

**THE EFFECT OF PROGRESSIVE RESISTANCE TRAINING ON THE
BLOOD LIPID PROFILE IN POST-MENOPAUSAL WOMEN**

BY

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THESIS

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ABSTRACT

The main purpose of this study was to assess the effect of progressive resistance training on the blood lipid profile in post-menopausal women. Thirty-four female subjects aged 50 to 75 years were selected from the population of Grahamstown, South Africa. All participants were previously sedentary and possessed at least one lipid profile abnormality but were otherwise healthy. Pre-tests included a sub-maximal stress Electrocardiogram, measures of stature, mass, central and limb girths as well as an oral glucose tolerance test (OGTT) and a total blood lipid profile. Participants took part in a 24-week progressive resistance training programme, consisting of three supervised sessions per week, each lasting 45 minutes and were not permitted to lose more than 10% of initial body mass during the 24-week study. All pre-test measures, excluding the stress ECG and the OGTT, were repeated every four weeks for the duration of the study. Results were that body mass, body mass index and waist-to-hip ratio did not change. Girth measures at mid-humerus, chest, waist, hip, mid-quadriiceps and mid-gastrocnemius all decreased significantly ($p=0.05$). LDL-cholesterol increased significantly over the course of 24 weeks (3.61mmol.L^{-1} to 4.07mmol.L^{-1}) as did total cholesterol (5.81mmol.L^{-1} to 6.24mmol.L^{-1}). Triglyceride concentration remained unchanged and HDL-cholesterol decreased significantly between the pre-test measure (1.55mmol.L^{-1}) and the measure after six months (1.42mmol.L^{-1}). It can be concluded that the blood lipid profile in a sample of post-menopausal women was not positively affected by a progressive resistance training programme over a 24 week period.

This research is dedicated to

GLADYS LILIAN PRINGLE

14.12.1910 – 12.11.2008

In admiration of her strength and in deep gratitude for her influence in my life.

If in my life I can be half the woman my Gran has been, I will have succeeded.

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CHAPTER I

INTRODUCTION

Morbidity and mortality related to sedentary living remain at increasingly high levels worldwide (Chakravarthy and Booth, 2004). Of particular relevance is cardiovascular heart disease (CHD) which is closely linked to risk factors such as obesity, insulin resistance, high blood pressure and abnormal blood lipid profiles. Due to the “hidden” nature of abnormal lipid profiles, hypercholesterolaemia is referred to as the “silent killer” as individuals frequently overlook the need to have regular cholesterol tests. Poor diet and insufficient activity exacerbate the expression of hypercholesterolaemia, which quickly results in atherosclerotic conditions (Poli *et al.*, 2008).

CHD is a risk for both men and women, from a relatively young age right through the age spectrum. Traditionally women have been thought to be exempt from CHD, especially pre-menopause (Skouby, 2004). Now it is understood that the risk of developing CHD increases exponentially post-menopause, and that it is vital for a woman’s cholesterol levels to be closely monitored (Jensen, 1992).

Despite education programmes about the dangers of hypercholesterolaemia it remains a burgeoning problem and while prevention of chronic disease is ideal management is also important. Drug intervention, such as prescription of cholesterol-lowering drugs (of which the ‘statins’ are the most common), can have unpleasant side-effects and does not necessarily improve the individual’s lifestyle. It is important to establish the effect of lifestyle alterations on improving health status in these individuals. Of these interventions, diet and exercise are the most common. Diet

has been conclusively shown to positively affect cholesterol levels and is effective in preventing hypercholesterolaemia as well as managing dyslipidaemia (Ntanios **et al.**, 2002; Weidner **et al.**, 2008). The effect of exercise on the plasma lipoproteins is less clear (Halverstadt **et al.**, 2006; Trejo-Guiterrez **et al.**, 2007). Aerobic endurance exercise has been reported as an effective means of reducing atherogenic lipid levels by some researchers (King **et al.**, 1995; Kokkinos **et al.**, 1995; Spate-Douglas and Keyser, 1999) but while this evidence exists there remains controversy as there is counter-evidence which calls the efficacy of aerobic endurance training into question (Williams, 1996; Williams 1998). Resistance training has received less attention than aerobic endurance training to date and is inconclusively effective in ameliorating high plasma lipoprotein levels (Trejo-Guiterrez **et al.**, 2007). Maesta **et al.** (2006) found that resistance training was effective in lowering lipid concentrations, however Thompson **et al.** (2007) report less clarity on the efficacy of resistance training in reducing cholesterol levels.

Therefore this study investigated the effect of a specific regimen of exercise (resistance training) on the blood lipid profile of previously sedentary, post-menopausal women with no manipulation to any other lifestyle parameters.

STATEMENT OF THE PROBLEM

The impact of a progressive resistance training programme on the blood lipid profiles of post-menopausal women has not been well established. Therefore the primary problem addressed by this research was to determine the effect of a progressive resistance training programme on the blood lipid profile of a sample of previously sedentary, post-menopausal women over a period of 24 weeks (6 months).

RESEARCH HYPOTHESIS

It is expected that the blood lipid parameters (total cholesterol, LDL-cholesterol, HDL-cholesterol and Triglycerides) will change over time (24 weeks) as a result of the implementation of a progressive resistance training programme.

STATISTICAL HYPOTHESES

1. The first null hypothesis proposed is that LDL-cholesterol will remain unchanged over time.

$$H_0: \mu LDL_{PRE} = \mu LDL_1 = \mu LDL_2 = \mu LDL_3 = \mu LDL_4 = \mu LDL_5 = \mu LDL_6$$

$$H_a: \mu LDL_{PRE} \neq \mu LDL_1 \neq \mu LDL_2 \neq \mu LDL_3 \neq \mu LDL_4 \neq \mu LDL_5 \neq \mu LDL_6$$

2. The second null hypothesis states that HDL-cholesterol will remain unchanged over time.

$$H_0: \mu HDL_{PRE} = \mu HDL_1 = \mu HDL_2 = \mu HDL_3 = \mu HDL_4 = \mu HDL_5 = \mu HDL_6$$

$$H_a: \mu HDL_{PRE} \neq \mu HDL_1 \neq \mu HDL_2 \neq \mu HDL_3 \neq \mu HDL_4 \neq \mu HDL_5 \neq \mu HDL_6$$

3. The third null hypothesis proposed is that triglyceride levels will remain unchanged over time.

$$H_0: \mu TG_{PRE} = \mu TG_1 = \mu TG_2 = \mu TG_3 = \mu TG_4 = \mu TG_5 = \mu TG_6$$

$$H_a: \mu TG_{PRE} \neq \mu TG_1 \neq \mu TG_2 \neq \mu TG_3 \neq \mu TG_4 \neq \mu TG_5 \neq \mu TG_6$$

4. The final null hypothesis states that total cholesterol will remain unchanged over time.

$$H_0: \mu TC_{PRE} = \mu TC_1 = \mu TC_2 = \mu TC_3 = \mu TC_4 = \mu TC_5 = \mu TC_6$$

$$H_a: \mu TC_{PRE} \neq \mu TC_1 \neq \mu TC_2 \neq \mu TC_3 \neq \mu TC_4 \neq \mu TC_5 \neq \mu TC_6$$

Where:

- LDL = low density lipoprotein

- HDL = high density lipoprotein
- TG = triglycerides
- TC = total cholesterol
- PRE = pre-test measurement
- 1;2;3...6 = time in months

DELIMITATIONS OF THE STUDY

In order to ensure that the results obtained through this study were as reliable and valid as possible, all extraneous influences had to be carefully controlled. Selection of the subjects was the first consideration. In order to reduce the effects of other diseases on the lipid profile, all subjects were required to be healthy, apart from one or more lipid abnormality. The steroid hormone, oestrogen, has an important cholesterol-lowering function and thus all the women selected were post-menopausal. It was important to separate those subjects who were taking prescribed hormone replacement therapy (HRT) from those who were not, due to the continuing effects of synthetic oestrogen on the lipid profile. As smoking can adversely affect the lipid profile subjects were required to be non-smokers. Chronic medication was declared by subjects so that the researcher could determine if any of the medication taken regularly could have secondary effects on the cholesterol levels of the individual. No subject taking prescribed lipid-lowering medication was permitted to take part in the study.

This study focused on the effects of resistance training alone and thus effects of diet had to be limited. Subjects were not required to adhere to a specific diet and due to the “real” nature of the study, it was unrealistic to expect the subjects to eat specially prepared meals at the laboratory. Thus the subjects were required to adhere to their habitual diets and were instructed not to make any big changes or to restrict caloric

intake in any way. This was indirectly controlled by ensuring that subjects retained in the sample did not lose more than 10% of initial body mass. This stipulation also removed the significant effect of weight loss alone on the lipid profile.

As the study was designed as a longitudinal study, all subjects were required to commit to the 24 week programme. The importance of compliance was explained in detail to the potential subjects prior to accepting them onto the programme. In addition, subjects were required to be sedentary¹ prior to commencing the resistance training programme, so that conclusions could be drawn regarding chronology of results. Following a full physical exam by a Specialist Physician all the women who commenced the study were declared musculo-skeletally healthy to undertake exercise training. Cardiac health was evaluated, not only as a delimitation but also as a safety precaution, via a submaximal cardiac electrocardiogram (ECG) exam in the presence of the attending Specialist Physician to the research. Subjects were required to continue habitual lifestyle activity and diet. This was discussed at length in preliminary information meetings with prospective participants.

Measurements were taken prior to commencing the exercise programme and every 4 weeks thereafter. These included a full fasting blood lipid profile analysis from a local pathology laboratory, body mass, and selected girth measures (mid-humerus, (over-bust) chest, waist, hip, mid-quadricep and mid-gastrocnemius).

LIMITATIONS OF THE STUDY

¹ 'Sedentarism' is defined by the American College of Sports Medicine (ACSM, 1986) Guidelines for Exercise Testing and Prescription as activity of a duration equal to or less than 30 minutes of brisk walking three days per week

As this research was not in a controlled laboratory setting, and owing to its longitudinal nature, it was inevitable that there would be certain parameters which could have affected the outcome.

There was no control group for this study. As a consequence the results could not be compared to age- and sex-matched individuals which presents a limitation in the extent to which the results could be interpreted.

No control could be exercised over actual motivation of the participants and thus, compliance could be monitored but not controlled. Attendance registers as well as regular feedback and external motivation ensured that compliance was high, but not all participants fulfilled minimum attendance requirements.

As participants continued leading their habitual lifestyles no control could be executed over whether the individuals took vacation time during the 24-week period of the study. Certain subjects did have prior commitments which took them away for periods of two to three weeks which could have affected the results. However, as mentioned in (ii) above, compliance was high, with 87% of the sample attending 80% or more of the sessions.^{iv}The study commenced in January, and continued until the first week of August. Thus, it spanned three seasons – summer, autumn and winter. The effect of the seasonal changes on individual motivation, dietary habits and biorhythms could not be adequately controlled. Compliance was lowest during the months of March and April. It was clear that the winter months brought a decrease in internal individual motivation, and the researcher relied more heavily on external motivators to keep the momentum of the study going. Associated with the seasonal changes in climate and temperature were increased levels of illness, such as the common cold, influenza and bronchitis. It is not safe for any individual to continue

training when the chest is infected, and thus the primary researcher had to advise certain participants at various times to take time off until pronounced healthy by a General Practitioner (GP). This resulted in occasional breaks of one to two weeks by a small number of the subjects, but was an eventuality that could not have been foreseen. The design of the resistance training programme was very generic and in order to standardize it as far as possible it contained primarily machine-based weight training exercises that could be controlled by measuring the 1-repetition maximum (1RM). Progression by means of increased weight was structured into the programme but there remained very little room for creative changes to the routine and boredom could have resulted from this, as could a plateau in the physiological and physical adaptations to the training programme. Measurements were taken every four weeks during the study, a total of seven times (pre-test and following each of six months thereafter). It was not possible to measure the individuals in exactly the same situation each time, and thus body mass and girth measurements could have been affected by time of day (morning versus late afternoon, for example), whether food and drink had been consumed prior to measurements or not and water content or retention levels. Each candidate was measured during the exercise session period and thus the time of day for each measurement remained constant. The skinfold caliper method of assessing fat mass content was not used as it is not only invasive but can be inaccurate when attempting to measure overweight or obese subjects.

Although the study design stipulated post-menopausal women there were two perimenopausal subjects included in the sample. The results obtained from these subjects did not display different trends from the results obtained from the post-menopausal counterparts, and thus these subjects were included in the final analyses.

CHAPTER II

REVIEW OF RELATED LITERATURE: HYPERCHOLESTEROLAEMIA

HYPERCHOLESTEROLAEMIA

Cholesterol is a natural component of the lipids in the bloodstream and of all the cells of the body (Tortora and Grabowski, 1996). Lipids are hydrophobic in nature and in order to be transported in the blood are combined with apolipoproteins and 'Lipoproteins' are the resulting molecules. Three classes of lipoproteins exist: low density lipoproteins (LDL), high density lipoproteins (HDL) and very low density lipoproteins (VLDL) and all three classes fulfil the same basic function, which is the transportation of lipids in the bloodstream (Tortora and Grabowski, 1996). Cholesterol is manufactured in the liver and is also ingested as a dietary component. It is an essential part of a healthy body as it is required for building plasma membranes and it is a precursor to the formation of vitamin D. It is also a primary component in steroid hormones (adrenal gland hormones, oestrogen, androgen and progesterone) and bile salts (McArdle **et al.**, 1996; Tortora and Grabowski, 1996).

However, high levels of cholesterol in the blood known as hypercholesterolaemia, increase an individual's risk of cardiovascular disease which can lead to aneurysms or myocardial infarction (McArdle **et al.**, 1996). It is noted that the relationship between serum cholesterol and mortality related to coronary heart disease (CHD) is continuous and graded – therefore any reduction in dangerously high cholesterol levels offers protection to the individual (McArdle **et al.**, 1996). Presence of excess cholesterol in the bloodstream may encourage a degenerative process characterized by the formation of "plaque" deposits on the interior arterial walls (McArdle **et al.**,

1996). Narrowing, and eventual closure of the arteries due to this process, termed 'atherosclerosis', can result which may eventually obstruct or even block the flow of blood to the brain, heart and other organs (McArdle **et al.**, 1996). Hypercholesterolaemia is a global problem and McRae (2008) cites that the American Heart Association estimates that 36.6million Americans have total cholesterol in excess of 6 millimoles per litre (mmol.L^{-1}) (240milligrams per deciliter (mg.dL^{-1})). In addition, increasing prevalence of hypercholesterolaemia is being seen in all sectors of the South African population (Tibazrwa **et al.**, 2008). While genetic predisposition may be a factor for some people, increasingly sedentary lifestyles combined with diets high in saturated fats appear to be the main contributors to this condition (Haskell 2003; Tibazrwa **et al.**, 2008). Increasing daily levels of activity and improving dietary intake may be two means of counteracting the negative effects of the modern lifestyle.²

The normal range for total blood cholesterol is between 3 and 5 mmol.L^{-1} (140 and 200 mg.dL^{-1}) of blood. Levels between 5 and 6 mmol.L^{-1} (200 and 240 mg.dL^{-1}) indicate moderate risk, and levels surpassing 6 mmol.L^{-1} (240 mg.dL^{-1}) indicate high risk. While total cholesterol level is important, it is not the best indicator of risk (Windler, 2005). HDL is generally considered to be "good" cholesterol, as its primary role is the removal of fats from the blood, while LDL is considered "bad" as it is associated with deposition of fats in the blood vessels, and hence atherosclerosis. Triglycerides are a third type of fatty material found in the blood and while the role of these molecules in heart disease is not entirely clear, it appears that there is a relationship between triglyceride levels and levels of HDL. As triglyceride levels rise,

² Progressive Resistance Training is defined as the voluntary activation of skeletal muscle against an external force. It is this mode of activity that was selected for this research.

levels of "good" (HDL) cholesterol fall (Jeppeson, 2003). The complex interaction of these three components of the blood lipid profile defines and determines the presence of hypercholesterolaemia. Hypercholesterolaemia is characterized by elevated levels of LDL cholesterol, normal or low levels of HDL cholesterol and normal or elevated levels of triglycerides. It is well accepted that an assessment of risk related to cholesterol levels must include analysis of the full lipid profile and that it is insufficient to make reference only to total cholesterol level (Jeppeson, 2003; St Pierre **et al.**, 2004; Windler, 2005). McRae (2008) emphasizes that it is the ratio between LDL-C and HDL-C that remains the best predictor of cardiac disease.

LOW DENSITY LIPOPROTEIN

Low density lipoprotein (LDL) cholesterol makes up 60-70% of total cholesterol in the body and is the lipoprotein primarily involved in atherogenesis (Kanat **et al.**, 2007). It is also the primary lipoprotein used for synthesis of adrenal and non-adrenal steroid hormones, glucocorticoids and mineralocorticoids in the body (Kanat **et al.**, 2007). Current trends accept LDL-C levels at 2 mmol.L^{-1} (100mg.dl^{-1}) as 'safe' but new medical research suggests that levels of 1.5 mmol.L^{-1} (70mg.dl^{-1}) should be reached for individuals at high cardiac risk to be considered safe from potential cardiac events (Kanat **et al.**, 2007). Physiological needs are met if LDL-C falls between 0.5 and 1.5 mmol.L^{-1} (25 and 60mg.dl^{-1}) (Kanat **et al.**, 2007).

The LDL-C value remains the focus of lipid-lowering therapy as it is highly associated with increased cardiovascular mortality (Sniderman, 2008). A little known fact about LDL-C is that the value obtained via laboratory tests may differ

substantially from the value obtained via ultracentrifugation (Sniderman, 2008). LDL-C particles may differ dramatically in the amount of cholesterol they contain, and even the most reliable LDL-C values may in fact underestimate actual clinical cardiovascular risk (Sniderman, 2008). Specialised centrifugal techniques are not widely available and carry high cost implications, and thus for the purposes of this study, laboratory testing was the most reliable indicator of plasma lipid levels.

HIGH DENSITY LIPOPROTEIN

High density lipoprotein (HDL) cholesterol particles are complex and contain almost equal volumes of protein (apolipoproteins) and lipids, and may be an undervalued lipid profile element (Szapary and Radar, 2001). HDL-C is a dynamic molecule, responsible for the reverse cholesterol transport system and also, for improved endothelial function. It has an anti-thrombotic role and possesses anti-inflammatory and anti-oxidant properties (Link **et al.**, 2007). HDL-C is an independent risk factor for coronary heart disease (CHD) (Link **et al.**, 2007) and may prove a more potent predictor than LDL-C, TG or total lipid profile in CHD. Link **et al.** (2007) report that an 8% increase in HDL correlates to a 24% reduction in CHD risk. Lipid-lowering medication such as statins reduce CHD mortality by 25-40% (Link **et al.**, 2007) but the prevalence of CHD has not decreased, and thus more attention needs to be paid to HDL-C.

The metabolic pathways for triglycerides and HDL-C are closely linked, and thus it is usual to find that high HDL-C levels are associated with low TG levels and vice versa (Szapary and Radar, 2001). Instances where this does not necessarily hold true are

in individuals who regularly drink alcohol, and in women who take oral oestrogen supplementation (Szapary and Radar, 2001). In these instances, raised HDL-C levels are accompanied by increased TG levels.

Non-pharmacologic interventions such as weight control, a correct diet as well as regular exercise can raise HDL-C by 10-15% (Link **et al.**, 2007). Smoking decreases HDL-C concentration, whereas moderate consumption of alcohol increases levels of HDL-C (Link **et al.**, 2007). Notably, women are more affected by smoking than men, and HDL-C in female smokers is lower than that in male smokers.

TRIGLYCERIDES

Triglycerides are a simple form of lipids constituting 95% of body fat. Triglycerides consist of two clusters of atoms: one “glycerol” which is a 3-carbon molecule which is not actually a lipid as it is water soluble, and attached to the glycerol molecule are three clusters of carbon-chained atoms called “fatty acids” (McArdle **et al.**, 1996). This ‘1 glycerol + 3 fatty acids’ molecule (a triglyceride) constitutes a major form of storage lipid in the adipose (fatty) tissue in the body (McArdle **et al.**, 1996). Triglyceride levels exceeding 2.26mmol.L^{-1} are considered ‘hypertriglyceridaemic’ (Eberly **et al.**, 2003).

Elevated non-fasting levels of triglycerides are reflective of remnant lipoproteins and are associated with a high risk for atherosclerosis (Freiberg **et al.**, 2007; Nordestgaard **et al.**, 2007). Eberly **et al.** (2003) undertook research on a cohort of men with mean fasting triglyceride level of 2.11mmol.L^{-1} and a non-fasting level of 3.21mmol.L^{-1} and found that increased levels of both fasting and non-fasting

triglycerides reflected increased risk for cardiovascular incidents. Bansal **et al.** (2007) concurred with this finding, and concluded that non-fasting triglyceride levels were associated with cardiovascular events independent of other traditional cardiac risk factors, other lipid levels or markers of insulin resistance. Mazza **et al.** (2005) found that triglycerides were a predictor of cardiovascular heart disease in elderly women, and that elevated triglyceride levels in conjunction with lowered levels of HDL cholesterol quadrupled this risk.

