of this research study is to investigate the changes that resistance training will make to my body composition (fat vs. Muscle) and muscular strength.

I hereby consent to being placed in a rehabilitation program that will include monitoring of my heart, blood pressure, feelings of physical exertion, muscular strength and body composition.

Explanation and Procedures

I understand that I will be randomly selected to participate in 1 of 3 groups which may or may not involve weight training.
Group 1 will perform aerobic exercise only (cycling, waking etc.)
Group 2 will perform both aerobic and weight training exercise (weight training will start **4 weeks** after joining the program)
Group 3 will perform both aerobic and weight training exercise (weight training will start **10 weeks** after joining the program)

I realize that this study will last for 4 months (16 weeks) and I must attend 2 exercise sessions per week at the Healthy Heart Program for the entire 4 month duration. I realize that I can only miss 1 session in a 2 week period for a maximum of 8 missed sessions over the 4 month period. I understand that should this occur, I will be disqualified from the study, HOWEVER, I will continue to receive the Healthy Heart Program's regular medical and rehabilitation services.

I understand that if I am chosen to participate in the weight training group, I will perform both the aerobic and resistance training exercises at each training session and that my total exercise time will be 75 minutes per visit (1hr and 15 minutes). Each exercise session will follow the following format:

Warm-up: 10 minutes (cycling, treadmill etc.)
Aerobic Component: 20 minutes (divided into 2,10 minute sections)
Resistance Training: 20-25 minutes (using machines)
Cool down: 10 minutes stretching and relaxation

I understand that I will be given exact instructions regarding the frequency, intensity, and type of exercise appropriate for me and my physical ability and it is my responsibility to perform the exercises as instructed. I understand that I can not change any part of my program until I have spoken to the medical director, Dr. Ignaszewski or André Noël Potvin. I understand that I will perform aerobic exercise such as treadmill walking, stationary bike riding and arm cranking according to the exercise protocol established by the clinic's trained personnel. I understand that every effort has been made to ensure that the equipment has been tested and is safe and well maintained. I will not be asked to exert myself beyond what I am comfortable doing. I understand that I can not change any part of my program until I have spoken to the medical director, Dr. Ignaszewski or André Noël Potvin.

I understand that I will have my body composition (fat vs. muscle) assessed using a simple skin grasping tool that measures the thickness of my skin at my arm, back, hip, stomach, front thigh and calf. I acknowledge that I have had this technique demonstrated to me beforehand by André Noël Potvin and that I feel comfortable with having it performed on me. I am aware that this test will be performed 4 times over the next 4 months (16 weeks) and will be performed at the 4th, 10th, and 16th week of my joining the Healthy Heart Program.

I understand that I will have my muscular strength and endurance assessed 4 times over the next 4 months (16 weeks) using the clinic's weight training equipment. These resistance exercises and tests will be performed at the 4th, 10th, and 16th week of my joining the Healthy Heart Program and will measure my strength performance. I have been assured that the clinic's weight training program is safe for my cardiac condition and will improve my physical strength so that I may perform my daily activities with less risk of injury. I understand that every effort has been made to ensure that the equipment has been tested and is safe and well maintained. I am aware that I will be asked to lift a weight until I wish to stop and that it is considered safe and well within my physical ability. I will not be asked to exert myself beyond what I am

Letter To The Subject Explaining The Study

[St. Pauls Hospital Letterheaed)

The Effects Of Resistance Training During Early Cardiac Rehabilitation (Phase II) On Muscular Strength And Body Composition

What?
The Healthy Heart Clinic and the University of British Columbia are conducting a 4 month (16 weeks) research study. We want to look at better, more effective ways of rehabilitating the cardiac patient. This study will focus on improving your physical ability to perform work and daily living activities. It will also help you to reduce your body fat , improve your muscular strength and increase your self-confidence.

How do you fit in?
We are looking for patients who are interested in learning how to lose body fat and improve muscular strength. You will be randomly selected to participate in 1 of 3 groups.

When?
You will be contacted within 1 week of receiving this letter by André Noël Potvin to discuss the study in more detail. The study will run from Monday, July 1, 1996 to Friday, February, 28 1997. Your participation in the study will last only 4 months. It will involve approximately 1.5 hours/day, 2 x/week.

What does it involve?
While you are participating in the Healthy Heart Clinic's exercise program for your heart, you will also have your body fat and muscular strength measured. This will happen every 4-8 weeks. The tests are very simple and painless. You will meet with André Noël Potvin and he will show you exactly what the tests are all about.

What are the risks?
As with any exercise there is always an inherent risk. There is a possibility that you may experience some adverse changes in blood pressure, heart rhythm and state of well-being, including the very rare possibility of a heart attack, stroke or even death. However, these risks are very unlikely (0-1% chance of this happening). **To date, no one has died or suffered a heart attack/stroke due this type of research.** It is considered safe and is well supervised to ensure your safety and comfort. In addition, you can withdraw from the study at any time without any consequence to present and future medical care.