PREVALENCE

Tolonen **et al.** (2005) collated data from 32 countries on three continents, gathered over a period of nine years (1989 – 1997) on populations aged 35-64years. Prevalence of hypercholesterolaemia (defined as total cholesterol $\geq 6.5 \text{ mmol.l}^{-1}$ or prescription of lipid-lowering drugs) was an average of 25% amongst female respondents (Tolonen **et al.**, 2005). There appeared to be no geographical pattern related to prevalence of hypercholesterolaemia. Men appear to be at a higher risk of hypercholesterolaemia until women reach menopause, at which stage the risk rises exponentially in the female population.³

The South African Demographic and Health Survey (SADHS) (2003) report that the prevalence of self-reported hypercholesterolaemia in 1998 was 1.8% (men) and 1.3% (women). By 2003 these figures had risen to 2% (men) and 2.2% (women) which reflects faster growth in the occurrence of hypercholesterolaemia in women than in men in South Africa over the course of five years. The estimated total

³ Menopause is the cessation of ovarian function which is characterized by a decrease in circulating levels of oestrogen. Oestrogen is a female, sex-specific hormone associated with a protective function with regard to cardiovascular heart disease.

number of South Africans living with hypercholesterolaemia is 5.7 million and lipid-lowering drugs accounted for 5% of chronic medication use in 1998 and in 2003 (SADHS, 2003).

High cholesterol was most prevalent in men aged between 45 and 54 years (6.9%) compared to a prevalence of 1.8% for men aged 55 to 64 years. In contrast, 3.6% of South African women aged 45 to 54 years reported high cholesterol compared to a far greater prevalence (4.9%) in the older age group (55 – 64 years of age) (SADHS, 2003). The frequency of hypercholesterolaemia in pre-menopausal women was 1.3% (incorporating women aged 15 to 44 years) and in post-menopausal women this frequency rose by 2.7% to 4% for women aged 45 years and older (SADHS, 2003).

The current study was undertaken in the Eastern Cape Province and 91% of the sample were urban dwelling, Caucasian women with at least a high-school education. In 2003 2.6% of urban dwelling women reported high cholesterol levels, 0.2% fewer than urban dwelling men. Women with at least a Grade 8 level of education had lower incidences of hypercholesterolaemia (2.4%) as opposed to women who had no education (2.5%). This was not the case for the men as educated men reported a 1.6% higher prevalence of high cholesterol compared to those who had received no education (SADHS, 2003).

Caucasian men and women reportedly have the highest prevalence of hypercholesterolaemia in South Africa (10.1% for men and 7.8% for women). The SADHS (2003) reported that white men have a 1.7% greater prevalence than Indian men, and a 5.4% greater occurrence of dyslipidaemia than coloured men. Similarly levels of high cholesterol in white women are 0.7% higher than Indian women and

5% higher than coloured women. In the Eastern Cape, in 2003, 2.3% of men reportedly had hypercholesterolaemia and 2.1% of women had been similarly diagnosed (SADHS, 2003). The population group least at risk for hypercholesterolaemia is the black population.

CAUSES AND RISK FACTORS

Causes of elevated cholesterol levels fall into two categories: those that the individual does not have control over (genetic and disease factors) and those over which the individual does have control – often referred to as “lifestyle” factors. Medical conditions which are associated with high cholesterol levels include hypothyroidism, diabetes mellitus, and polycystic ovary syndrome. Certain medications may also contribute to increased risk of elevated blood lipid profile (McArdle **et al.**, 1996).

Age, sex, and hereditary factors are largely cited as “uncontrollable” causes of high cholesterol. Increasing age, particularly in women, is associated with elevated cholesterol levels (Skouby, 2004). Under the age of 55 years men are at highest risk of developing high cholesterol, but over the age of 55 years women are at an equal risk, particularly if post-menopausal. Until the onset of menopause, the presence of the sex-based hormone oestrogen serves to protect women against high blood lipid levels but post-menopause the risk of high cholesterol exponentially increases (Skouby, 2004). Genetic predisposition towards a high cholesterol level is a strong indicator of the presence of elevated blood lipid levels in either sex (Lee, 2002).

Factors which are associated with lifestyle habits and thus within the individual's control include body mass, diet, alcohol consumption, smoking and exposure to stress. Overweight or obese individuals are predisposed to higher levels of blood lipids, particularly LDL and triglyceride components. Reduction in body weight alone is known to reduce the dangerous levels of LDL and increase the HDL component (Martini **et al.**, 2008; Volek **et al.**, 2008). Poor nutrition is a key cause of high cholesterol and, as the liver manufactures all the cholesterol the body needs, any cholesterol ingested is unnecessary (McArdle **et al.**, 1996). Poli **et al.** (2008) recommend that exogenous cholesterol intake should not exceed $300\text{mg}\cdot\text{day}^{-1}$ in the general population and $200\text{mg}\cdot\text{day}^{-1}$ in individuals with hypercholesterolaemia, diabetes or cardiovascular disease. Modern lifestyles characterized by increased sedentarism have resulted in metabolic derangements such as high levels of triglycerides and low HDL concentration which is primarily due to an increase of fuel storage (Chakravarthy and Booth, 2004). Cholesterol is largely found in animal and dairy products and a diet that is low in fibre is a risk factor for the development of high cholesterol levels (del Balzo **et al.**, 1996). While alcohol is "good" in that it can raise HDL levels in middle-aged men it was found that the HDL-cholesterol levels in post-menopausal women were not positively affected by alcohol consumption (Hines **et al.**, 2005). In addition, over-consumption of alcohol raises blood pressure, can damage the liver, and contributes to an elevated triglyceride level in the blood. Smoking reduces the HDL (or "good" cholesterol) level in the blood. Stress, per se, does not increase cholesterol, it is the behavioural factors linked to high levels of stress which result in detrimental effects (Steptoe and Bryden, 2005). High stress levels may encourage poor dietary habits, increased tendency to smoke and reduction in physical activity (Steptoe and Bryden, 2005). The effect of living in an

industrialized country is not insignificant. Studies refer particularly to sedentary, white collar modes of employment, in conjunction with increased consumption of fast foods, which are high in saturated and trans-fats. An increased reliance on motorized transport and electronic entertainment has also dramatically reduced activity in all age groups, which has contributed to an escalation in cholesterol risk. (Chakravarthy and Booth, 2004).

Chen **et al.** (2007) report that individuals who smoke present with higher triglyceride and HDL-C levels compared to those who had previously smoked and those who had never smoked. The effects of smoking appear to be dose-dependant and cessation of smoking results in an associated reduction in blood lipid profile risk. Of interest were associated lifestyle factors amongst the subject group examined by Chen **et al.** (2007). The smokers were also noted to have the highest alcohol intake (compared to non-smokers), were also the most physically active and had the highest regular intake of dietary fibre. This highlights the relative risk of smoking, as this factor alone affected the blood lipid profile, independent of physical activity (Chen **et al.**, 2007). Smokers were excluded from the present study, as the effects of smoking, as noted, could have masked any effect brought about by the resistance training programme.

An additional “risk” category includes disease status. Rose **et al.** (2007) report that incidence of Human Immunodeficiency Virus (HIV) and Auto Immune Deficiency Syndrome (AIDS) has a significant effect on HDL-C reduction. Presence of HIV/AIDS, as well as use of the highly active antiretroviral treatment (HAART) reduces the functionality of the reverse cholesterol transport system in the body (Link **et al.**, 2007; Rose **et al.**, 2007) and is thus associated with increased atherosclerosis.

DIAGNOSIS

Since most people have few, if any, symptoms of hypercholesterolaemia, blood screening is very important. An initial blood test is done to check a "random" measurement of total and HDL cholesterol, meaning that the test is performed at any time during the day, regardless of what has been eaten. Those with abnormal levels (total cholesterol more than 200 mg.dL⁻¹ or HDL less than 40 mg.dL⁻¹), will go on to have a test called a fasting lipid profile (in which the person being tested refrains from eating for 8 to 12 hours, usually overnight, prior to the test). The fasting test will indicate whether or not total cholesterol levels fall within the normal range (between 140 and 200 mg.dL⁻¹), are moderately high (between 200 and 240 mg.dL⁻¹), or if they are in the very high range (240 mg.dL⁻¹ or greater). This blood test also reveals the levels of LDL, HDL, and triglycerides. According to guidelines released by the National Cholesterol Education Program (NCEP), the optimal level for LDL cholesterol depends on whether the individual has heart disease or not and whether there are other risk factors present for heart disease (such as diabetes and high blood pressure). The optimal level for HDL for all people (healthy or otherwise) is a measurement higher than 60 mg.dL⁻¹; low levels are 40 mg.dL⁻¹ and below.

TREATMENT

Proper management and care of patients at risk for cardiovascular disease is vitally important, and monitoring of blood lipids and lipoproteins is a fundamental aspect of this holistic management (Trejo-Gutierrez and Fletcher, 2007). Effective drug therapies exist, but may be subject to a number of barriers to use, such as cost, adherence to therapy and physician visits (Trejo-Gutierrez and Fletcher, 2007).

Thus alternative or complementary therapies require investigation, and the role of lifestyle modification in management of chronic disease in the modern world is becoming more and more essential.

It is accepted that reduced cholesterol levels are related to reduced recurrence of cardiovascular events and a slowing of the progression of atherosclerotic disease (Kotseva **et al.**, 2007). Robinson (2008) indicates that the focus of cholesterol treatment should remain on reducing LDL-C levels, in order to reduce the risk of cardiovascular mortality. The magnitude of LDL-C reduction is directly related to the degree of reduction of risk for cardiovascular events (Robinson, 2008). Treatment can be divided into two primary categories, namely pharmacologic and lifestyle interventions. Pharmacologic treatment carries the risk of side-effects and also, in rare cases, of ineffectiveness. However, lifestyle interventions carry minimal risk, and have the added benefit of positively affecting other aspects such as reduced weight and improved insulin resistance (Poli **et al.**, 2008). The importance of non-pharmacological control has increased in recent years as has the number of individuals requiring intervention for high plasma lipid concentrations (Poli **et al.**, 2008).

PREVENTATIVE CARE

Prevention is key and research has shown that adherence to healthy lifestyle practices is accepted as the most effective means of controlling cholesterol levels (Trejo-Gutierrez and Fletcher, 2007). Saturated fat and trans-fatty acids both raise cholesterol levels significantly, and it is suggested that these be reduced or eliminated from the diet (Poli **et al.**, 2008). Saturated fat is directly linked with

elevated LDL levels (Poli **et al.**, 2008) and as already established, LDL is the “dangerous” element in the blood lipid profile as it encourages the deposition of atherosclerotic plaque on arterial walls. Reducing body mass is also an effective means of reducing cholesterol levels, particularly the LDL levels. Physical activity is cited as an important means of reducing blood lipids, but research is not conclusive as to the exact frequency, intensity, nature and duration of exercise which might produce the required cholesterol-lowering effect (Poli **et al.**, 2008). As there are no specific exercise prescription guidelines and because there is limited research which has focused on resistance training, this study focused on treatment, as opposed to prevention, as all participants had to present with at least one abnormal lipid profile.

MEDICAL INTERVENTION

In 2004 Tolonen **et al.** reported that an average of 45% of hypercholesterolaemic men sampled from 32 populations were using some form of prescribed treatment. A reported 8% were utilizing drug intervention alone, and 14% were combining drug treatment with diet intervention. The authors reported that 44% of women with known hypercholesterolaemia were using some form of treatment, 6% using drug intervention alone (Tolonen **et al.**, 2004). Drug and dietary treatment was the preferred intervention for 14% of the sampled female populations. Notably, in the summary by Tolonen **et al.** (2005), the only interventions investigated were drug and dietary changes – no mention is made of exercise interventions. This is either a limitation of the study, or simply an indication that the medical fraternity has not, to date, recommended exercise as a means of controlling hypercholesterolaemia.

Drug treatments for hypercholesterolaemia include statins, niacin, bile-acid resins and fibric acid derivatives (Schmitz and Langmann, 2006). Statins block production of cholesterol in the liver, and have the effect of lowering the LDL, and slightly raising the HDL, thus improving the lipid profile (Schmitz and Langmann, 2006). Niacin, while found in food, can be prescribed at higher dosages, and the primary effect of this drug is to reduce LDL and raise HDL. However, side effects of niacin include itching, flushing, tingling and headaches (Schmitz and Langmann, 2006). Bile acid resins act within the intestine, and bind with lipids, preventing re-absorption into the circulatory system. Side effects include stomach upsets, constipation and excess gas. Fibrates reduce the production of triglycerides and can raise the HDL level. All these drugs are effective in improving a dangerous blood lipid profile (Schmitz and Langmann, 2006), but all carry risk of uncomfortable side effects such as muscle aches, abnormal liver function, heart burn, allergic reaction (in the form of skin rashes), constipation and decreased sexual desire. In some instances, individuals fail to respond to lipid-lowering medication and in these cases, lifestyle adjustments are necessary (Schmitz and Langmann, 2006 and Becker **et al.**, 2008). Participants in this study were not taking any medication for hypercholesterolaemia.

Schmitz and Langmann (2006) highlight that the optimal treatment for hyperlipidaemia is medication combined with lifestyle modification. According to Kotseva **et al.** (2007) a survey of 9 European countries indicated that management of patients with hyperlipidaemia is falling short and that for many individuals taking lipid-lowering medication the goal of reducing LDL-C is not reached. Kotseva **et al.** (2007) only surveyed medical records and thus did not take lifestyle factors into account at all. This serves to highlight the importance of combining different

treatment modalities, in this case, medication (where necessary) with correct diet and recommended activity levels.

Vitamin supplementation is generally advised and “multi-vitamins” are easily purchased over the counter. During the current study, subjects may have been taking vitamin and mineral supplements, and thus an exploration into the possible effects of additional vitamins and minerals in the daily diet is needed.

Farvid **et al.** (2004) evaluated the effects of 3 months of supplementation with Vitamins C and E, as well as Magnesium and Zinc. A synergistic action has been identified between Vitamin E and Vitamin C, and also with the elements Zinc and Magnesium (Farvid **et al.**, 2004). There is an established inverse relationship between these four elements and total cholesterol and serum triglyceride content (Farvid **et al.**, 2004). These authors found that HDL-C increased significantly after the dietary supplementation period of 3 months.

McRae (2008) investigated the effects of Vitamin C alone and found no significant increases in HDL-C, but did find significant decreases in both LDL-C and triglyceride content after 4 weeks. Nicolosi **et al.** (1999) and Redlich **et al.** (1999) investigated Vitamins E and A respectively. After a 5 year period of Vitamin A supplementation Redlich **et al.** (1999) found no change in serum cholesterol. Nicolosi **et al.** (1999) report a significant decrease in LDL-C after supplementation with Vitamin E, which is an effective lipid-soluble anti-oxidant.

Natural anti-oxidants are widely used as dietary supplements. Gorinstein **et al.** (2006) explored the suggestion that addition of garlic to the diet reduces plasma lipid concentration. Short-term therapy in adults has shown no changes to plasma lipid concentrations, but Gorinstein **et al.** (2006) demonstrated that a dose of 500mg of

garlic per kilogram of bodyweight hindered plasma lipid escalation in hamsters. Whether this finding can be extrapolated to human subjects needs further investigation. Omega-3 fatty acids, found naturally in fish and in flax seeds have also been found useful in the management of severely hypertriglyceridaemic individuals (Szapary and Radar, 2001).

A number of subjects in the current study reported self-medication with cod-liver oil and omega-3 capsules. It is unlikely that the recommended dose of these dietary supplements would have affected plasma lipid levels, as reduced levels of triglycerides have only been noted at three times the recommended daily dose of omega-3 capsules (Szapary and Radar, 2001).

DIETARY INTERVENTION

Rhew **et al.** (2007) evaluated a cohort of previously sedentary women of an average age of 61 years. The authors hypothesized that improving one health behavior (physical activity) would have a similarly positive effect on other health behaviours (dietary choices, reduced use of medication). The study revealed that medication use remained static and that dietary choices remained similar between the 3rd month of physical activity and the 12th month on a moderate exercise programme (Rhew **et al.**, 2007). For subjects who reported alcohol consumption at the start of the study there had been no change in consumption rates but it was noted that healthier choices of alcohol had been self-selected during the course of the study, and subjects reported an increased use of multi-vitamin supplementation, but that was the extent of 'dietary' changes (Rhew **et al.**, 2007).

A limiting factor of the current study was the lack of attention paid to dietary choices. Although Rhew **et al.** (2007) concluded that the addition of physical activity over a period of 12 months was not sufficient to alter other health behaviours at the same time it is possible that the limitation of not controlling diet during this study is ameliorated.

Dietary changes alone have been reported to lower cholesterol levels by 10-20% in individuals who previously followed a high-fat diet (Poli **et al.**, 2008). In individuals whose diet was not as extreme, a 5-8% improvement could be expected. In contrast, Stefanick **et al.** (1998) have shown that diet alone did not have an effect on LDL-cholesterol and showed that in a cohort of post-menopausal women LDL-cholesterol was only affected when aerobic exercise was added to dietary alterations. Saturated fats (those which become hard at room temperature, such as butter) should be excluded from the diet, and replaced with monounsaturated fats, for example olive or canola oils (Poli **et al.**, 2008). Animal fat consumption should be reduced by reducing intake of meat and milk products or by selecting low fat options (for example low fat or 2% fat milk rather than full cream milk). No more than 300mg of cholesterol should be included in the diet daily (for the general population) or 200mg for those with existing hypercholesterolaemia, diabetes or cardiovascular disease (Poli **et al.**, 2008). Fibre is an important dietary component, and soluble fibres, such as oat bran, oatmeal and barley may in fact assist in lowering cholesterol by up to 2%. Haskell **et al.** (1992) found that water-soluble dietary fibre had distinct lipid-lowering effects. LDL-cholesterol was reduced by 5.6%, 6.8% and 14.9% respectively when ingesting 5g.day⁻¹, 10g.day⁻¹ and 15g.day⁻¹ of water-soluble fibre (Haskell **et al.**, 1992). Insoluble fibre does not in fact lower cholesterol per se, but does assist in maintaining bowel health. Examples of insoluble fibres are

wholewheat breads, wheat fibres, cabbage, carrots and apple skins. The main problem addressed in this study was the effect of exercise on cholesterol levels and as such dietary changes were not made.

EXERCISE INTERVENTION

Pioneering investigations in the 1950s demonstrated that individuals with higher 'fitness' levels, defined as greater functional capacity during standardized tests, displayed reduced risk of cardiovascular complications (Trejo-Gutierrez and Fletcher, 2007). Used therapeutically, exercise demonstrated a 20% to 30% decrease in cardiovascular mortality in coronary disease patients (Trejo-Gutierrez and Fletcher, 2007). Thus, given the link between dyslipidemia and coronary heart disease, it follows that an investigation into the effect of physical conditioning (exercise) on the blood lipid profile is necessary to further understand how best to manage this risk factor.

Table I: Literature Summary

AUTHORS	PRT/ AET⁴	DURATION	MEN / WOMEN	AGE	EFFECTS
Trejo-Gutierrez and Fletcher (2007)	AET	(a) Jogging 20 miles per week @ 65 – 85% max VO ₂ (b) Walking at 65 – 75% of heart rate reserve 5 – 7 times a week	Men and Women	Not stated	Increased HDL in both instances
Halverstadt et al. (2007)	AET	24 weeks	58 Men and 42 Women	50 - 75	TC, TG and LDL decreased; HDL remained the same
Kokkinos et al. (1995)	AET	Not stated	Women	“adult”	Exercised at 10METs. Noted that moderate fitness (equivalent to 10METs) is required to improve coronary risk profile in women
King et al. (1995)	AET	24 months	149 Men and 120 Women	50 - 65	Increase in HDL in year 2. Had both a high intensity and a low intensity group and

⁴ Where PRT refers to Progressive Resistance Training and AET to Aerobic Endurance Training

					it was noted that the lower intensity group with more frequent exercise sessions had greater effects
Poli et al. (2008)	AET	Threshold needs to be met: 700 -2000kcal per week, with further improvements when expenditure exceeds 3000kcal per week			HDL increased by 9-50% and TG decreased by 19 – 50%
Trejo-Gutierrez and Fletcher (2007)	PRT	Not stated	Not stated	Not stated	Decreased fat mass
Joseph et al. (1999)	PRT	12 weeks	18 Men and 17 Women	54 - 71	HDL increased in male sample, remained unchanged in females.
Goldberg and Elliott (1985)	PRT	“self report of vigorous activity”	Not stated		FIND of precise exercise dose requires refining

Aerobic Endurance Training

Total cholesterol levels are found to be lower in individuals with high aerobic fitness compared to more sedentary counterparts (Trejo-Gutierrez and Fletcher, 2007). However, it has not been conclusively demonstrated that exercise training lowers cholesterol levels (Trejo-Gutierrez and Fletcher, 2007). It is surmised that a physically active lifestyle may prevent the age-related rise in triglycerides normally

seen in men, and it is also surmised that endurance training may assist in lowering triglyceride levels in individuals who have elevated levels at the outset. This conclusion is shadowed by the fact that it may be the long term reduction of body fat related to participation in endurance activity that has a positive effect on the triglyceride levels, and not the exercise per se. Trained athletes are consistently seen to present with higher HDL levels and lower LDL levels than untrained counterparts (Haskell, 1984).

“Frequency, intensity, nature and duration (FIND)” are the guiding principles for exercise prescription. In the case of abnormal blood lipid profiles it is not exactly clear which exercise is most effective (Halverstadt **et al.**, 2006; Trejo-Gutierrez and Fletcher, 2007). Trejo-Gutierrez and Fletcher (2007) highlight studies which evaluated ranges of duration and intensity of exercise bouts, and the effect of these factors on the blood lipid profile. High-intensity, high-duration endurance activity (equivalent to 65-80% of maximal oxygen uptake and running a distance of 32km per week) elicited the only significant change, that of increased HDL. However, this result was accompanied by significant weight loss during the study and thus, the altered lipid profile cannot be solely attributed to the exercise (Trejo-Gutierrez and Fletcher, 2007). All other reported attempts to assess the effect of moderate-duration and moderate-intensity combinations produced no significant changes to the blood lipid profile.

Halverstadt **et al.** (2007) found that endurance exercise training had a positive effect on cholesterol. LDL-C was found to drop significantly after 24 weeks of endurance exercise training while simultaneously, HDL-C (the desirable cholesterol) was found to increase significantly. These results also extended to the particle sizes of the various cholesterol: a significant decrease in the VLDL-C particle sizes as well as

an increase in the HDL-C particle sizes was noted (Halverstadt **et al.**, 2007). However, these authors could not conclusively separate the results as being the direct result of the exercise itself, or of improved body composition of the subjects which occurred during the testing phase.

It is noted that the effects on the blood lipid profile are more consistent following aerobic endurance training compared to results seen post resistance training (Joseph **et al.**, 1999). However, Trejo-Gutierrez and Fletcher (2007) reviewed a number of studies that had employed both aerobic endurance training and resistance training, and revealed that neither aerobic nor resistance training had in fact resulted in significant changes to the plasma lipid levels.

There does seem to be agreement amongst existing studies regarding a “dose” of exercise that is required for positive changes to be brought about in the blood lipid profile. With particular reference to HDL, studies have suggested that in men, an intensity of 6METs (metabolic equivalents) or more is required, although other researchers report that exceeding 6METs is unnecessary and produces no further positive benefit (Leclerc 1985). Positive changes were seen in men who were trained at 75% of heart rate maximum, but no positive changes were elicited in men who trained at 65% of heart rate maximum.

Poli **et al.** (2008) report that physical activity can effectively lower triglyceride concentration by 19 – 50% and increase HDL-C concentration by nine to 50%, but acknowledge that these alterations do not reflect until a specific exercise threshold is reached (specific type of physical activity is not stated). This threshold has yet to be defined, but is possibly within a weekly activity-related energy expenditure of 700 to 2000kcal, with further benefits noted at an energy expenditure of over 3000kcal (Poli

et al., 2008). It appears that high amounts of high intensity exercise have the best effects on plasma lipid levels, particularly with reference to aerobic exercise training (Poli **et al.**, 2008).

Further research by Kokkinos **et al.** (1995) revealed that HDL was positively affected in women who jogged at a speed of 10 – 11 minutes per mile. Therefore exercising at a moderate intensity is sufficient to raise HDL (“good” cholesterol) levels in both male and female subjects.

It is acknowledged that studies focusing on women and cholesterol are rare, and those which focus on the effect of exercise on cholesterol in female subjects are not only rare, but present conflicting results. The authors reiterate that research to date investigating the impact of exercise on cholesterol has yielded inconsistent results (Trejo-Gutierrez and Fletcher, 2007). Furthermore, this type of research focusing on post-menopausal women is not only limited, it is also conflicting. Durstine and Haskell (1994) report that exercise increases the prevalence and action of enzymes fundamental to the “reverse cholesterol transport” system. The authors cannot cite specific mechanisms, but state that it is clear that exercise plays a role, together with diet and body weight, in altering the rates of synthesis, transport and clearance of cholesterol from the blood (Durstine and Haskell, 1994).

Duncan **et al.** (1991) trained young females (29 to 40 years of age) for 24 weeks, requiring that 4.8km be walked each session, regardless of intensity. These researchers found increases in the HDL levels in the subjects. Spate-Douglas and Keyser (1999) found that moderate intensity training over a 12 week period was sufficient to raise HDL levels. It appears, in conclusion, that women who present with

lower HDL levels at commencement of exercise training are more likely to see positive changes than women who start with higher HDL levels.

The effect of hormonal changes post-menopause has direct bearing on cholesterol levels. A study was undertaken on two female groups who exercised at 70% of heart rate maximum for 24 weeks. The first group exercised and took hormone replacement therapy (HRT) and the second group was not on HRT (Lindheim **et al.**, 1994). It was found that no increases were seen in HDL in the exercise only group. Further, Seip **et al.** (1993) report that nine to 12 months of exercise at an intensity as high as 80-90% of heart rate maximum significantly increased HDL levels in post-menopausal women. King **et al.** (1995) also assessed post-menopausal, previously sedentary women, and had two groups that engaged in exercise – one group at a low-intensity and the other at high-intensity. These researchers found no changes to HDL in the first year of training, but did see significant changes to HDL in year two. Also of interest was the finding that the low intensity exercise group displayed bigger changes to HDL (King **et al.**, 1995). This was attributed to more frequent training, and the researchers drew the conclusion that frequent, habitual, low-intensity training may increase HDL levels in post-menopausal women with or without HRT.

Exercise volume threshold has not yet been established. Many suggest that there exists a dose-response relationship between exercise and HDL cholesterol level, but due to inconsistent results these researchers cannot adequately quantify this exact dose (Kokkinos **et al.**, 1995; Williams, 1996; Williams, 1998).

Attention has been paid to the short- and medium-term changes in lipid profiles after exercise bouts. Gill **et al.** (2005) evaluated the effect of prior moderate exercise on post-prandial blood lipid profiles. Twenty apparently healthy “middle aged” (average

age of 47.2 years) men were required to walk for 90mins on a treadmill at an intensity of 50% of VO_{2max} , on the afternoon prior to the blood lipid testing. Treadmill walking may be classified as “aerobic endurance training” and it was shown that this form of activity had reduced the post-prandial concentration of Very Low Density Lipoproteins (VLDL). The “desirable” cholesterol – HDL-C – was demonstrably higher, with lowered triglyceride concentrations after exercise than for the control group who had not exercised prior to their post-prandial blood sampling (Gill **et al.**, 2005).

Progressive Resistance Training

Increased strength is positively associated with reduced risk of all-cause mortality (Williams **et al.**, 2007). Resistance training is known to reduce negative blood lipid profiles, and reduce the risk associated with hypercholesterolaemia (Williams **et al.**, 2007). Goldberg and Elliott (1985) found that decreases in total cholesterol as well as LDL are seen in both female and male subjects after resistance training protocols. Triglycerides were also seen to decrease (Goldberg **et al.**, 1984). However, this could not be attributed solely to exercise in that alteration to lifestyle habits (weight loss, and increased fat-free mass) could not be isolated. Boyden **et al.** (1993) is one study which focused on the effect of resistance training on cholesterol levels in female subjects, and this study reports conclusively that 5 months of training lowered total cholesterol as well as LDL cholesterol in pre-menopausal female subjects.

Trejo-Gutierrez and Fletcher (2007) acknowledged that there are very few studies that have examined resistance training and cholesterol levels. The authors acknowledge that inter-study variation in methodologies was a confounding factor in

terms of comparison but it did appear, however, that a minimum level of caloric expenditure needed to be reached in exercise bouts for any changes to become evident in the plasma lipid profile. Similarly, aerobic endurance training only elicited lipid profile changes at high intensity and high duration (Trejo-Gutierrez and Fletcher, 2007).

The conclusion that a lower limit of caloric expenditure is required in each exercise bout for inducing lipid-related changes was reached, and is cited as the most probable reason for the apparent lack of effect of resistance training on the blood lipid profile. Where resistance training did not result in changes to total body mass, lean body mass or percentage fat mass, it was noted that total cholesterol and LDL remained unchanged (Trejo-Gutierrez and Fletcher, 2007). In instances where fat mass was decreased and lean mass increased there is a decrease in total cholesterol and in LDL, but in most studies HDL remained unchanged despite anthropomorphic changes (Trejo-Gutierrez and Fletcher, 2007).

Maesta **et al.** (2006) investigated the effect of resistance training on the blood lipid profiles of post-menopausal women. After 16 weeks of exercise intervention significant changes were noted in the subjects' waist circumference and android adiposity, with concomitant increase in total muscle mass. Results indicated slight improvements to discrete lipid profile elements, but none was statistically different. Joseph **et al.** (1999) found that total cholesterol, LDL-C and TG remained unchanged and that HDL-C reduced significantly in older women after 12 weeks of resistance training, twice weekly.

Literature to date is equivocal as to the efficacy of resistance training versus aerobic training on the lipid profile (Williams **et al.**, 2007). One study reviewed by Williams **et**

al. (2007) acknowledges a reduced risk of hypercholesterolaemia in a group of over 8000 men who had been involved in resistance training for more than 4 hours per week. It is of interest that while muscle strength did not seem directly related to reduced lipid values, it was demonstrated that greater upper- and lower-body strength in men was related directly to reduced triglyceride levels (Williams **et al.**, 2007).

SEX DIFFERENCES

The physical strength of men and women differs throughout life and older adults reflect this pattern (Beneka **et al.**, 2005). The effects of aging on muscle strength particularly the rate at which strength is lost over the adult lifetime, as well as the level to which the muscles atrophy, have also been noted to be sex-specific. Beneka **et al.** (2005) report that older men exhibited greater strength gains after a resistance training programme than matched female counterparts, and attributed this to females losing more Type IIA and IIB muscle fibres while men tend to lose only Type IIA fibres during the course of natural aging.

Energy requirement reflects another physiological area in which there are marked sex differences. Campbell **et al.** (2002) found that while resistance training did not increase the energy requirement of older men and women, it remained evident that the energy requirement of older men was greater than that of older women.

Sex-specific differences exist between men and women. Anthropometric differences have been classified by Behnke in a theoretical model for a “reference” man and woman (McArdle **et al.**, 1996). Lean mass (muscle) accounts for 88% of a man’s

build, but only 85% of the physical build of a woman. Essential fat is estimated at 2.1% for men, and 6.8% for women, indicating the higher level of fat mass present in the female form. Behavioural factors dictate that the percent of body fat in an average adult is much higher than this level, and hormonal differences are cited for a large proportion of fat-free mass in adult women.

WOMEN

In pre-menopausal women, high levels of activity may be associated with hormonal disturbances, and conditions known as oligomenorrhea and amenhorrea (McArdle **et al.**, 1996). In post-menopausal women levels of oestrogen and progesterone, the primary female -specific hormones, are markedly reduced.

In the Eastern Cape Province of South Africa 31.9% of women were classified as obese on the basis of their body mass index (BMI) (SADHS, 2003). Compared to this, only 8.8% of men had BMI ratings over $30\text{kg}\cdot\text{m}^{-2}$ (obese classification). Pre-menopausal women in South Africa had an average BMI of $26.3\text{kg}\cdot\text{m}^{-2}$ (which is considered “overweight”) in 2003, while post-menopausal women were $2.4\text{kg}\cdot\text{m}^{-2}$ higher with an average BMI of $28.7\text{kg}\cdot\text{m}^{-2}$ (also considered “overweight”) (SADHS, 2003). The mean pre-test BMI for the current sample was $29.8\text{kg}\cdot\text{m}^{-2}$ which is $1.1\text{kg}\cdot\text{m}^{-2}$ higher than the South African average in 2003, and is within the “overweight” classification.

Menopause

Women who have not menstruated for a period of 12 months are said to have entered menopause which is the permanent cessation of fertility and the menstrual cycle (Teoman **et al.**, 2006). Symptoms associated with menopause include hot flushes, irritability, sleep disorders, fatigue, anxiety and loss of concentration (Teoman **et al.**, 2006).

Menopause is associated with increased weight gain, increased cardiovascular risk, and increased sedentarism (Barnett and Spinks, 2008). Barnett and Spinks (2008) reported that 50% of Australian women over the age of 45 are classified as overweight, or obese. Impediments to exercise in the middle-aged or peri-menopausal female population contribute to decline in exercise levels at a time when regular exercise at a moderate intensity is cardioprotective (Barnett and Spinks, 2008). Kanaley **et al.** (2001) related the increased abdominal fat distribution characteristic of post-menopausal women to lack of physical activity rather than to other factors such as increased age or decreased circulating oestrogen.

Grandjean **et al.** (1998) examined whether menopause would affect responses to aerobic exercise in previously sedentary women. Menopause was not found to affect responses to exercise pertaining to serum lipids or apolipoproteins (lipids attached to 'apoproteins' which are protein carriers that facilitate the movement of lipids in the blood) (Grandjean **et al.**, 1998). In a study on a cohort of post-menopausal women Teoman **et al.** (2006) found that after six weeks of moderate exercise the subjects displayed increased strength, endurance, flexibility and balance. Importantly, all reported an improved quality of life. The symptoms of

menopause can be ameliorated by habitual physical activity during this period of life (Teoman **et al.**, 2006).

Decreased plasma adiponectin levels are associated with increased risk of atherosclerosis and coronary heart disease (Im **et al.**, 2006). Nakamura et al. (2004) found that older females with cardiovascular disease possess higher levels of adiponectin than male counterparts expressing with cardiac abnormalities. The authors note that in general females have higher levels of adiponectin and attribute this on part to the sex-specific hormone, oestrogen (Nakamura et al., 2004). Skouby (2004) reports that decreased oestrogen levels associated with the onset of menopause are linked to increased morbidity in females over the age of 50 years, a 46% risk increase of CHD exists in post-menopausal women (Skouby, 2004). Hormone replacement therapy (HRT) has been associated with decreased risk of coronary disease, although this was challenged by Im **et al.** (2006) who found that adiponectin levels were lower in a cohort of post-menopausal women taking HRT than in a group not on the hormone supplementation. HRT has been associated with decreases in LDL cholesterol and increases in HDL cholesterol (Skouby, 2004). In the present study a requirement was that the subjects were not taking HRT and thus the results have not been affected by the presence of synthetic hormone supplementation.

Increased triglyceride and LDL-C levels and reduced HDL-C levels are characteristic of women post-menopause (Gaspard **et al.**, 1994; Wakatsuki **et al.**, 1998; de Aloysio **et al.**, 1999; Chamberlain **et al.**, 2008). It is thought that the increased hepatic lipase activity, which results from a reduced natural supply of oestrogen, contributes to this altered lipid profile. Samaan and Crawford (1995) note that an effect of exogenous oral doses of oestrogen is hepatic metabolism of lipids. Reduced endogenous

oestrogen, symptomatic of the menopause, directly affects lipoprotein concentrations (de Aloysio **et al.**, 1999; Hak **et al.**, 2004; Chamberlain **et al.**, 2008). This change is directly associated with the hormonal changes at the time of menopause, as there is no “time delay” between onset of menopause and the effects on the lipoproteins (de Aloysio **et al.**, 1999).

A study by Jensen (1992) revealed that post-menopausal levels of total cholesterol increased by as much as 6%, similarly triglycerides increased by 11%, LDL by 8% and the “good” cholesterol – HDL – decreased by as much as 7%. These dramatic changes were attributed solely to reduced ovarian function, and the drastic reduction of circulating oestrogens which results. Gaspard **et al.** (1994) concluded that replacement of the oestrogens post-menopause (in the form of hormone replacement therapy) would not only revert the lipid profile to a pre-menopause level, but would also improve the antioxidant action of the oestrogens which can significantly reduce the local atherogenic process and resulting lesions on arterial walls.

Other positive effects attributed to oestrogen include reduced circulating fibrinogen and reduced systemic vascular resistance (Samaan and Crawford, 1995). As cardiovascular biomechanics are mildly suppressed after menopause, oestrogen may play a fundamental role in normalising cardiovascular function by increasing ventricular contractility and relaxation (Samaan and Crawford, 1995). Folsom **et al.** (1996) stated that post-menopausal women taking replacement oestrogen were at 50% of the risk for cardiovascular disease compared to women who were not taking replacement hormones.

Green **et al.** (2004) found that exercise training did not alter the lipid profile in post-menopausal women irrespective of oestrogen replacement therapy, a result which has been seen in other studies. It is surmised that studies investigating the effect of oestrogen on the blood lipid profile in conjunction with exercise need to standardize the dosage of the hormone, as well as the length of time for which the subjects take the hormone. Until such standards are put in place, the results remain inconclusive.

Green **et al.** (2004) point out that the frequency, nature, intensity and duration of the exercise protocols used in studies during which exercise was found ineffective in improving atherogenic lipid profiles in post-menopausal women were sufficient to elicit positive changes in other populations. This emphasizes the strength of the effect of oestrogen-reduction post-menopause.

Menopause and related factors (Figure 1) are closely related to cholesterol kinetics and the effect of lifestyle changes on cardiovascular health. Intrinsic factors (such as insulin function) and extrinsic factors (such as stress and medication) affect lipid metabolism.

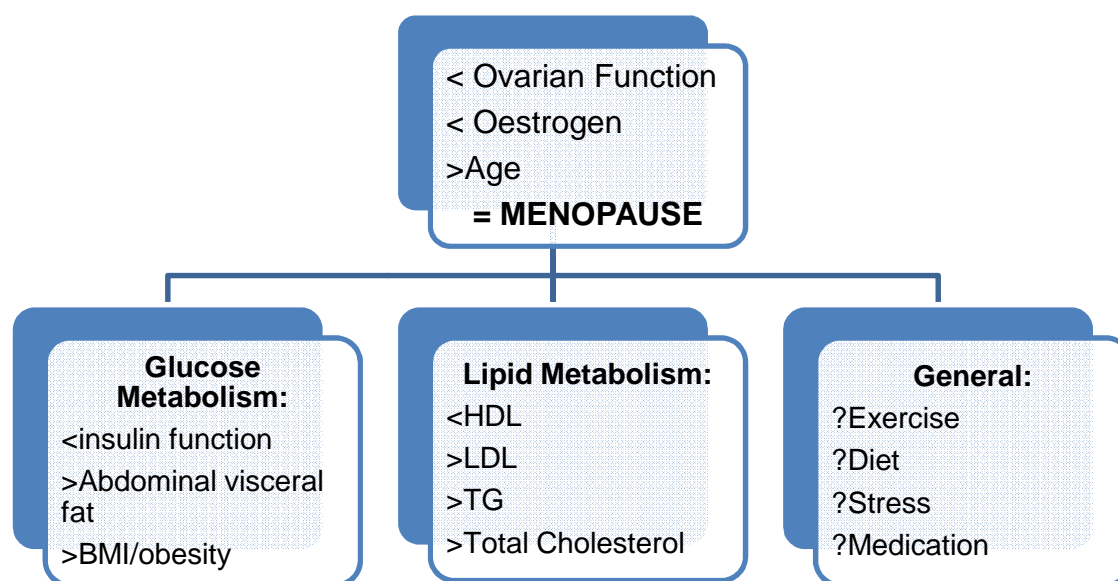


Figure 1: Depiction of factors linked to changes related to menopause⁵

The protective nature of oestrogens in the form of “estrone” is further highlighted by Silva **et al.** (2008). Estrone is a weak derivative of oestrogen which is found in the body post-menopause. It is derived from androstenedione by the enzyme aromatase which is found in fatty tissue (Silva **et al.**, 2008). Presence of increased levels of fatty tissue result in higher levels of estrone in the body and BMI has thus been correlated to estrone levels (Silva **et al.**, 2008). It is thought that estrone is a compensatory mechanism which exists to protect the cardio-vascular system post-menopause through its effects on lipid and glycaemic metabolism (Silva **et al.**,2008). Given this evidence, it is important to ascertain the effect of BMI in the current sample on lipid profile results, as it would appear that individuals with higher BMI scores should experience more positive effects on the lipid profile, due to the

⁵ “Abdominal visceral fat” (AVF) refers to fat mass which is stored in between the organs of the trunk, as opposed to subcutaneous fat found directly below the skin on the trunk and extremities.

endogenously higher levels of the weaker oestrogen, estrone. However, it is questionable whether this benefit would outweigh the negative effects of increased body mass on the blood lipid profile.

It is conclusive that loss of ovarian function results in changes to metabolic and vascular function (Stevenson, 2007). Senoz **et al.** (1996) queried whether these systemic changes were related to loss of ovarian function, or whether the salient factor affecting the metabolism and vascular physiology was advancing age. This question can be linked to the fact that HDL cholesterol does not increase at the onset of puberty and higher levels of oestrogen are evident at that stage in a woman's life. After a study compared post-menopausal women to younger women who had prematurely lost ovarian function, Senoz **et al.** (1996) were able to conclude that oestrogen, and not age, was in fact correlated to increased risk of cardiovascular disease (particularly an atherogenic lipid profile). It remains inconclusive as to whether replacement of oestrogen with synthetic hormones improves cardiovascular risk status.

The effects of oestrogen on the lipids and lipoproteins vary according to the dose of oestrogen and the route of administration (Stevenson, 2007). Oral administration increases levels of HDL whereas transdermal administration does not show a similar effect (Samaan and Crawford, 1995). This effect appears to be due to the high levels of oestrogen in portal circulation after intestinal absorption which leads to hepatic metabolism of lipids, which Samaan and Crawford (1995) note is not an effect seen in transdermal application of oestrogen. However, oral administration raises triglyceride levels which is an unwanted effect, but if oestrogen is taken in the form of progestogen, triglycerides do not increase. It is generally accepted that oral oestrogen replacement is beneficial to cardiovascular function (Wakatsuki **et al.**,

1997). However, it does appear that there is a 'window of opportunity' and that oestrogen replacement needs to commence at the time of menopause for the expression of the beneficial effects (Stevenson, 2007).

Exogenous oestrogens were found to be as effective as endogenous oestrogen in protecting the individual against cardiovascular disease and mortality (Westerveld, 1998). This indicates that replacement with synthetic hormones post-menopause should produce the same effect as naturally produced oestrogen pre-menopause. Approximately 25 – 50% of the protective function of oestrogen is achieved by its favourable effect on fasting lipids. In particular, post-prandial lipaemia is notably reduced by endogenous oestrogens. Exogenous oestrogens were found to function similarly in attenuating the post-prandial decrease in HDL noted in post-menopausal women (Westerveld, 1998).

This is not a simple conclusion, however, as effects of exogenous oestrogen replacement can vary according to the nature of oestrogen used (mostly equine oestrogen in varying quantities) and also according to length of use of the replacement therapy (Folsom *et al.*, 1996). Omu and Al-Qattan (1996) found this during a study on post-menopausal women given a combination hormone replacement, containing oestrogen and progestin. The lipid and lipoprotein profiles did not change after 12 months on this combination therapy, leading Omu and Al-Qattan (1996) to conclude that if progestin is included in the therapy it needs to be a minimal dose.