How does it benefit you?
Many participants in past research have shown and reported improvements in their physical ability to perform work and home activities, increased self-confidence, loss of body fat and improved strength. They have said they felt better and more confident about returning to their normal daily activities. Many have enjoyed learning how to exercise properly and have continued to exercise.

Confidentiality
All information obtained during the study will be treated as privileged and confidential and you will not be identified by your name or initials.

For more information, contact the medical director, Dr. Ignaszewski, or the head researcher, André Noël Potvin. You can also leave your name, phone number and best time to call with reception and André will contact you.

Overview of Study

Weeks 1 and 2

- Clinic assesses and screens patient
- Patient asked to participate in study (by medical director)
- Informed consent signed and returned (first 2 weeks)
- Body composition assessment 1 (within first 2 weeks)
- Start Healthy Heart Program

Week 3

- Patient re-assessed for eligibility into study
- Subject selected and assigned to a group
- Orientation to equipment and training protocol

Week 4

- Body composition assessment 2
- Muscular Strength and Endurance measured
- Peak aerobic capacity recorded (from clinic's record)

Week 10

- Body composition assessment 3
- Re-test muscular strength and endurance
- Peak aerobic capacity recorded (from clinic's record)

Week 26

- Body composition assessment 4
- Re-test muscular strength and endurance
- Peak aerobic capacity recorded

You will have your body composition and muscular strength tested as shown below:

0 Wk	4th Week	10th Week	16th Week
I________________	I______________	I______________	I
Assessment 1	Assessment 2	Assessment 3	Assessment 4

Schedule of Training Sessions (Monday and Wednesday OR Tuesday and Thursday)

Time	Mon	Tues	Wed	Thurs
6:45 am	Arrive and Set-up	Arrive and Set-up	Arrive and Set-up	Arrive and Set-up
7:00 am	Warm-up (10 min) 20 minutes of Aerobic Training	Warm-up (10 min) 20 minutes of Aerobic Training	Warm-up (10 min) 20 minutes of Aerobic Training	Warm-up (10 min) 20 minutes of Aerobic Training
7:30	Weight Training (20-25 minutes)	Weight Training (20-25 minutes)	Weight Training (20-25 minutes)	Weight Training (20-25 minutes)
8:00 am	Weights Finished	Weights Finished	Weights Finished	Weights Finished
8-8:15	Stretching	Stretching	Stretching	Stretching
5:15 PM		Arrive and Set-up		Arrive and Set-up
5:30		Warm-up (10 min) 20 minutes of Aerobic Training	Warm-up (10 min) 20 minutes of Aerobic Training	Warm-up (10 min) 20 minutes of Aerobic Training
6:00 PM		Weight Training (20-25 minutes)	Weight Training (20-25 minutes)	Weight Training (20-25 minutes)
6:30 PM		Weights Finished	Weights Finished	Weights Finished
6:30-6:45 PM		Stretching (André)		Stretching (André)

Subjects Information Form

Name/address	Phone	Age	Cond/date	Sed	Ht/Wt/BMI	BP/ HTN	Strs	Appointmnts	Medications	Doctors	Phone/Fax
					Ht/Wt /			Talk			
					Var /			BC			
					BMI			Start			
Comments:											
					Ht/Wt /			Talk			
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					BMI			Start			
Comments											

Schedule Of Testing Dates: Thursday, June 19, 1997

(modified to fit this paper)

Subject #	Start Date	BC Ass 1	Wt Tr Practice 1 & 2	Wt Tr Test 1	BC Ass 2	Wt Tr Practice 3 & 4	Wt Tr Test 2	BC Ass 3	Wt Tr Practice 5 & 6	Wt Tr Test 3	BC Ass 4	Dcharge From HHP
1 AO	Oct 2	Oct 7 & 9	Oct 23,28	Oct 30,	Nov 1	Dec 11	Dec 18	Dec 13	Jan 29,3	Feb 5	Feb 7	Feb 19
						& 16						
2 ESRT	July 24	July 12	Aug 7,12	Aug 14	Aug 12	N/A	Oct 30	Oct 25	N/A	Dec18	Nov 20	Nov 20
		DXA										
3 LSRT	Aug 7	Aug 7	Aug 26,28	Sept 4	Sept 4	Oct 23, 28	Oct 30	Oct 25	N/A	Dec 9	Dec 11	Dec 11
4 AO	Aug 21	Aug 26	Sept 9, 11	Sept 18	Sept 20	Oct 30	Nov 6	Nov 1	Dec 11,16	Dec 18	Dec 18	Dec 11
						Nov 4						
5 ESRT	Aug 21	Aug 26	Sept 9,11	Sept 18	Sept 20	N/A	Nov 6	Nov 6	Nov 1	Dec 11	Dec 12	Dec 12
6 LSRT	Oct 9	Oct 11	Oct 30	Nov 6	Nov 8	Dec 11,16	Dec 18	Dec 13	N/A	Jan 29	Jan 31	Feb 17
			Nov 4									
7 AO	Sept 18	Sept 26	Oct 16,21	Oct 23	Oct 25	Nov 27	Dec 4	Nov 29	Jan 15,20	Jan 22	Jan 17	Jan 26
						Dec 2						
8 ESRT	Oct 8	Sept 26	Oct 24,29	Oct 31	Nov 1	N/A	Dec 12	Dec 13	N/A	Jan 30	Jan 31	Feb 6
Subjects 9-28 not shown												