Omu and Al-Qattan (1996) raise an important point in relation to the current study. These researchers felt that not only were the results attained in the 1996 study affected by the type of hormone replacement utilized, but that the effects were also

attenuated by obesity in the cohort, and more importantly, lack of exercise. The inference is that the researchers acknowledged that treatment of atherogenic lipid profiles in post-menopausal women requires an exercise regime. The current study evaluated the efficacy of an exercise regime (resistance training) on the lipid profile but did not evaluate the effects of hormone replacement therapy, and the sample was not taking hormone replacement therapy.

Orsatti **et al.** (2008) investigated the effects of resistance training on age-related loss of muscle-mass (sarcopenia) in sedentary post-menopausal women. Increasing age as well as menopause, combine to decrease the secretion of anabolic hormones such as testosterone, growth hormone and insulin-like growth factor (IGF-1). Particularly low levels of these hormones in post-menopausal women lead to reduced muscle mass and strength output (Orsatti **et al.**, 2008; Lee **et al.**, 2007). By the age of 70 muscle mass has declined by 25-30%, strength output has depreciated by 30-40% and the size of, particularly, Type II muscle fibres, has significantly decreased (Lee **et al.**, 2007).

Lower levels of oestrogen are also related to strength decline in women (Orsatti **et al.**, 2008; Lee **et al.**, 2007). Resistance training is known to increase the concentration of anabolic hormones in the body. Orsatti **et al.** (2008) found elevated levels of IGF-1 and concluded that the muscle mass and strength gains noted were strongly correlated with increased anabolic hormone levels. This is important as it is decreases in the steroid-based hormones that are associated with decreased concentrations of IGF-1, an associated decrease in the concentration of muscle fibres, and a significantly decreased number and efficacy of satellite cells (Lee **et al.**, 2007).

Satellite cells play an important role, as they function as myogenic stem cells, and proliferate in an area of damaged muscle in order to repair the area. Senescence-related sarcopenia combined with reduced satellite cell capacity and function together result in a situation of reduced regenerative capacity and thus failure to recover properly from any muscle-incident in older adults (Lee **et al.**, 2007). Resistance training has the effect of reversing this decline in muscle health.

Physiological changes in the climacteric extend to metabolic energy expenditure, particularly at rest. Dos Reis **et al.** (2003) noted that resting energy expenditure (REE) was reduced after menopause. This decreased demand on fuel supply, combined with decreased lean body mass characteristic of sarcopenia results in an increased fat mass which is most evident within the first 3 years of menopause. Oestrogen is usually associated with increased levels of growth hormone (GH) which would in turn result in reduced sarcopenia and a possible reduction in the onset of fat mass. Notably, dos Reis **et al.** (2003) found that oestrogen replacement did not alter body mass index, body mass or resting energy expenditure in a cohort of post-menopausal women who had been menopausal for at least 24 months.

The researchers stated that physical activity had a more profound effect on abdominal fat than the oestrogen replacement therapy, particularly in early post-menopause (which is defined as up to four years from the cessation of menses). It is possible that physical activity holds the key to the unexplained abdominal fat deposits and increase in cardiovascular risk seen in post-menopausal women.

Abdominal Visceral Fat

The presence of raised levels of abdominal visceral fat (AVF) increases with age regardless of whether the individual displays a 'normal' body mass index (BMI), or whether the BMI indicates that the individual is 'overweight' or 'obese' (Weltman **et al.**, 2003). Piche **et al.** (2008) noted the importance of the location of adipose tissue (visceral or subcutaneous). Total body fat and sex are confounding factors with respect to AVF. In younger individuals men display higher levels of AVF corrected for total fat mass (FM) whereas in older individuals (60 years and older) this difference is no longer evident (when corrected for FM).

Weltman **et al.** (2003) found that older females had higher levels of body fat and FM while matched male counterparts had higher levels of AVF before correcting for total body fat content. Notably, the higher AVF correlated with higher blood lipid profile values, in other words a more atherogenic lipid profile, indicative of higher cardiovascular risk (Weltman **et al.**, 2003). Laws **et al.** (1993) have demonstrated that obesity and abdominal obesity predict HDL-cholesterol and triglyceride concentration in post-menopausal women. Recent research undertaken by Piche **et al.** (2008) concluded that it was visceral fat, rather than subcutaneous fat, which affected metabolic and lipid profile values negatively.

In 2003 pre-menopausal South African women had an average waist circumference of 805mm which was 76mm lower than the average for post-menopausal women at the same time (SADHS, 2003). The percentage of women aged 15 to 44 years with waist circumferences in excess of 880mm was 27.4% in 2003, 21.7% lower than the percentage of post-menopausal women (49.1%) with waist circumferences over 880mm (SADHS, 2003).

The link between AVF and the lipoproteins reveals a number of possible mechanisms. AVF plays a role in altered insulin sensitivity, and in conjunction with this, enlarged omental fat cells result in increased levels of free fatty acids (FFA) in portal circulation in the body. Weltman **et al.** (2003) note that this increase in FFA results in decreased hepatic insulin extraction. Decreased levels of available insulin affect the synthesis of lipoprotein lipase (LPL) in adipocytes. This results in reduced function of LDL in hydrolyzing lipids into lipoproteins and creates an increased plasma concentration of triglyceride (TG)-rich lipoproteins, a situation which encourages the transfer of TG to LDL or HDL particles. Ultimately, as noted by Weltman **et al.** (2003), there is an increase in the levels of LDL cholesterol, and simultaneously a decrease in “good” (HDL) cholesterol is noted.

It was concluded by these researchers that increased FM, increased AVF and also the evidence of increased AVF when corrected for total body FM all result in a more negative (more atherogenic) lipid profile which in turn is responsible for a significantly increased risk of coronary artery disease (CAD) (Weltman **et al.**, 2003). Kwon **et al.** (2005) agree that increased levels of fat are linked to increased mortality, but caution that the molecular mechanism of the causal nature of this relationship is not yet clearly understood.

Obesity, particularly abdominal, may facilitate the dysregulation of adipokine production which in turn results in the development of metabolic and vascular diseases. It is also noted that obese individuals display reduced circulating levels of adiponectin (Kwon **et al.**, 2005). Low levels of adiponectin have been linked to more atherogenic lipid profiles, and also to reduced insulin sensitivity. Kwon **et al.** (2005) found that plasma levels of adiponectin in women positively correlated to HDL, and negatively correlated to BMI, intra-abdominal fat distribution, LDL and TG.

Adiponectin is thus described as an endogenous anti-atherogenic factor, and is thought to be a plausible mechanism linking obesity to increased CAD risk (Kwon *et al.*, 2005).

CHRONIC EXERCISE TRAINING

Exercise training falls into two broad categories: aerobic endurance training and progressive resistance training as previously highlighted in this text. No matter the modality selected, the principles of training programme design as well as attention to safety factors remain common elements of both types of training.

THE “FIND” PRINCIPLE

Design of any exercise training programme should be a precise amalgam of frequency of training, intensity of training bouts, nature of the exercise undertaken, and duration of each training session (Figure 2). Resistance training, also referred to as strength training, should follow a precise formula allowing for muscles to be stimulated for 30 - 90 seconds per execution of each exercise, with marginally increased loads between sets and sessions to facilitate physiological stimuli which result in increased protein synthesis and simultaneous development of the skeletal muscles in question (Winett and Carpinelli, 2001). It should be remembered that exercise training is by definition a stressor to the finely balanced homeostasis of the body's physiological processes and thus the frequency, nature, intensity and duration (FIND) should be carefully balanced to avoid injury and weakening of the immune system (Winett and Carpinelli, 2001).

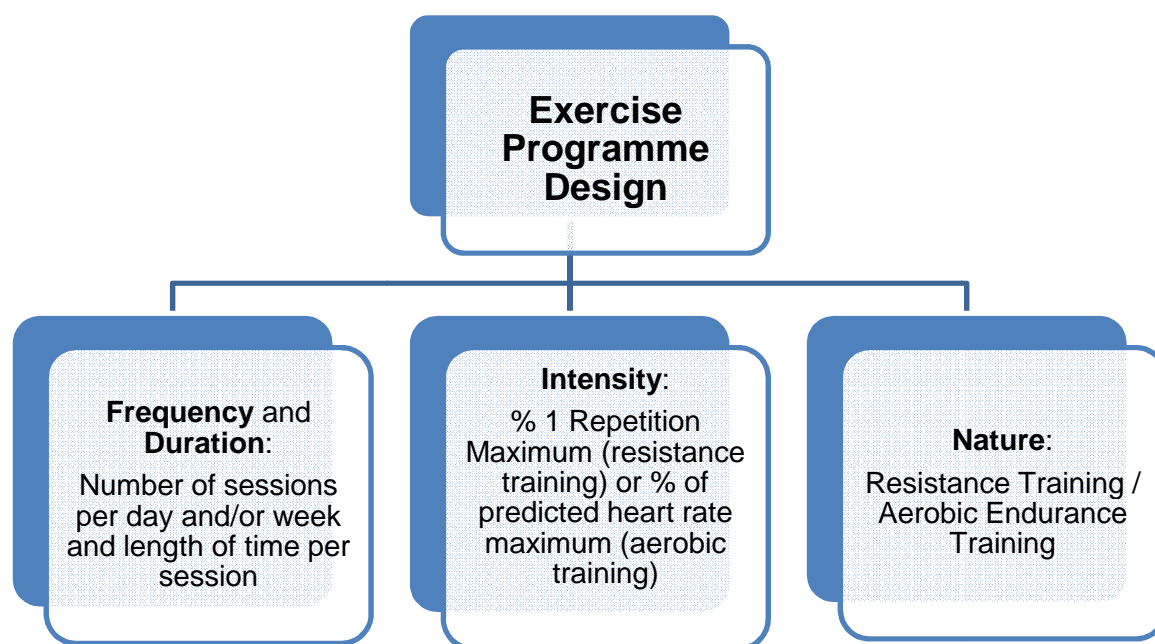


Figure 2: Depiction of the “FIND” principle guiding exercise programme design

EFFECTS OF EXERCISE INTENSITY

Beneka **et al.** (2005) examined the effect of resistance training intensity on strength gains in men and women. Low-, moderate- and high-intensity workouts revealed that high intensity (85% of 1-RM) produced the greatest strength increases in both sexes. Females were seen to develop strength gains at a significantly better rate than men when repetitions were executed at high intensity (strength gains of up to 15.2%) but low velocity (Beneka **et al.**, 2005). Existing recommendations cite an intensity of 80% of 1-RM as the ideal level for resistance training for strength and functional gains in the elderly. Beneka **et al.** (2005) concluded that moderate- and low-intensity resistance training also produced strength gains in both sexes, but to a lesser extent than high-intensity training.

Intensity must be coupled with frequency of training, and it was noted by Nakamura **et al.** (2006) that women who exercise three times a week (as opposed to once, or twice) derived greater benefits with regard to functional fitness. The participants in the current study were required to attend three sessions weekly, for a period of 24 weeks.

SAFETY DURING EXERCISE

The current study focused on the effect of resistance training (RT) on hypercholesterolaemia. Williams **et al.** (2007) report that the risks associated with RT are analogous to those linked to aerobic endurance training. Before an individual engages in RT it is important to take into account the individual's age, existence of underlying cardiovascular complications and habitual activity level. As the subjects in the current study were between the ages of 50 and 75 years and were previously sedentary, there existed an inherent risk in the study cohort.

Of particular concern during RT is elevated blood pressure. Williams **et al.** (2007) note that blood pressure can reach dangerous levels during exercise at 80% to 100% of the 1-RM. However, correct breathing, avoidance of the valsalva manoeuvre, as well as close monitoring counteract this danger (Williams **et al.**, 2007). For the purposes of the current study correct breathing was emphasized throughout and each exercise session was supervised by a knowledgeable post-graduate student.

Resistance training is associated with a more favourable myocardial oxygen supply than aerobic endurance training at similar intensities (Williams **et al.**, 2007) due to a

lower heart-rate combined with higher perfusion pressure during exertion of weight training. In addition, isometric resistance exercise elicits no symptoms of angina pectoris, results in no ischaemic 'ST' segment depressions (in electrocardiogram evaluations), does not result in ventricular arrhythmias, and does not produce general ischaemic responses (Williams **et al.**, 2007).

Thus resistance training is considered safe, even for individuals who exhibit controlled hypertension, or who may be considered "low risk" cardiac patients. Williams **et al.** (2007) also indicate that women, with or without cardiac complications, also benefit substantially from resistance training regimes.

ADAPTATIONS TO EXERCISE TRAINING

Biological adaptations to regular activity may be divided into two broad subclasses: anaerobic adaptations and aerobic adaptations. McArdle **et al.** (1996) note that anaerobic changes take place as a result of power-type training, and that these adaptations include increased levels of anaerobic substrates (such as resting levels of muscular adenosine tri-phosphate (ATP), creatine phosphate (CP), free creatine and glycogen), an increased quantity and activity of key enzymes (such as those which control glucose breakdown and thus energy availability at the level of muscle metabolism), and an increased capacity for generating blood lactate during high-intensity exercise.

Training-induced changes to the aerobic system relate predominantly to functional capacity to transport and deliver oxygen to working muscles (McArdle **et al.**, 1996). These positive alterations can be broadly classified as metabolic, cardiovascular,

pulmonary and 'other' changes (these include body composition changes, and notable improvements in heat transfer within the body as well as psycho-emotional benefits) (McArdle **et al.**, 1996).

The extent to which training adaptations can be seen is determinant on four primary factors: individual's initial level of 'fitness', the intensity of the training regime, the frequency of training bouts and the duration (length per session) of the training sessions (McArdle **et al.**, 1996). These initial determining factors will affect the individual's progress in both aerobic endurance type activity and also predominantly resistance type training, where the adaptations to training are largely anaerobic, but there are also notable improvements to the aerobic system.

How quickly training adaptations express in individuals is related to the four factors listed above, and it is noted in McArdle **et al.** (1996) that adaptations are evident within days and improvements are initially noted from week to week. The overall effect of a training regime is also affected by sex and age, both salient factors for the purpose of the current study as the subjects in the current study were post-menopausal females between the ages of 50 and 75 years. This represents an "older" age group, and it is well documented that increasing age has significant effects on the musculoskeletal system, particularly the decline of muscular strength (Calder and Gabriel, 2006; Reeves **et al.**, 2006).

Resistance training has been found to reverse the negative changes to the musculoskeletal system in older adults. Calder and Gabriel (2006) found that resistance training increased strength output by reducing the co-contraction of the antagonist muscle, thus permitting the agonist to exert full force without the "interference" of the antagonist.

Reeves **et al.** (2006) reported that resistance training in individuals over the age of 65 improves isometric and concentric torque by nine to 37%. This improvement to torque is due to an increased muscle mass, as muscle cross-sectional area improved by five to 17% after three months of resistance training. Muscle architecture is also seen to alter significantly after resistance training (Reeves **et al.**, 2006). The number of sarcomeres increased both in-series and in-parallel (Reeves **et al.**, 2006). Other changes such as 65% increase in tendon stiffness, and increased neural drive are also observed after resistance training in older adults (Calder and Gabriel, 2006; Reeves **et al.**, 2006).

Resting metabolic rate (RMR) represents 60-75% of an individual's daily energy expenditure. RMR declines with age, largely due to reduced fat-free mass. Santa-Clara **et al.** (2006) examined the effect of exercise training on the RMR in a cohort of post-menopausal women. RMR did not increase after longitudinal study, but the study paid no attention to muscle-mass as it was an endurance exercise protocol (Santa-Clara **et al.**, 2006). Resistance training does elicit fat-free mass increases in post-menopausal women (Orsatti **et al.**, 2008) and thus may increase RMR.

Sarcopenia, which is associated with increasing age, is the result of a combination of factors. Lee **et al.** (2007) highlight physical activity, diet, oxidative stress (strongly associated with obesity (Devries **et al.**, 2008)), inflammatory insults on the system and hormonal changes as the primary factors. Notably, sarcopenia (loss of muscle mass) results in reduced energy needs (Lee **et al.**, 2007). Unless diet is altered the individual will eventually consume too many calories thus upsetting the "energy in, energy out" balance. This in turn will lead to increased fat mass, and concomitant health and wellness problems, including raised cholesterol levels.

Dionne **et al.** (2004) noted no change to Resting Energy Expenditure (REE) in older women, and attribute this to the fact that bodyweight remained stable during the 6 month resistance training study, and also to the fact that norepinephrine secretion remained unchanged indicating no change to the sympathetic nervous system following resistance training (Dionne **et al.**, 2004).

EXERCISE COMPLIANCE

Increased age is associated with increased perception of barriers to exercise (Barnett and Spinks, 2008). Particularly noticeable in post-menopausal women is a tendency to reduce levels of activity with advancing age. Levels of self-efficacy were noted by Barnett and Spinks (2008) to be a reliable predictor of adherence to exercise programmes. Assessing the individual's level of self-efficacy can inform exercise programme design in much the same way as the principles of frequency, nature, intensity and duration (Barnett and Spinks, 2008). Long-term adherence is directly related to this concept.

Conducting research in the context of "real life" situations requires some flexibility in terms of adherence to training schedules. Unforeseen eventualities cannot be factored into the study design, and thus minimum attendance for reliable results needs to be considered. Dionne **et al.** (2004) permitted subjects to miss one session per month for the duration of their longitudinal study.

CONCLUSION

High levels of plasma lipoproteins are directly correlated to increased risk of cardiovascular disease, particularly conditions of atherosclerosis (McArdle **et al.**, 1996). In 2003, 2.2% of South Africa women self-reported the condition of hypercholesterolaemia, and the prevalence of the condition is 2.7% higher in post-menopausal women compared to pre-menopausal women (South Africa Demographic and Health Survey (SADHS), 2003). The estimated number of South Africans living with dyslipidaemia is 5.7 million (SADHS, 2003).

Hypercholesterolaemia may be treated either with drug or lifestyle intervention, or a combination of both. Poli **et al.** (2008) noted that the side-effects of drug intervention are far less preferable to lifestyle intervention which carries minimal risk and only a small chance of side-effects.

Therapeutic use of exercise in the prevention and management of cardiovascular heart disease has been well documented (Trejo-Gutierrez and Fletcher, 2007). The efficacy of exercise in the treatment of hypercholesterolaemia is less clearly understood (Trejo-Gutierrez and Fletcher, 2007). A number of studies have focused on the effect of aerobic resistance training on the blood lipid profiles of post-menopausal women (Seip **et al.**, 1993 and King **et al.**, 1995) but very little research has focused on the effect of resistance training (Trejo-Gutierrez and Fletcher, 2007).

Post-menopausal women are at increased risk of cardiovascular disease due to reduced levels of circulating oestrogen (Skouby, 2004). Chamberlain **et al.** (2008) note that post-menopausal women characteristically present with increased triglyceride and LDL cholesterol levels, and reduced HDL cholesterol values. Thus post-menopausal women possess an inherent risk for dyslipidaemia, particularly if

oestrogen is not replaced via synthetic hormone replacement therapy (Gaspard **et al.**, 1994).

Therefore the main aims addressed by this study were to analyse the effect of longitudinal adherence to a progressive resistance training protocol on the blood lipid profiles of post-menopausal women.

CHAPTER III

METHODOLOGY

INTRODUCTION

The current research had at its core an investigation into the effect of resistance training on the discrete elements of the blood lipid profile. As an independent risk factor for cardiovascular disease (McArdle **et al.**, 1996), hypercholesterolaemia is infrequently recognized in many individuals, most particularly in post-menopausal women. The effect of exercise on the blood lipid profile remains inconclusive (Joseph **et al.**, 1999; Maesta **et al.**, 2006; Trejo-Gutierrez and Fletcher, 2007). Post-menopausal women have the added effect of reduced circulating oestrogen which accompanies cessation of ovarian function, thus increasing risk of cardiovascular disease exponentially to reach that of similar proportions of male counterparts (Chamberlain **et al.**, 2008).

The selection of post-menopausal women for a prospective study requires careful screening for confounding factors such as hormone replacement therapy, disease (such as lung, liver, heart or kidney complications) and smoking which is known to affect the blood lipid profile. In addition, the motivation to comply with the study for the full 24 week period required high levels of intrinsic and extrinsic motivation for the cohort.

Resistance training is not associated with loss of body mass *per se*, but may be linked to improved muscle tone and metabolic function (Campbell **et al.**, 2002; McArdle **et al.**, 1996; Reeves **et al.**, 2006). Thus, the selection of anthropometric

measures to reflect the anticipated morphological response to resistance training was selected in the form of girth measures. Human error is inherent in such measurements and, as such, the primary researcher repeated all measurements to reduce this error as far as possible.

PILOT RESEARCH

In order to establish the best experimental design pilot studies were conducted between May and October 2007. Although the analysis was specific to exercise and changes to the blood lipid profile, further investigation was required to establish other criteria such as the sex, age and health status of the subjects.

Men and women of all ages were referred by a local Specialist Physician who deemed the individuals healthy to undertake exercise and who had also diagnosed the individuals with hypercholesterolaemia and associated risk factors for the Metabolic Syndrome. The impact of aerobic endurance training (AET) and resistance training (RT) on associated blood lipid profiles was evaluated during this phase of the investigation. Ten subjects (five men and five women) were allocated to the RT group and eight individuals (one man and seven women) undertook the AET programme. All subjects adhered to the respective programmes for a minimum of three months (12 weeks).

All sessions, during this phase of the research, were supervised in the Health Suite facility at Rhodes University. The pilot study revealed a number of important factors, including the importance of supervision in retaining the subjects over a period greater than four weeks duration. In addition, the importance of a strong progressive

element in the training programme design was noted as subjects soon reported finding the programme “easy”.

The AET subjects’ results revealed that time duration is of the essence if AET is to have an effect on the blood lipid profile as three weekly sessions of 30 – 45 minutes duration did not reveal any significant changes to cholesterol levels, independent of age and sex. The RT programme, by its progressive nature, ensured that the subjects were always challenged. Monthly fasting blood lipid profile test results showed that there were significant positive changes within the blood lipid profiles of individuals adhering to the RT in both men and women, however none of the women during the pilot study were post-menopausal.

This result, in conjunction with the dearth of literature on the effect of resistance training on the blood lipid profile, channelled the focus of this study toward resistance training. As post-menopausal women are considered a group at high risk for atherosclerotic, and related, conditions and because research focusing on this population group was also sparse, these individuals were targeted as subjects. Pilot studies had also revealed higher compliance amongst the women than the men, and particularly amongst the older women. One reason for this could have been that a number were retired or in part-time employment and that they did not have the responsibility of young families or work commitments, permitting them a more flexible daily schedule into which they could fit their exercise sessions.

EXPERIMENTAL DESIGN

TRAINING PROGRAMME

Design of the training programme had one fundamental guiding factor behind it: the programme had to be generic enough to suit previously sedentary, middle-aged females, all of whom were unaccustomed to an exercise environment such as the controlled one they were introduced to for this study. A sensitive approach guaranteed that the participants felt comfortable with their environment and each other, overcame their inhibitions very quickly and were able to concentrate on the exercises. In addition, one of the primary aims of this study was to assess the effects of progressive resistance training on the blood lipid profile with a view to making recommendations to General Practitioners – who would, in turn, make recommendations to patients expressing with abnormal blood profiles. Thus, it would have been counter-productive to develop such a specialised programme that it could not easily be replicated for future benefit to the broader population.

In order to fulfil the requirement that the training programme be progressive, and that the nature of exercise be ‘resistance’ rather than ‘aerobic’, careful design was required. The 24 week programme was divided into stages, each developing in a specific manner. In addition, the ‘FIND’ (frequency, intensity, nature and duration) principle was engaged. Controlling the intensity of the exercise sessions at all times, in order to retain comparability between subjects and effectively ensure progression intra-individually was fundamental. Borg’s Rating of Perceived Exertion (RPE) scale was used during sessions (Appendix F), along with participant education, whereby the individuals gradually learnt how to gauge their own effort during sessions. Heart rate was monitored via pulse counts, with fingers at the pulse site antero-medial to

the cervical spine. In designing the programme, the FIND principle was applied, and only one element was increased or altered at each adjustment of the training programme.

Pollock **et al.** (1998) have stated that resistance training is recommended for increased muscular strength and endurance as well as physical function in populations of 50 years and older. While cautioning that the adaptation period is longer in older population groups, Pollock **et al.** (1998) recommend two to three days training per week for no longer than 60 minutes per session. One or two sets is recommended, of 10-15 repetitions, completing a total of eight to ten resistance exercises focusing on major muscle groups with stretching highlighted as essential (Pollock **et al.**, 1998).

Given that the population sample for this study comprised women between the ages of 50 and 75 years, most of whom would be post-menopausal, the effects of the loss of the sex-specific hormones needed enquiry. Pollock **et al.** (1998) indicate that up to 30% of an individual's total strength may be lost post-menopause, but that menopause does not alter strength-training responses to exercise, despite a longer adaptation period associated with age. This information informed the selection and prescription of the exercise training protocol followed for the present study.

Control of Intensity

In order to ensure that results were comparable, the intensity exerted by each individual needed to be tightly monitored. As the subjects were untrained, previously sedentary females, all over the age of 50 years, it was expected that their general

strength and condition at the start of the training programme would be below average. The execution of a 1-repetition maximum (1-RM) test is the generally accepted means of assessing an individual's discrete strength (Levinger **et al.**, 2007). Given the population from which the subjects had been drawn, it was unclear whether a 1-RM test would be reliable, given the sedentary status of the sample, and the fact that each individual was over 50 years of age. Levinger **et al.** (2007) found that the 1-RM test is reliable in a sample characteristic of that of the current study – untrained, middle-aged individuals. Moreover, the researchers found that one familiarisation session and one testing session were sufficient to provide reliable data pertaining to maximal strength (Levinger **et al.**, 2007).

Previous studies that made use of resistance training protocols for the purpose of assessing the relationship between exercise and risk factors for the metabolic syndrome were consulted for further guidance as to the correct resistance levels for the training protocol. Maesta **et al.** (2007) commenced resistance training sessions at an intensity of one set of 12 repetitions at 40 – 50% of the individuals' 1-RM, increasing up to a level equivalent to three sets of 12 repetitions at 60 – 80% of the 1-RM. Ramalho **et al.** (2006) maintained intensity at three sets of eight to 12 repetitions utilising 60 – 80% strength based on the 1-RM test. In 2005 Stewart **et al.** conducted a test at 50% of 1-RM, executing two sets per machine exercise, and increasing the weight once the subject could easily complete two sets of 15 repetitions at a weight level. Behall **et al.** took a different approach in 2003, when the researchers set the intensity of the training at 70% of the 1-RM, and chose to add an additional set to the exercise protocol every third week, from an initial set consisting of eight to 12 repetitions. A summary of these study designs revealed that the most acceptable intensity level ranges between 50% and 80% of the 1-RM, as

assessed during a preliminary test, after habituation to the exercise (Levinger **et al.**, 2007). In addition, set and repetition prescription ranged between the execution of one set of eight to 15 repetitions to a maximum level of three sets consisting of eight to 12 repetitions. This information served as a guide in the design of the training protocol of the current study. Regarding the present study it is worth noting that that the initial intensity of 12 repetitions at 50% of the 1-RM posed no challenge to the subjects. This required the researcher to increase the intensity sooner than originally intended. Duration of exercise sessions also required attention. Ramalho **et al.** (2006) and Maestra **et al.** (2007) structured 40-minute sessions, three times weekly. Within the sessions, Behall **et al.** (1998) allowed 60-second breaks between sets and between stations.

It may be argued that monitoring the subjects' heart rates rather than perceived effort and 1-RM would have been a more reliable measure of individual effort. Studies that employed aerobic training protocols, such as Varady **et al.** (2007) controlled the intensity of the exercise bouts by monitoring the individuals' heart rates. This study maintained an intensity at 60% of heart rate maximum, as determined by the age-predicted maximum heart rate formula ($220 - \text{age}$). With the use of technology such as Polar® Heart Rate Monitors, this becomes a very reliable measure of effort. However, in the case of resistance training, the effort is not as sustained as it is during aerobic exercise, as borne out by the 60-second respites between sets and exercises (Behall **et al.**, 1998).

Stages of the Training Programme

Phase 1: Weeks 1-4

With a focus on habituation to exercise, which is important in individuals previously unused to regular exercise, Phase 1 began with a higher relative period of time dedicated to aerobic warm up, as can be seen in Figure 3. Whole-body mobilisation dominated these sessions, with an emphasis on whole-body stretching at the conclusion of the session.



Figure 3: Study participants completing the aerobic warm-up

Phase 2: Weeks 5-8

Figure 4 reflects exercises which target large muscle groups (for example the quadriceps group, hamstring group, rectus abdominus, pectoralis major and latissimus dorsi). Introducing resistance training in the simplest and safest form, all exercises at this stage were executed on weight training machines with stacks of plate weights, with the exception of simple “activities of daily living” such as travelling lunges (subject on the right in Figure 4) and ‘step-ups’.

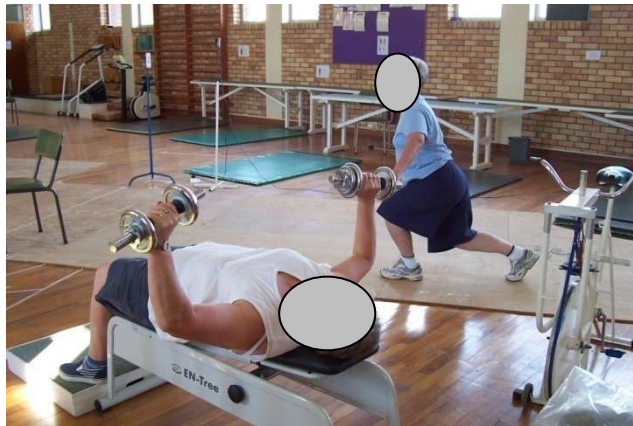


Figure 4: Subjects training large muscle groups

Phase 3: Weeks 9-12

With the larger muscle groups accustomed to machine weight-training, the FIND principle was applied again for an adjustment to the intensity of the workout. Smaller, more specific muscle groups were introduced as depicted in Figure 5, thus increasing the 'duration' of the exercise bout, and by the addition of more exercise, the intensity. Smaller muscle groups such as the biceps brachii, triceps brachii, gastrocnemius and the abdominal oblique muscles were brought into focus.



Figure 5: Subject executing a two-handed cable bicep-curl

Phase 4: Weeks 13 - 16

At this stage a full range of muscles had been introduced into the workout regime, and consolidation was required. During Phase 3, habituation of the new exercises had occurred, and in Phase 4 the emphasis was on increasing the intensity of the exercises, without introducing any new moves. Emphasis was placed on correct execution, breathing, and increases to the load during movement.



Figure 6: Subject (on left) executes an advanced abdominal exercise; subject (on right) executes a controlled machine-based abdominal crunch

Phase 5: Weeks 17 -20

Participants had completed 16 weeks of the training programme by this stage. Their general condition was such that by this stage the introduction of balance exercises and core-training principles could occur. Figure 6 illustrates a subject being assisted in completing an abdominal crunch on the exercise ball. The difficulty of exercises was increased by the addition of wobble and balance boards, Bosu ® Balls and exercise balls on which the exercises were to be executed. These offered an unstable base of support, thus forcing the participants to engage postural muscles previously under-utilised. Emphasis was also placed on the use of free weights (in the form of dumbbells and barbells) rather than machines, and also of body weight exercises (such as push ups and pull ups).

Phase 6: Weeks 21 - 24

This stage signalled the last four weeks of the 24-week programme. During this stage the duration and intensity of the exercise sessions were at “maximum” for the purposes of the training programme design. Frequency had remained constant (three sessions over a seven day period) throughout the training programme, as had the “nature” of the exercises executed (resistance type) due to the design of the study. During the final four weeks, participants were encouraged to develop independence, in the hope that once the study period was completed, they would continue to adhere to the routine they had become accustomed to over the preceding six months. Participants were also encouraged to engage in a range of machine, free weight and core-training exercises, at the highest viable intensity

whilst retaining correct execution and subjective feedback that indicated moderate to high effort, but did not drop below moderate and did not exceed high effort.

Table II: Training Programme

Exercise	Phase 1¹ 50%² Set/Rep	Phase 2 60% Set/Rep	Phase 3 60% Set/Rep	Phase 4 70% Set/Rep	Phase 5 70% Set/Rep	Phase 6 80% Set/Rep
Lat-Pull-Down Machine	1 12	1 12	2 12	2 12	3 12	3 12
Seated Cable Row	1 12	1 12	2 12	2 12	3 12	3 12
Chest Press	1 12	1 12	2 12	2 12	3 12	3 12
Leg Extensions	1 12	1 12	2 12	2 12	3 12	3 12
Abdominal Crunches	1 12	1 12	2 12	2 12	3 12	3 12
Hamstring Curls	1 12	1 12	2 12	2 12	3 12	3 12

¹ Where each phase is a period of four weeks

² % = percent of the pre-determined 1-RM

Programme Design

Table I (page 66) depicts the generic training programme followed for 24 weeks. Each phase represents an increase in intensity of effort, initially accompanied by an increase in session duration (from a minimum of 30 minutes to a maximum of 50 minutes). Later phases also introduced more difficult exercises to encourage interest and facilitate neuro-muscular training and adaptation.

MEASUREMENT AND EQUIPMENT

ANTHROPOMORPHIC

Resistance training programmes are not associated with significant weight loss unless combined with aerobic training and dietary caloric restriction. The effects of weight loss on cholesterol levels have been documented, and thus the subjects were instructed not to lose more than 10% of starting body mass. Participants were weighed every four weeks during the study on an electric Toledo® scale (Figure 7A) to monitor body weight in order to ensure that effects observed in the lipid profile reports could be attributed to the exercise programme alone. An initial measure of stature (Figure 7B) was attained by means of an adjustable stadiometer, and this measure was used in conjunction with the measure of body mass to calculate the body mass index (BMI) ratio every four weeks.



Figure 7: (A) Body mass and (B) stature measurements

Girth measures were obtained monthly at the same time as body mass measurements were taken, in order to track body composition changes. All measurements were obtained using the same flexible tape measure (Figures 8A, 8B, and 8C). It is well documented that resistance training increases fat free mass and lowers fat mass, without necessarily reducing body mass per se. The waist and the hip circumference measures were used to calculate the waist-to-hip ratio (WHR) which is an important indicator of abdominal adiposity and cardiovascular risk. It must be noted that the measurements were always conducted by the same individual, the principal researcher, in order to eliminate the effect of inter-individual differences in measuring techniques.

Girth measures were standardised as follows:

- Chest (over-bust): measurement taken across breasts at nipple level, with tape measure horizontal
- Upper arm (mid-humerus): (depicted in Figure 8A) measurement taken in the centre of the humerus (as determined by a measure between the top of the humerus and the head of the ulnar at elbow level)
- Waist: this measure was taken at the level of the umbilicus (navel) (Figure 8b)
- Hip: taken at the widest part of the hip region, from a lateral aspect (Figure 8C)
- Thigh (mid-quadricep): measured in the centre of the femur, bisecting the measure between the femoral head (palpated) and the centre of the patella
- Calf (mid-gastrocnemius): from a lateral aspect a measure was taken from the head of the fibula to the distal portion of the tibia and bisected to provide an accurate measure of the halfway point between knee joint and ankle joint



Figure 8: Girth measures of (A) mid-humerus (B) waist and (C) hip

SCREENING

Following the initial selection process subjects underwent a full physical examination, following the guidelines prescribed by the American College of Sports Medicine (ACSM) for safe commencement of exercise. The Specialist Physician attending the study examined all the candidates, and was also present for the sub-maximal stress cardiac electrocardiogram (ECG). All subjects underwent a two-hour oral glucose tolerance test (OGTT) as well as an initial full blood lipid profile (BLP) test. The OGTT revealed individuals with symptoms of diabetes (resistance to insulin), or full-blown diabetes. Two individuals were eliminated from the study, due to the interference of diabetic symptoms and medication with the BLP results. The remainder of the subjects did not express with symptoms of diabetes. The preliminary BLP test confirmed abnormalities of the BLP as a starting point for this study. This test also revealed individuals with dangerously high lipid profile values, and these individuals were not eliminated but for safety reasons were required to consult their GP prior to final acceptance.

LIPID PROFILE

It is well documented that a simple cholesterol measurement, revealing only the total cholesterol value, is insufficient in predicting cardiovascular risk. It is the ratio between the components of the lipid profile, namely the LDL-cholesterol, HDL-cholesterol and triglyceride content that are important. It was thus impossible to make use of finger-prick cholesterol tests for this study, and all blood tests had to be taken by a local pathology laboratory (Du Buisson's, Grahamstown).

Full, fasting blood lipid profiles were collected every four weeks from each individual. Each subject presented at the laboratory at 08h15 on the designated day, having fasted from 22h00 the previous night. The concept of being tested under fasted conditions, and the reasons for this requirement, were explained carefully to the subjects by the principal researcher. The qualified medical staff at the laboratory drew all the blood samples and carried out the subsequent biochemical testing on the blood. The blood was drawn into a 5ml BD (Becton-Dickinson) Vacutainer® (SST™ Advance Ref 367955) at the time of blood sampling. The blood was processed according to standard operating procedure (Appendix J) using the Dimension® Xpand® Plus clinical chemistry system. Once the analysis had taken place the blood was stored at -15°C. Results were returned to the principal researcher within 24 hours from the date and time of testing.

PERCEPTUAL RESPONSES

During the initial screening phase as well as during pilot testing and initial phases of the training programme, Borg's Rating of Perceived Exertion (RPE) scale was used to obtain the subjects' qualitative feelings of effort. The RPE scale is numerically rated from least effort (1) to highest effort (20) and is a reliable indicator of exertion related to heart rate (refer to Appendix F for a copy of the RPE scale used during this study). This indicator ensured that the individual was exerting the effort required, but also ensured safety, particularly during the sub-maximal stress-test during which the researcher did not require the subjects to exercise to maximum effort.

EQUIPMENT

All the machines used for the resistance training circuit programme were standard, commercially available Zest® weight-stack machines. The exercise balls utilized were original 65cm diameter burst-proof Gymnic Plus® and Body Sculpture® brands respectively. The 500mm x 500mm x 150mm square non-slip carpeted steps used to create a 450mm high step for free-stepping exercises were the property of the Human Kinetics and Ergonomics laboratory. Two Cybex® stationery cycles were used for the warm-up along with a Concept II® rowing ergometer. Flat interlinking gym mats were used on the floor to soften impact where necessary.

SUBJECT CHARACTERISTICS

SELECTION

Post-menopausal⁶ women aged between the ages of 50 and 75 years were sought from the broader Grahamstown community in the Eastern Cape of South Africa via an advertorial placed in a free community newspaper (“AdMix”) as well as via flyers which were placed in the waiting rooms of local medical practitioners, and in local pharmacies. The selection criteria were stated clearly in both the advertorial and on the flyer so that prior to contacting the principal researcher, the interested individual was aware of the criteria.

⁶ Post-menopausal status determined by reported cessation of regular menstrual cycles as an indication of reduced ovarian function and limited circulating oestrogen.

CHARACTERISTICS

Thirty-four women commenced the study in January and February 2008. Following exclusions from the study due to poor attendance, or the recurrence of pre-existing conditions, data from twenty-six subjects was used in the eventual analyses (n=26). The average age of the sample was 56.77 years (Table II). Of the subjects, 69% were post-menopausal (n=18) and 30% (n=8) were reportedly “peri-menopausal” (in the process of completing menopause). The peri-menopausal subjects were included in the study as each had understood that they had in fact entered menopause. It was only informally during the course of the 24 week period that the researcher was able to ascertain that in fact menses had not ceased entirely, despite initial assertions that this was the case. The fact that 7.7% (n=2) subjects were taking some form of natural (herbal supplement) hormone replacement therapy (HRT) at the time of participating in this study was recorded, and used in the analysis of the data. These subjects were included as natural or herbal HRT does not contain oestrogen or oestrogen derivatives but consists of herbs (such as ‘red clover’) which ameliorate the symptoms of menopause rather than reversing the mechanism of menopause.

Table III: Mean (\pm standard deviation) demographic data obtained from the participants

N	Age (Years)	Stature (mm)	Mass (kg)	BMI (kg.m⁻²)	WHR
26	56.77 \pm 4.12	1630 \pm 60	79.08 \pm 17.42	29.8 \pm 6.77	0.85 \pm 0.08

EXPERIMENTAL PROCEDURE

After information had been disseminated via local medical practitioners and pharmacies the researcher recruited interested individuals. Interested women contacted the researcher directly by means of email and telephonic communication. Once details for ten potential subjects had been gathered, an informative meeting was held. Three groups (A, B and C) were started as soon as there were enough participants. These groups commenced in mid-January, late-January and mid-February respectively (two weeks separated each group's commencement). These meetings took place in the Department of Human Kinetics and Ergonomics, in order to introduce the subjects to the facility in which the research would be conducted. Each potential subject was furnished with a comprehensive subject file, containing basic information pertaining to the study, as well as letters of information and consent forms. The contents of these files can be viewed in Appendix C. The principal researcher explained the background to the study, and outlined the requirements of the study in detail. Potential participants were afforded a chance to

ask questions, and these were handled by the researcher. Participants took the information home to read it thoroughly before making a commitment to the study. Within a week, each committed participant returned to the laboratory to attend a session for habituation to the machine-based exercises, and for an assessment of the 1-RM. This session did not count as an exercise session, but rather as an informative workshop.

Sub-maximal ECG tests as well as full physical exams by a Specialist Physician were scheduled prior to commencement of the exercise phases. Each subject committed to a 15-minute timeslot during given afternoon sessions during which the ECG was run using the Bruce sub-maximal cycle ergometry test (ACSM, 1986). The attending Specialist Physician viewed and analysed each ECG print-out. In instances where the medical specialist was not satisfied with an ECG reading, the subject was re-tested on a different day. The Specialist Physician also tested supine, sitting and standing blood pressure, assessed individuals for circulatory problems, and obtained a full medical history from each participant.

During this time subjects were also allocated a specific morning on which to present at the local pathology laboratory for an initial fasting blood lipid test as well as a two-hour oral glucose tolerance test (OGTT). It was important to screen for incipient diabetes in subjects who might be unaware of any blood-sugar related disorder. The OGTT revealed two subjects with abnormal⁷ blood glucose levels and the researcher immediately referred these women to their general practitioners. These potential subjects were also screened from the study due to the evidence of abnormal insulin activity.

⁷ "Abnormal" as defined by guidelines followed by the pathology laboratory

With the preliminary tests complete, the subjects commenced the exercise phase. Exercise sessions were offered Monday to Friday at 06h00, 07h00, 13h00, 16h00 and 17h00 which permitted individual flexibility in attending three sessions weekly. Each session was supervised by the researcher or a research assistant (all of whom were first year Masters students in the Department of Human Kinetics and Ergonomics). This routine continued for the duration of the six month data collection period.

IMPLEMENTATION

Once the subjects had been selected and screened, training commenced. Supervised sessions were offered according to most popular time choices as selected by the participants themselves. Each subject was required to attend three weekly sessions. Initially, an evaluation of the 1-RM for the subject group was undertaken in order to establish workout intensity, starting at 50% of the 1-RM. Intensity increased after four weeks, to 60% of the 1-RM, and after a further four weeks to 70% of the 1-RM. This gradual increase in weight allowed the previously sedentary participants at least 12 sessions to adapt and permitted for muscular and systemic adaptations before progressing to the next intensity and thereby stressing the system once more. The progression of intensity coincided with the monthly lipid and anthropomorphic measurements, and thus the completion of a "phase" of four weeks heralded not only a new intensity, but results from 12 sessions worth of exercises.