Attendance Form
(modified for this paper; not all sessions are shown)

S	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22			32
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Completion Package
(Modified for this paper)

[St. Paul's Hospital Logo]

Dear ******, below is a report on the final results of your tests.

Patient: ***** **Age: 53**

Body Composition		**Pre**	**Post**	**Diff (lbs)**	**%**
Body Weight (lbs)		231	220	-11	-4.76
Fat Mass		65.85	49.61	-16.24	-24.66
Lean mass	155.7	163.73	8.03	5.16	
% Fat		28.7	22.5	-6.2	-21.60

Strength Test (Maximum Weight Lifted)	**Pre**	**Post**	**Diff (lbs)**	**%**
Weeks Wt. Training	0	12		
Vertical Bench	170	245	75	44.12
Single Leg Squat	50	183	133	266.00
Seated Row	166	210	44	26.51
Leg Press	466	747	281	60.30
Shoulder Press	144	179	35	24.31
Biceps Curl	33	39	6	18.18
Triceps Pushdowns	82	111	29	35.37

Attendance	**Max**	**Actual**	**Compliance %**
Aerobic	32	31	96.88
Weights	24	23	95.83

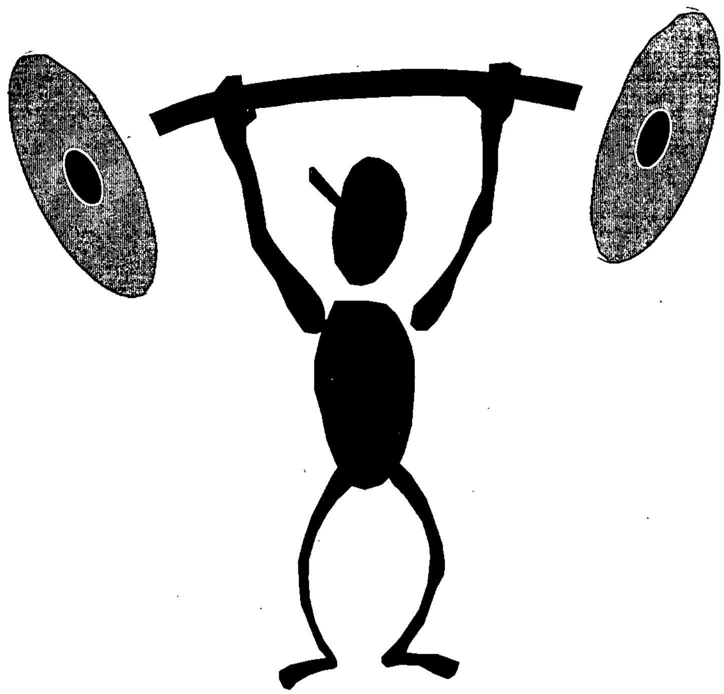
Additional Information	
Diet	Adhered to diet advice; consistent (Self-reported)

I want to thank you again for all your hard work and support during my study. I hope that you have found this as much of a religious religious experience as I have. Seriously, good luck with your new health and fitness lifestyle.

Cheers

André Noël Potvin
Study Investigator

Congratulations José!



You are a Healthy Heart Superstar

This certificate is to commemorate NAME for his outstanding performance and commitment to himself and his dream.

Letter To Doctor Explaining Patients Results

To:________________________________

Phone: ________________ Fax: ____________________

From: Dr. Andrew Ignaszewski, Medical Director and
André Noël Potvin, M.Sc. research student
Healthy Heart Program (HHP) St. Paul's Hospital

Re: Patient participation in our research study "Effects of Resistance Training During Early Cardiac Rehabilitation on Strength and Body Composition."

Enclosed are the results of your patient ________________________________ in our 4 month research study here at the HHP.

Thank you once again for your support and encouraging ______________________ to participate in our study.

Should you have any questions or concerns regarding the study or your patient's well-being, please feel free to contact either Dr. Andrew Ignaszewski or myself, André Noël Potvin, at the numbers listed below.

Sincerely,

André Noël Potvin

M Sc. Research Student

Healthy Heart Program

Dr. Andrew Ignaszewski

Medical Director

Healthy Heart Program

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