As the sessions were always supervised, safety was assured, but adherence to the required exercises and intensities was also monitored. Correct execution of the exercises was also evaluated, and assistance was offered where necessary.

PROGRAMME MANAGEMENT

The principal researcher co-ordinated all sessions, communicated with all the subjects and with the research assistants, and liaised with the Specialist Physician and Supervisor to this study at all times. All queries from subjects, assistants, and the supervisor were referred immediately to the principal researcher.

RESEARCH ASSISTANTS

Six female postgraduate students from the Department of Human Kinetics and Ergonomics at Rhodes University in Grahamstown volunteered to assist with supervision of the exercise sessions for the duration of the study (see Figure 9). A roster of weekly exercise sessions was established by the principal researcher and the assistants self-selected sessions to supervise.



Figure 9: Research assistant assisting subject during training session

COMMUNICATION AND INFORMATION

Communication was a fundamental feature of this research. Not only was it important to communicate organizational information, such as exercise session times and dates, or changes thereto where required, but communication became a vital external motivator for the cohort. Email was the primary means of contacting the group as a whole. This proved very effective, and was well received by the recipients. Short messages (“texts”) and phone calls were also frequent, particularly in instances unique to a particular subject, such as illness, or absenteeism. The attendance register provided a reference tool for the researcher and absenteeism was quickly identified and followed up on. Apart from the subjects who withdrew from the study due to pre-existing conditions (namely fibromyalgia, chronic bronchitis and chronic back pain) illness did not play a major role in absenteeism. Unforeseen absence due to family crises did affect three individuals, but these subjects had an otherwise excellent attendance record and fell within the 80% compliance requirement.

Face to face interaction is by far the most effective tool, and the principal researcher interacted with subjects throughout the six month study at exercise sessions on a weekly basis. Feedback was also received via a session diary which was maintained per session by the supervisor of that session. This diary provided invaluable information not only regarding progress of individuals during the study, but also of subjective information used later in the discussion of the results.

Social interaction between the researcher, the assistants, the participants, and also among the participants was noted to be very important in the cohesion of the cohort. This led to regular meetings being held, where social interaction was encouraged (tea and coffee were served), general discussion was initiated, and areas of interest pertaining to the study or allied queries were explored. The researcher undertook to research the various queries received and presented the literature by means of an informal lecture. When they became available, results were shared, and feedback pertaining to the group was made available to all. Subjective reports were sought from the participants, and these provided invaluable insight into the progress of the group. The greatest value of these interactions was the motivation it afforded. The element of competition naturally established amongst the candidates served to motivate the individuals and certainly contributed to maintaining attendance levels throughout the 24 week study.

STATISTICAL ANALYSES

Repeated measures analyses of variance (ANOVA) were used to examine the intra-individual effects across the time length from time of commencing the study to the end of the research period, thus examining seven sets of data per subject in the

cohort (n=26). Repeated measures ANOVAs were also used to test for BMI and age effects on the scores of LDL, HDL, triglycerides and total cholesterol across the seven time periods. Tukey post-hoc multiple comparison tests were used for significant group effects. Prior to analyses, homogeneity of variances and normality of the data were examined using Levine's tests and Shapiro-Wilk's tests, respectively (Johnson and Wichern, 2002). Statistical significance was set at the 5% level of significance. All tests were performed using Statistica © (StatSoft, 2007).

CHAPTER IV

RESULTS

INTRODUCTION

The purpose of this investigation was to establish whether a progressive resistance training programme would affect the blood lipid levels in a cohort of post-menopausal women. The resistance training programme was 24 weeks in duration, and comprised three training sessions per week, each lasting 45 minutes. Intensities of the training programme varied progressively from 50% to 80% of 1-repetition maximum (1-RM). In order to be included in the analyses participants had to have attended at least 80% of the sessions, which was true for 26 subjects. Anthropometric measurements (girth and mass) were recorded at the start and every four weeks thereafter and a full fasting blood lipid analysis was required at the same time period. The variables under consideration were analysed independently and were later assimilated into an integrated discussion for a holistic investigation into the effects of the resistance training programme. In addition, within effects such as the effects of age and pre-test body mass index were evaluated.

ANTHROPOMETRIC MEASURES

All girth measures recorded prior to and monthly during the trial are shown in Table V. Due to the large number of significant differences these are not shown in the table but are discussed within the text and in Chapter VI with the hypotheses. Significant decreases from the starting measure are shown in each figure.

Table IV: Anthropometric mean values of the sample investigated¹

	Stature (mm)	Body Mass (kg)	Body Mass Index (kg.m⁻²)	Waist to Hip Ratio
Pre-Test	1630 (60)	79.08 (17.42)	29.80 (6.77)	0.85 (0.08)
Month 1		78.64 (17.34)	29.65 (6.79)	0.84 (0.08)
Month 2		78.60 (17.13)	29.62 (6.68)	0.84 (0.08)
Month 3		78.69 (17.28)	29.36 (6.60)	0.83 (0.07)
Month 4		78.58 (16.93)	29.64 (6.61)	0.83 (0.08)
Month 5		78.63 (16.81)	29.67 (6.48)	0.84 (0.08)
Month 6		78.31 (16.80)	29.51 (6.51)	0.84 (0.08)

¹Standard deviations are indicated in brackets

[- refers to significant difference

Table IV presents an overview of the changes to body mass, the body mass index (BMI) and the waist-to-hip ratio (WHR) over the course of the 24 week study. No significant changes were noted in either body mass or the BMI, however the pre-test WHR measure was significantly different to the measure taken at month three.

BODY MASS

If diet is not altered or energy intake is in fact increased to balance the increased energy requirement of the training regime, body mass is not expected to change during a resistance training programme. This is primarily due to the development of muscle density during strength training, which has the effect of raising the simplified measure of scale weight. The increased muscle fibre density does contribute to a greater requirement for fuel and thus it is noted that metabolism does increase as a result of resistance training (McArdle **et al.**, 1996). Increased metabolic cost has the effect of reducing fat mass, improving the relative composition of the body – increased muscle mass, and reduced fat mass – without a concomitant reduction in weight (McArdle **et al.**, 1996).

As decreases in body mass are known to impact positively on the lipid profile (Volek **et al.**, 2008) it was important in this study that body mass did not change. This was the case, as pre-test body mass (79.08 ± 17.42 kg) did not change significantly (Table III and Figure 10) over the course of 24 weeks (78.31 ± 16.8 kg). It is evident in Figure 10 and Table III that there were large variations in body mass in the group as a whole. Body mass of the sample at the start of the experiment ranged from 55.36kg to 119.12kg, a 63.76kg difference. This was expected as subjects were not selected based on a specific body mass but were rather accepted on the basis of possessing one or more abnormal blood lipid profile values, sedentarism, and age (50 to 75 years of age).

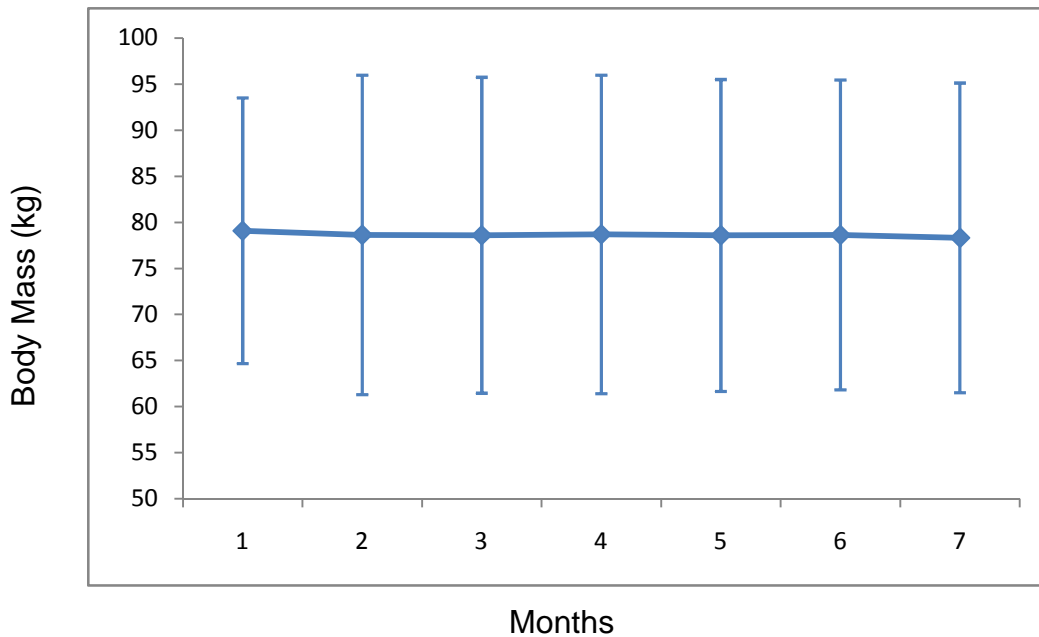


Figure 10: Body mass (kg) of the sample prior to, and during the resistance training programme

BODY MASS INDEX

As expected body mass index (BMI) reflected similar, non-significance at $p=0.05$ with a mean of $29.8 \pm 6.77 \text{ kg.m}^{-2}$ prior to the testing phase and a mean of $29.51 \pm 6.51 \text{ kg.m}^{-2}$ after completion of the 24 weeks of training (Table III). Pre-test waist to hip ratio (WHR) (0.85 ± 0.08) did not change significantly except for the third month when there was a significant decrease (0.2 lower than the pre-test measure) at $p=0.05$.

It is of interest to note that individuals with BMI values within the normal range ($20 - 24.9 \text{ kg.m}^{-2}$) expressed with hypercholesterolaemia as well as individuals with BMI values of greater than 35 kg.m^{-2} (considered extremely high). Notably this variation remained constant throughout the programme; there was a 0.62 difference between the pre-test standard deviation and the deviation for the results at month six. From

this it can be inferred that as the standard deviations did not change it appears that pre-test BMI did not affect body mass changes. Those with the lowest starting BMI values experienced similar body mass fluctuations as those with the highest pre-test BMI scores.

WAIST-TO-HIP RATIO

Pre-test waist to hip ratio (WHR) of $0.85(\pm 0.08)$ was significantly reduced (2.35% decrease) after 12 weeks of training (0.83 ± 0.07). However, after 12 weeks, this value stabilized (Table III) and increased slightly between weeks 16 and 20 to $0.84(\pm 0.08)$ at 24 weeks (representing a total non-significant decrease over the period of the study of only 1.18%). WHR represents the central morphology of the body, and values closer to 1.0 indicate 'apple' shaped individuals, who tend to carry weight in the trunk region as opposed to those with a WHR closer to 0.7 which is an indicator of the 'pear' shape and a tendency to carry weight across the hip region. There is a general sexual dimorphism in that men tend toward the apple shape (or, if lean, a narrower but uniform width at waist and hips) and women tend to be pear-shaped due to wider pelvic girdles (McArdle **et al.**, 1996).

There was a wide range of WHR in the current sample. The highest WHR of the group was 1.01 (BMI $27.2\text{kg}\cdot\text{m}^{-2}$) and the lowest 0.73 (BMI $25.7\text{kg}\cdot\text{m}^{-2}$). Notably, corresponding BMI values indicated in brackets, are both lower than the group average of $29.8\pm 6.77\text{kg}\cdot\text{m}^{-2}$ but both fall within the range. The shape of the sample therefore varied considerably.

ABDOMINAL VISCERAL FAT

Waist to hip ratio (WHR) was analysed and it was found that the LDL:HDL ratio in a subject with a WHR of 1.01 reflected greater cardiovascular risk than did the ratio for a subject with a WHR of 0.73. Waist circumference was not demonstrably linked to plasma lipoprotein concentration in the current study but this circumference measure did decrease by 5.06% overall over the course of 24 weeks.

GIRTH MEASURES

Also consistent with expectations were the significant reductions to girth measures at mid-humerus, (over-bust) chest, waist, hip, mid-quadricep and mid-gastrocnemius (Table II). Reflective of an improved body composition, as a result of muscle strength gains (evident by the increase in resistance training load from 50% to 80%), these findings indicate that the individuals were indeed exposed to a sufficient training dose to elicit body composition alterations.

Most circumference measures decreased from as early as four weeks, with continued significant decreases at eight, 12, 16, 20 and 24 weeks (Table IV). A plateau would infer that the individuals had been training at the same intensity and duration for too long, which offers the body sufficient time to adapt and then to become used to the training dose (McArdle **et al.**, 1996).

Table V: The mean girth measures for the sample (\pm standard deviations)³

	Chest (mm)	Waist (mm)	Hip (mm)	Arm (mm)	Mid-Quad¹ (mm)	Mid-Gastroc² (mm)
Pre	1062.2 (136.9)	947.9 (149.9)	1112.8 (122.4)	312.7 (41.4)	537.1 (60.1)	372.7 (44.3)
Month 1	1045.0 (123.9)	925.3 (141.9)	1090.4 (115.1)	307.6 (38.9)	537.0 (58.0)	369.6 (38.1)
Month 2	1038.9 (122.4)	909.5 (138.3)	1076.1 (113.0)	302.3 (38.1)	522.7 (55.7)	367.5 (36.3)
Month 3	1026.8 (121.9)	899.6 (130.2)	1077.5 (112.7)	301.2 (36.6)	517.9 (53.4)	364.0 (37.4)
Month 4	1023.0 (125.9)	899.7 (135.2)	1073.8 (113.2)	300.3 (38.1)	512.1 (56.4)	359.1 (37.9)
Month 5	1029.8 (118.9)	905.0 (131.7)	1072.3 (113.0)	298.7 (34.9)	503.4 (49.1)	354.1 (36.2)
Month 6	1028.9 (118.5)	902.3 (132.2)	1071.7 (113.5)	298.2 (34.8)	502.5 (48.6)	354.6 (35.7)

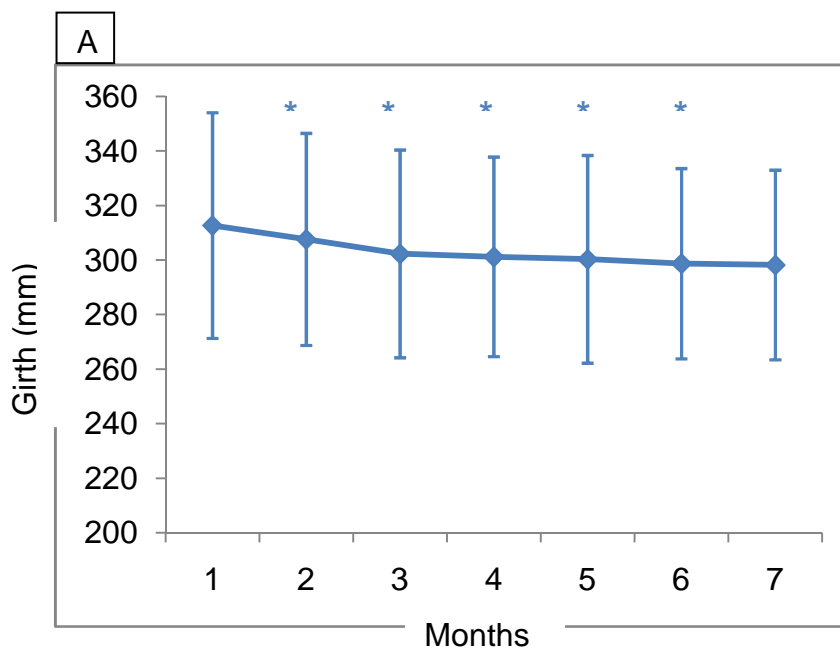
Shaded blocks refer to lowest values

¹ “Quad” refers to quadriceps muscle group

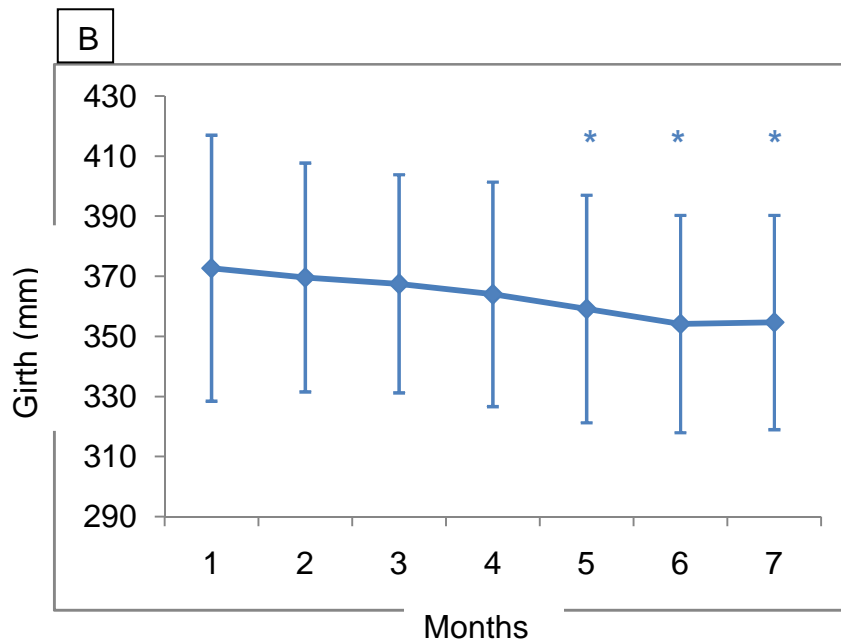
² “Gastroc” refers to the gastrocnemius muscle

Distal Extremities: Upper and Lower

Central upper extremity (humerus) measures (Figure 11A) decreased significantly between pre-test measures ($312.7\pm 41.4\text{mm}$) and measures taken at months two ($302.3\pm 38.1\text{mm}$), three ($301.2\pm 36.6\text{mm}$), four ($300.3\pm 38.1\text{mm}$), five ($298.7\pm 34.9\text{mm}$) and six ($298.2\pm 34.8\text{mm}$) (Table IV). Pre-test mid-gastrocnemius circumference ($372.7\pm 44.3\text{mm}$), as well as the measurement after four weeks ($369.6\pm 38.1\text{mm}$) and eight weeks ($367.5\pm 36.3\text{mm}$), were significantly higher ($p=0.05$) than measures repeated at months four ($35.91\text{cm}\pm 3.79$), five ($35.41\text{cm}\pm 3.62$) and six ($35.46\text{cm}\pm 3.57$) (Figure 11B).



Significances ($p=0.05$): * = Pre (1) and 2, 3, 4, 5, 6 (A)



Significances(p=0.05): Pre (1) and 5, 6, 7

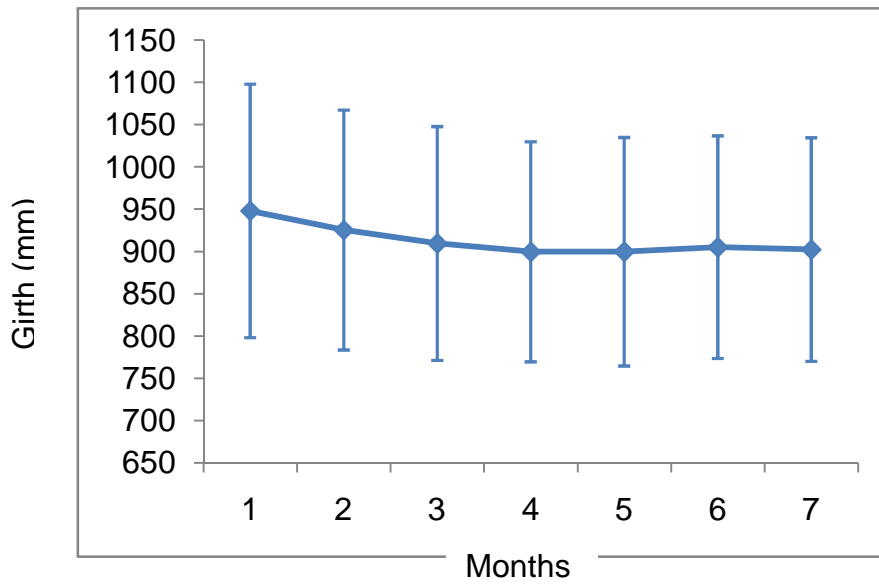
Figure 11: Distal extremity girth changes over the course of the study. Upper extremity (A) and lower extremity (B).

Chest

Pre-test (over-bust) chest measurements (1062.2 ± 136.9 mm) shown in Table IV (page 86) dropped significantly after months two (1038.9 ± 122.4 mm), three (1026.8 ± 121.9 mm), four (1023 ± 125.9 mm), five (1029.8 ± 118.9 mm) and six (1028.9 ± 118.5 mm). Chest circumferences measured after four weeks of training were 22mm greater than those recorded at 16 weeks.

Waist

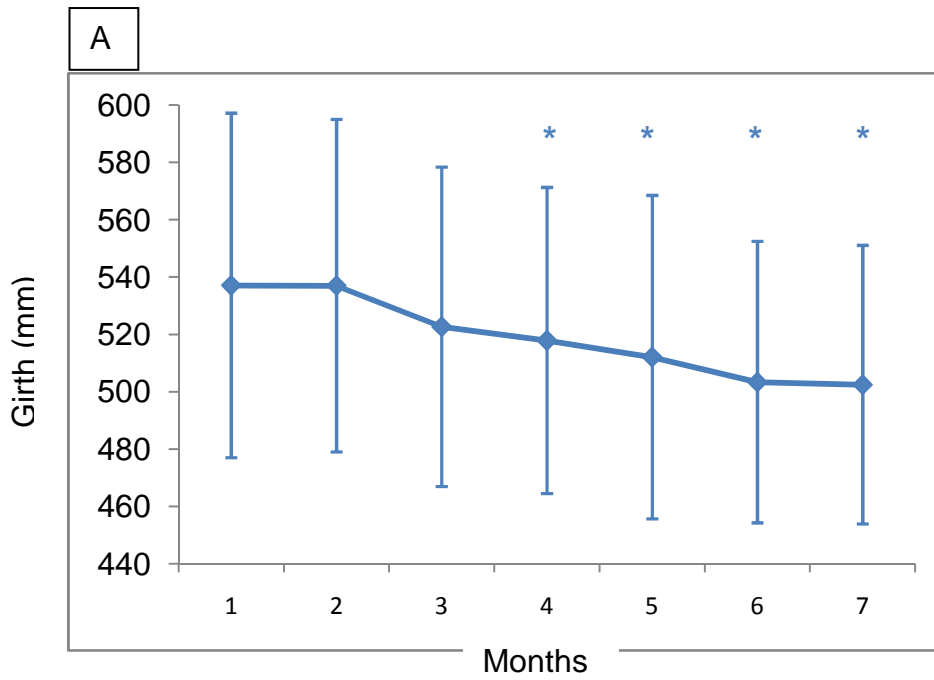
Waist measurements (Figure 12) displayed the quickest change with the pre-test circumference of 947.9mm (± 149.9) significantly higher than all subsequent measures.



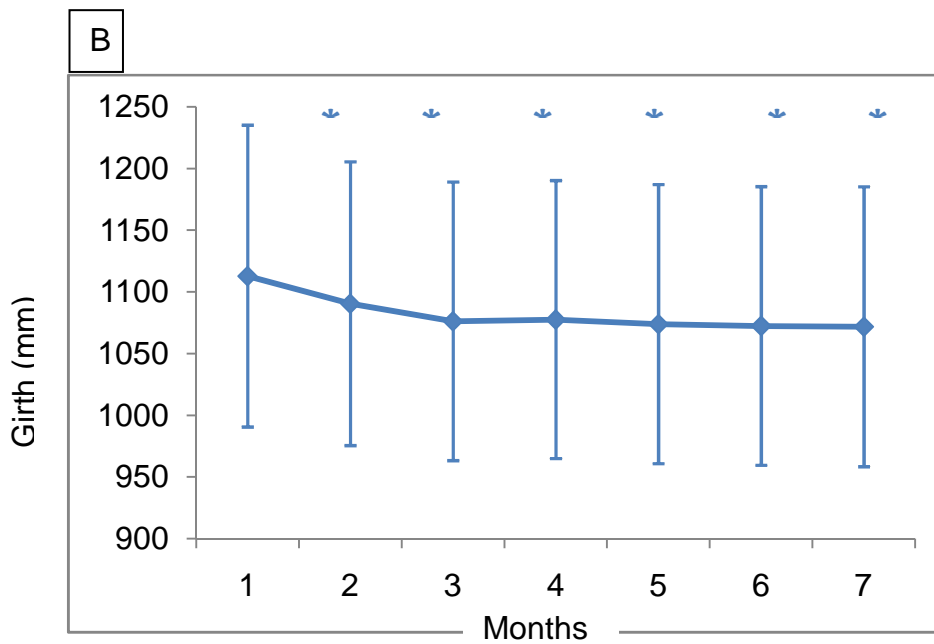
Significances (p=0.05): *= Pre (1) and 2, 3, 4, 5, 6, 7

Figure 12: Central morphology (waist circumference) changes over the course of 24 weeks

In addition, 925.3mm (± 141.9), recorded at week four was significantly higher than the measures obtained at weeks 16, 20 and 24 ($p=0.05$). Waist circumference measures are an indicator of the presence of abdominal visceral fat (AVF) which has been positively correlated to cholesterol content of the blood. Mean waist circumference dropped by 45.6mm over the course of 24 weeks.



Significance (p=0.05): *= Pre and 4, 5, 6, 7 (A)



Significance (p=0.05): *= Pre and 2, 3, 4, 5, 6, 7 (B)

Figure 13: Proximal extremity girth measures: (A) mid-quadricep and (B) hip circumferences

Mid-Quadricep

The largest overall loss of body mass per region (Table V), as indicated by the girth measures, occurred in the lower extremity at the level of mid-quadricep (total loss of 6.44% over 24 weeks). The mid-gastrocnemius girth measure, which also represents the lower extremity, dropped by 4.86% over the course of the six month study, representing the second largest decrease in circumference. As central girth decreases took place (waist decreased by 4.81%), the upper extremity loss of 4.64% was also notable and, together with the lower extremity results, indicates that the greatest weight loss occurred at the extremities followed by the waist with the fewest changes occurring in the upper regions of the body and the hips.

Table VI: Girth changes from pre-test value to final measure

	Thigh (mm)	Calf (mm)	Waist (mm)	Arm (mm)	Hip (mm)	Chest (mm)
Pre-test value	537.1	372.7	947.9	312.7	1112.8	1062.2
Final Measure	502.5	354.6	902.3	298.2	1071.7	1028.9
% decrease	6.44	4.86	4.81	4.64	3.69	3.14

Interactions

The chest and waist girth measures reflect the abdominal area which is the site of “abdominal visceral fat” which increases with increasing age independent of the body mass index. Within 12 weeks chest circumference had decreased by 3.33% and over the course of the following 12 weeks this circumference increased by 0.19%, a trend mirrored by the waist circumference which had decreased by 5.06% but then increased again by 0.25%.

Represented by the mid-humeral measure, the upper extremity lost 3.68% of the initial circumference measure within 12 weeks and only losing a further 0.96% in the second half of the training programme. The circumference measure at the level of mid-quadricep showed a less noticeable decrease of 3.57% by 12 weeks, only dropping by a further 2.87% thereafter. As the mid-humeral and mid-quadricep measures represent the extremities it could be concluded that weight lost further away from the trunk region does not happen quickly but after 24 weeks reflected the highest decrease overall. In contrast, the central regions represented by (over-bust) chest and waist measures seemed to decrease very quickly, reaching the highest decrease (3.33% and 5.06% respectively) by week 12, but tended to plateau and even increase slightly thereafter despite continuation of the exercise programme and increased levels of intensity every four weeks. It is possible that a critical level of fat loss occurs in the central region after which diet must be altered in order to see further decreases to this measure. In addition, given that resistance training continued for a further 12 weeks after the lowest values were recorded, it is also possible that muscle mass was increased with increasing intensity of the training programme. Rectus Abdominus (RA) which lies superficially over the anterior of the trunk region responds to resistance training by increasing in strength as a result of

greater muscle-fibre density which can increase the circumference of the area measured directly above the site of the RA muscle.

BLOOD LIPID PROFILE MEASURES

The changes in the blood lipid profiles of the post-menopausal women are shown in Table VI. The results of this study indicate that the blood lipid profile was not positively affected by this bout of exercise over a period of 24 weeks. Given that the morphological changes to the participants reflect that the exercise prescribed during this time was not only of a sufficient intensity, but also that it precluded stagnation in that it was progressive, this is not an expected result.

The cohort was previously sedentary in order to magnify the effects, if any, of the introduction of exercise to their lifestyles. In addition the participants were screened for health complications which could affect response to exercise, and were non-smokers. Apart from presenting with one or more unhealthy lipid profile values it can be assumed that the subjects did not present with any inherent reasons which could have affected the efficacy of the training programme. However, it must be acknowledged that it was beyond the control of the researcher to stringently monitor every aspect of the cohort's lifestyles due to the length of the study and the fact that the subjects were engaged in habitual lifestyle practices outside of the exercise session times.

Table VII: Plasma lipoprotein changes over 24 weeks

	LDL	HDL	Triglycerides	Total Cholesterol
Pre-Test (mmol.L⁻¹)	3.61 0%	1.55 0%	1.54 0%	5.81 0%
+ 4 weeks	4.71%	-6.45%	17.65%	3.61%
+ 8 weeks	0.55%	-3.87%	20.92%	2.24%
+ 12 weeks	6.09%	-3.23%	16.34%	5.85%
+ 16 weeks	10.53%	-3.87%	9.15%	7.06%
+ 20 weeks	11.91%	-4.52%	3.27%	7.57%
+ 24 weeks	12.74%	-8.39%	7.84%	7.40%

Shaded areas depict largest deviation from pre-test value

LDL refers to Low Density Lipoprotein; HDL refers to High Density Lipoprotein

Overall both LDL-cholesterol and total cholesterol increased significantly from week 16 onwards. Triglycerides remained fairly stable, while HDL-cholesterol decreased significantly by 24 weeks.

A healthy lipid profile (Figure 14) would reflect LDL as less than 2mmol.L^{-1} , triglyceride concentration below 2.26mmol.L^{-1} and total cholesterol below 5mmol.L^{-1} .

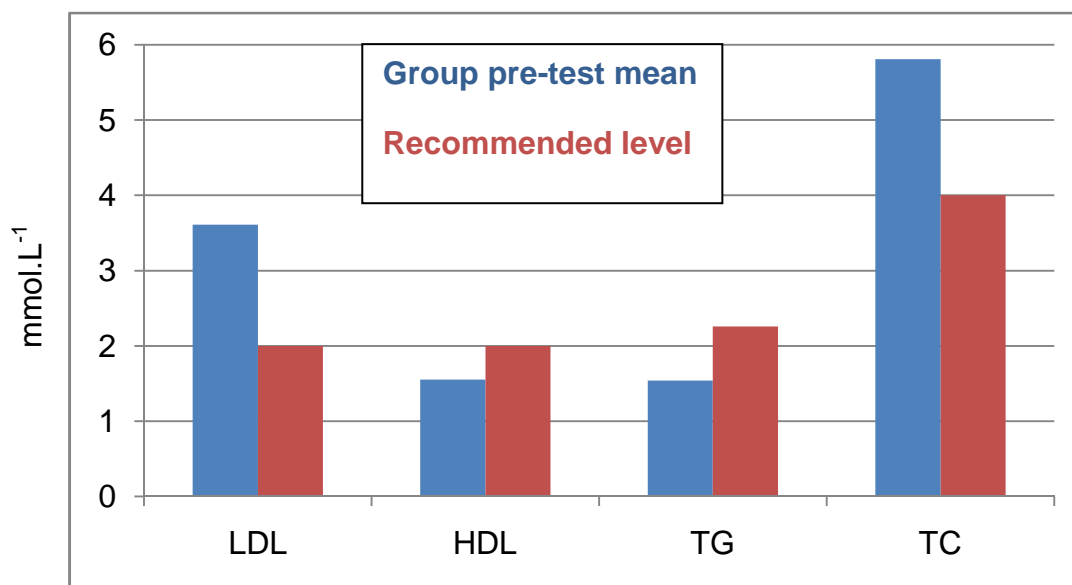
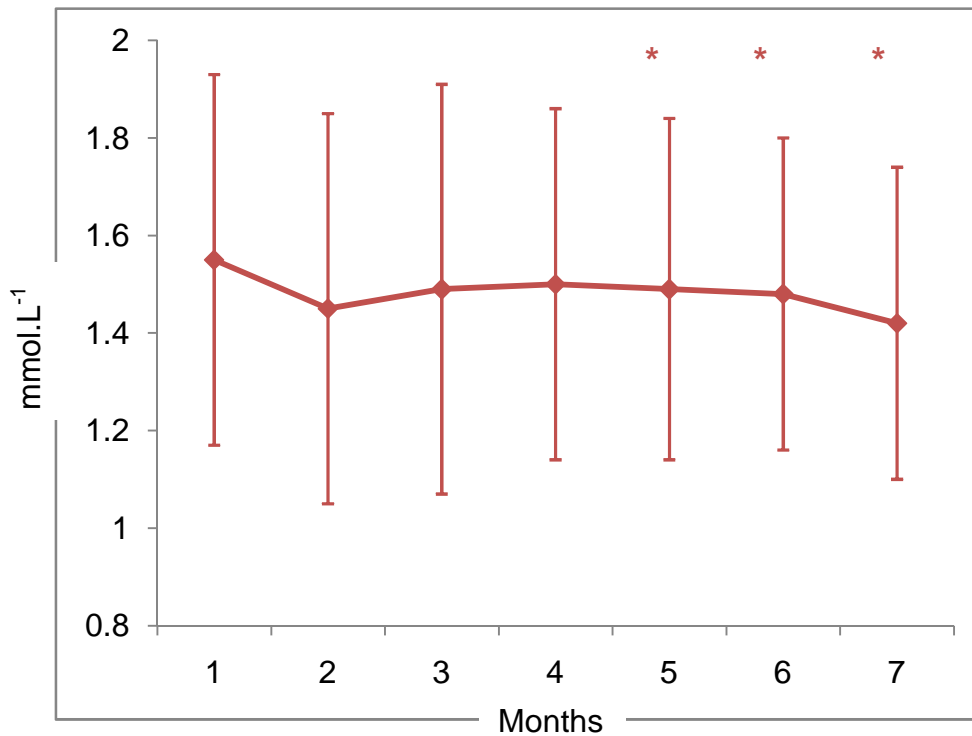


Figure 14: Group mean pre-test blood lipid profile data compared to recommended healthy lipoprotein levels

HIGH DENSITY LIPOPROTEIN

In contrast, HDL cholesterol decreased significantly over time (Table VI and Figure 15). Mean HDL at the start of the training programme was 1.55mmol.L^{-1} and at 24 weeks it had dropped by 8.39% to 1.42mmol.L^{-1} .



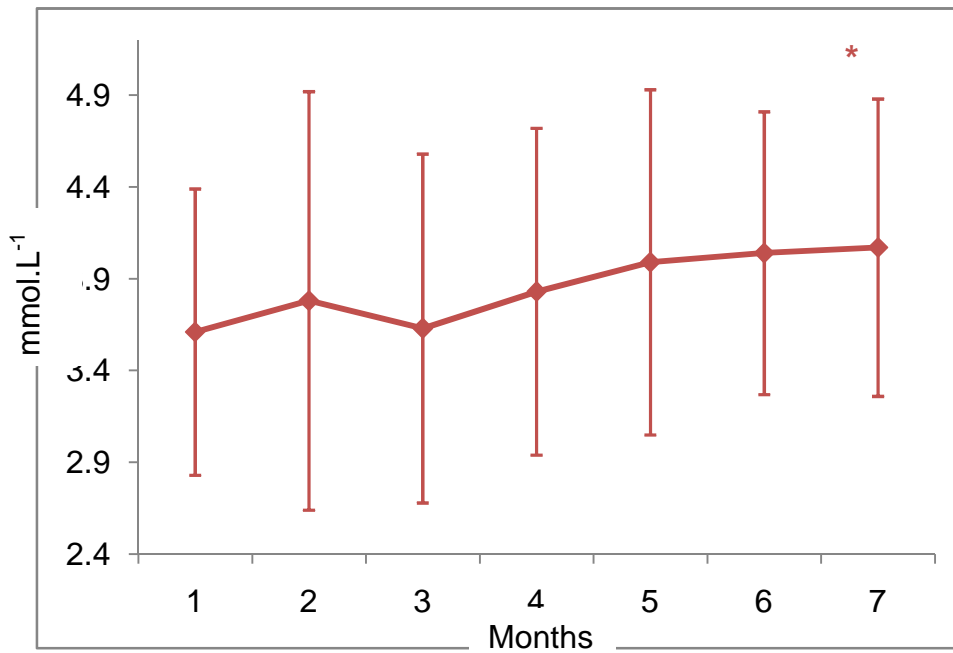
Significance (p=0.05): Pre (1) and 5, 6, 7

Figure 15: High Density Lipoprotein

Between the pre-test measure and week four HDL-cholesterol decreased by 6.45% which was the largest perturbation in this lipoprotein during the 24-week study. Between the first and third months HDL increased steadily by 3.22% and then decreased steadily by 5.12% between months three and six. The greatest deviation from the pre-test value occurred at the final measure of 1.42mmol.L⁻¹.

LOW DENSITY LIPOPROTEIN

LDL-cholesterol increased significantly when comparing the first two months to the remaining four months (Figure 16 and Table VI).



Significance (p=0.05): Pre (1) and 7

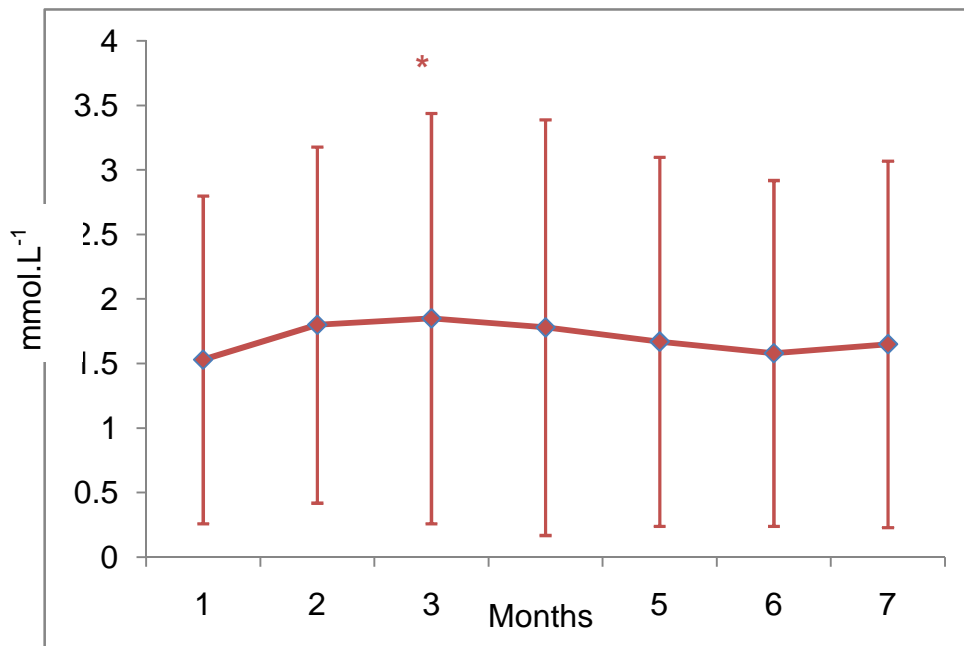
Figure 16: Low Density Lipoprotein

From pre-test ($3.61 \pm 0.78 \text{ mmol.L}^{-1}$) to the last measure ($4.07 \pm 0.81 \text{ mmol.L}^{-1}$), LDL increased by 0.46 mmol.L^{-1} . During the first four weeks LDL-cholesterol increased by 4.71% and by the third month LDL had increased to 6.09% higher than the pre-test value. A 6.65% increase from months three to six suggest that the increase in LDL-cholesterol was greater during the latter 12-weeks and not the first 12-weeks of the 24-week study. Between the second and third months LDL in fact decreased by 4.61% only to increase by 5.54% between the third and fourth months. The greatest increase from the pre-test value occurred in month six.

TRIGLYCERIDES

Triglycerides followed a similar pattern, increasing significantly until eight weeks, after which no significant difference was noted (Table VI and Figure 17). However,

the trend was for triglycerides to decrease as the final measure (1.65mmol.L⁻¹) was only 0.12mmol.L⁻¹ higher than the pre-test measure (1.55mmol.L⁻¹).



Significance (p=0.05): Pre (1) and 3

Figure 17: Triglycerides

By week eight triglycerides had increased by 20.92%, which was the largest deviation from the pre-test value overall, for triglycerides. Over the following 12 weeks triglycerides decreased by 17.65% to a level of 1.58mmol.L⁻¹ at month five, but saw an increase of 4.57% between months five and six (Table VI).

TOTAL CHOLESTEROL

In keeping with this trend, total cholesterol increased by 0.43mmol.L^{-1} over the course of the 24 week study from $5.81(\pm 0.92)\text{mmol.L}^{-1}$ to $6.24(\pm 1.07)\text{mmol.L}^{-1}$ (Figure 18).

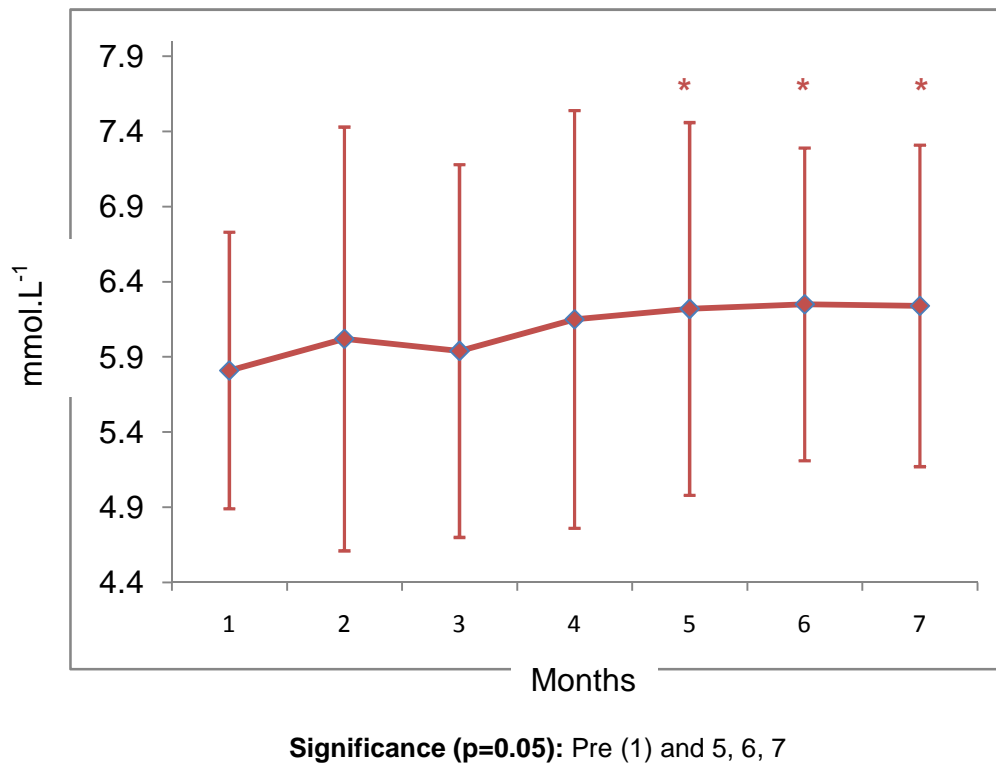


Figure 18: Total Cholesterol

Between months one and three total cholesterol increased by 5.85% and over the course of the following 12 weeks increased a further 1.55% indicating that the fastest increase occurred in the initial 12-week period (Table VI). The final measure reflected the largest difference to the pre-test measure (7.40% higher).

The changes observed in the blood lipid profile parameters were very different in peri- as opposed to post-menopausal subjects (Figure 28).

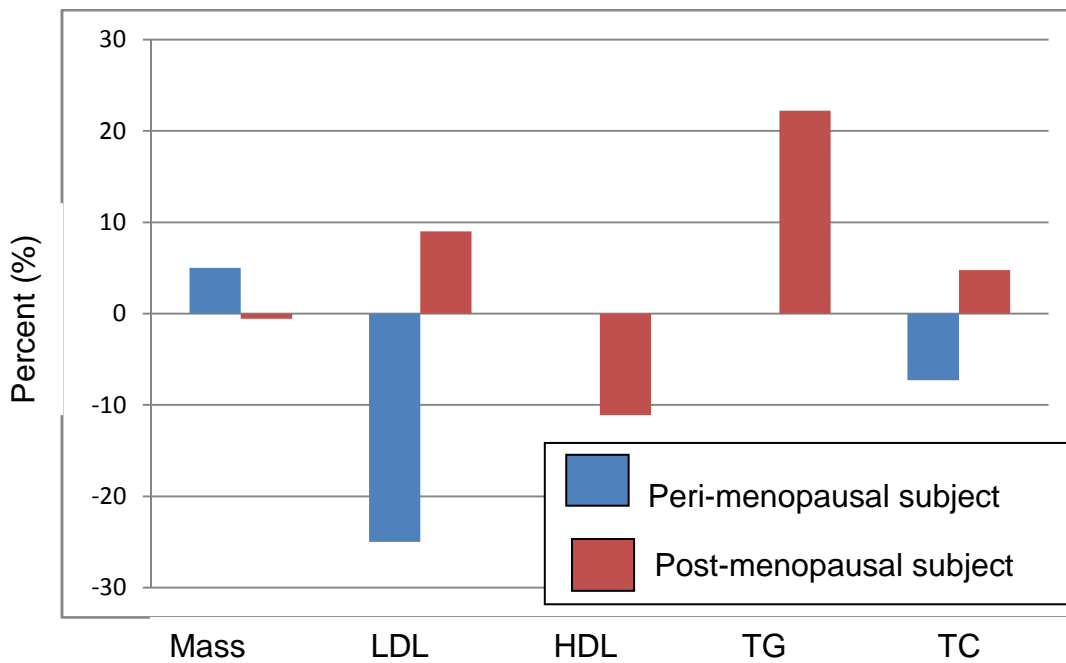


Figure 19: Peri-menopausal and post-menopausal age-matched subjects' responses

While the profile of the peri-menopausal subject appeared to alter positively over the course of 24 weeks, the profile belonging to the post-menopausal subject elicited no such change and appeared less healthy than it had at the commencement of the training programme.

MULTIVARIATE ANALYSES

BODY MASS INDEX

Multivariate analyses revealed that pre-test BMI was linked to HDL levels (Figure 19). Subjects whose starting BMI fell within the “normal” range ($20 - 24.9\text{kg.m}^{-2}$) had significantly higher HDL levels ($p=0.006$) than subjects who began the training programme with a BMI within the “very high” range (greater than 35kg.m^{-2}). This is in keeping with the findings of Laws **et al.** (1993) who found an inverse relationship between BMI and HDL-cholesterol.

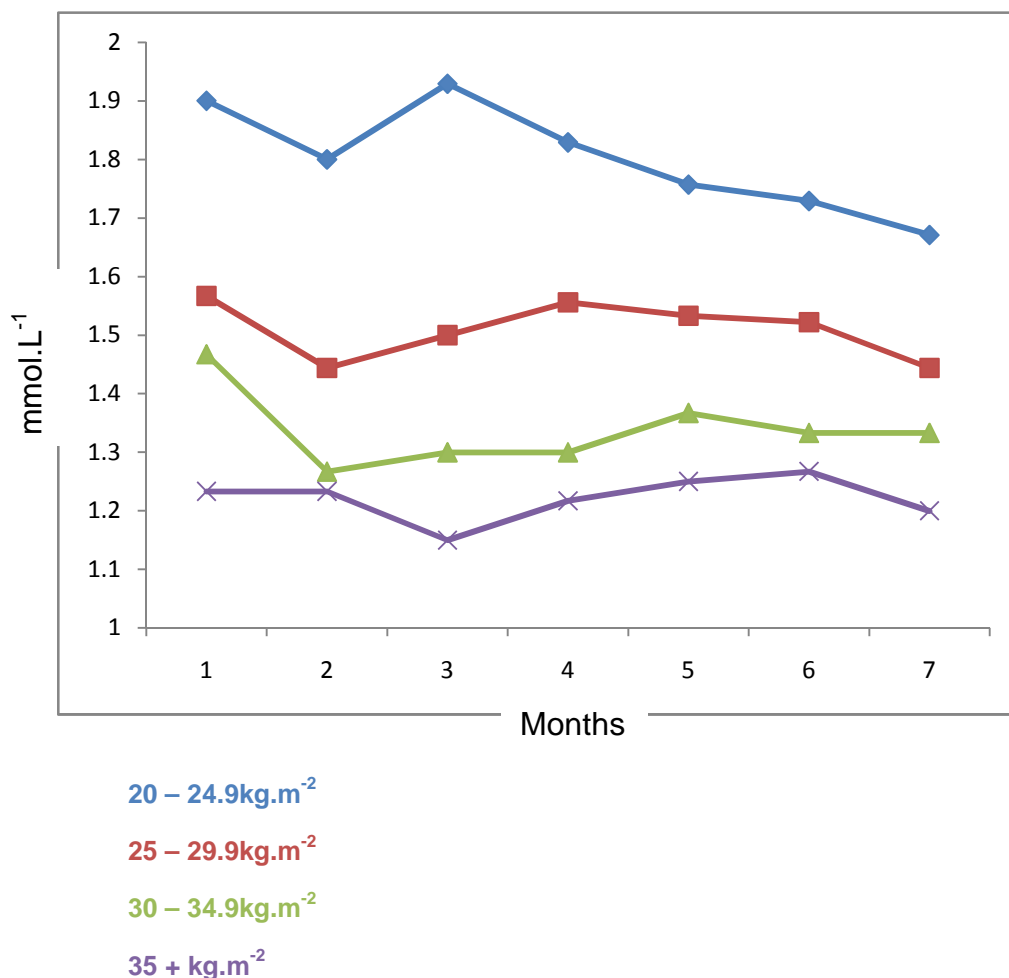


Figure 20: Representation of body mass index and high density lipoprotein

No relationship was found between pre-test body mass index and low density lipoprotein (Figure 20). Similarly triglycerides did not display any reaction related to the body mass index (Figure 21).

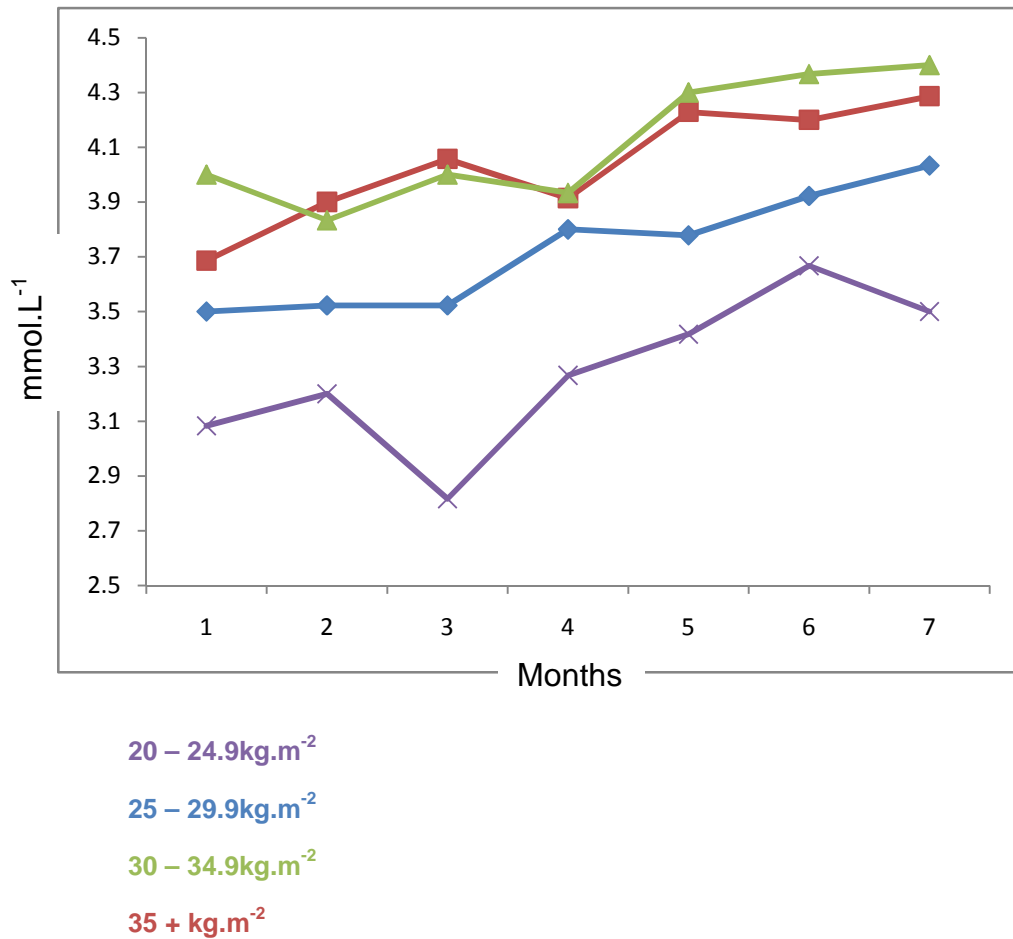


Figure 21: Representation of body mass index and low density lipoprotein

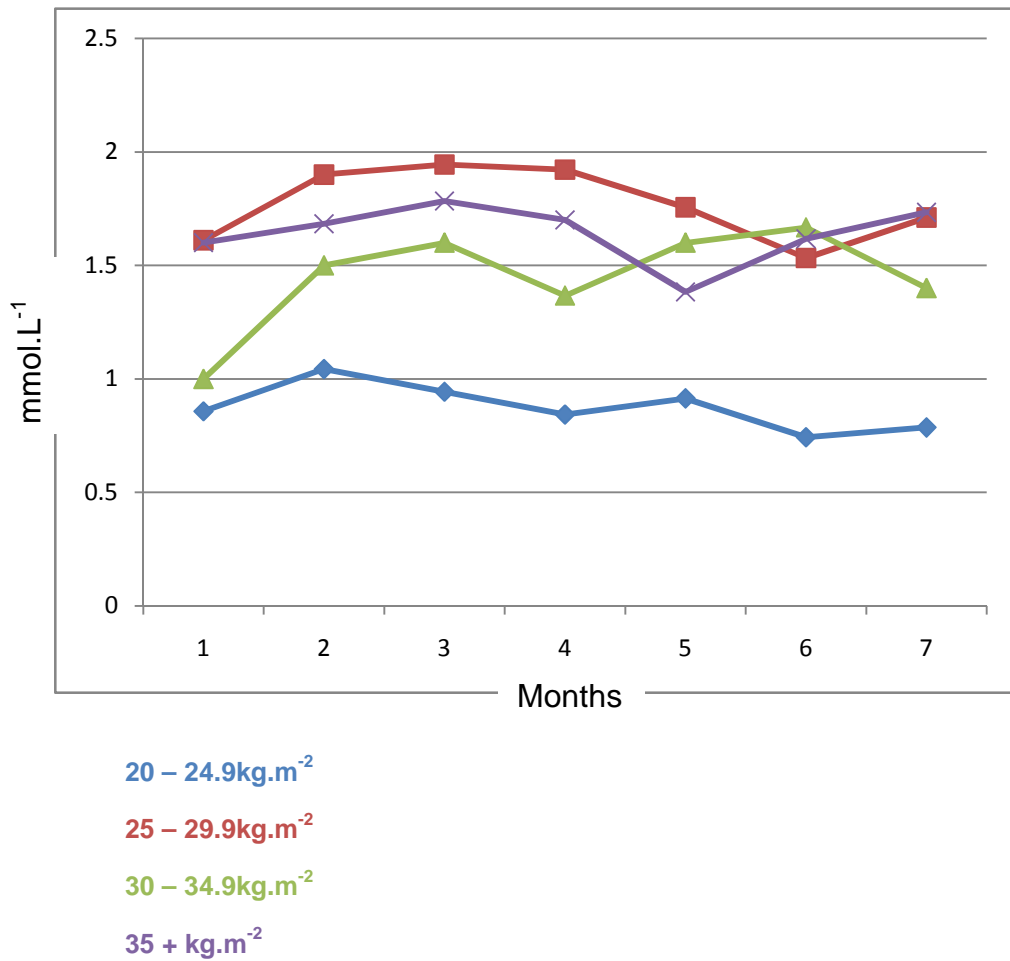
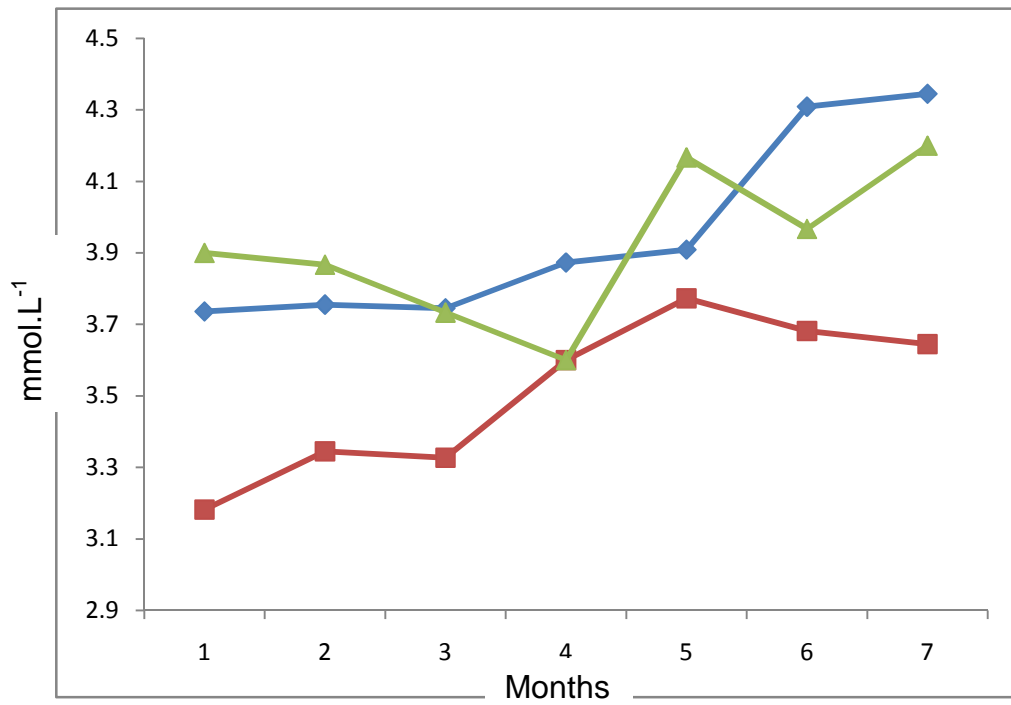


Figure 22: Body mass index and triglyceride concentration

AGE

Age was not found to be linked to blood lipid profile responses in this sample (Figures 22, 23 and 24). The age range of the participants was 51 to 72 years, but multivariate analyses (MANOVA) found no relationship between age and lipid responses.

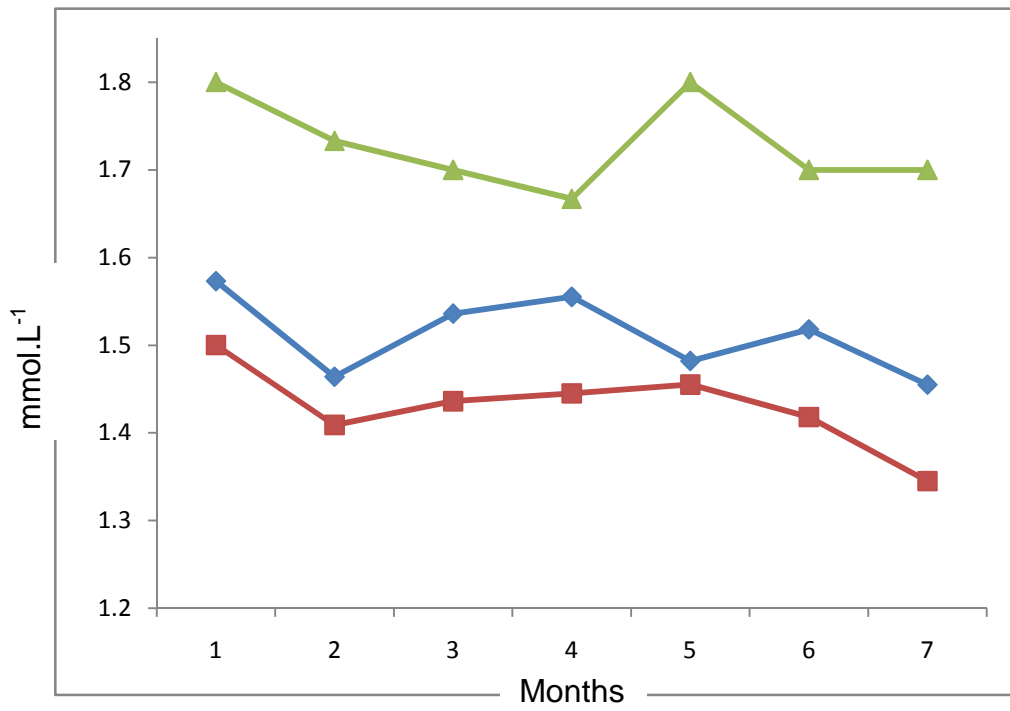


50 – 54 years

55 – 64 years

65 – 75 years

Figure 23: Age and low density lipoprotein responses



50 – 54 years

55 – 64 years

65 – 75 years

Figure 24: Age and high density lipoprotein responses

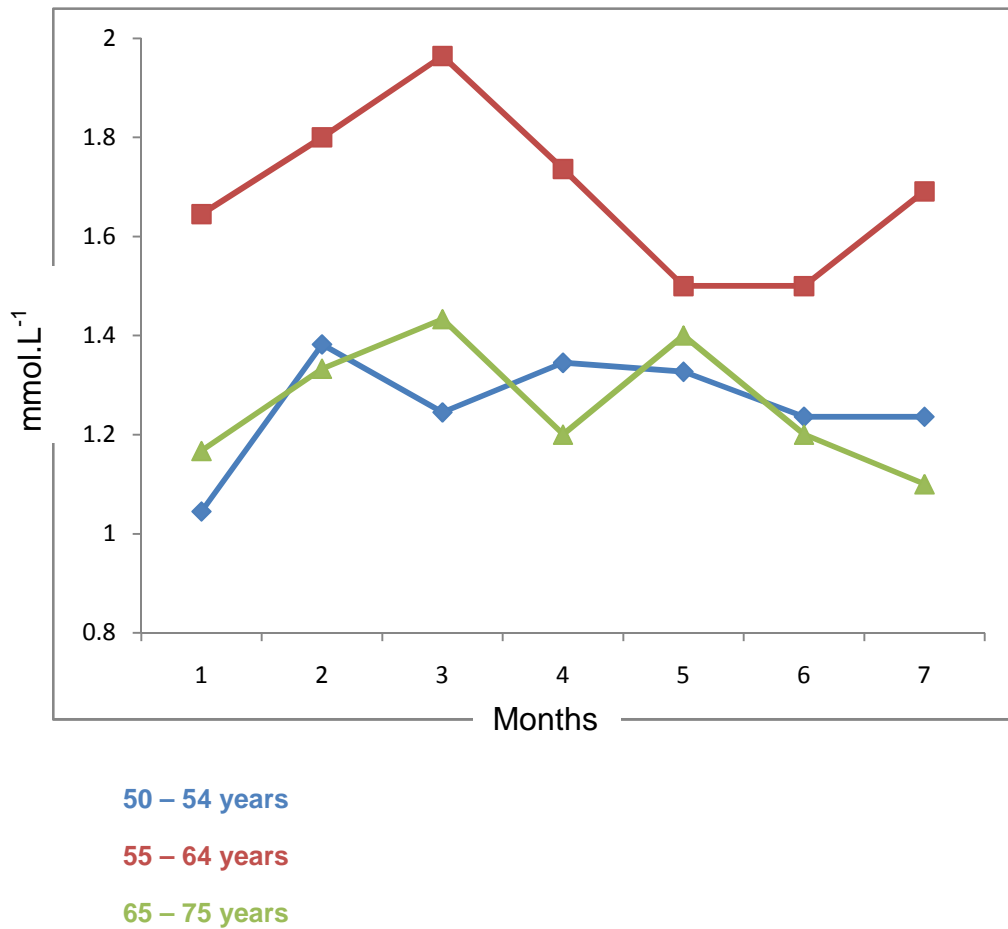


Figure 25: Age and triglyceride concentration

A comparison between the oldest subject (71 years of age at the start of the study) and the youngest subject (50 years at commencement) was undertaken to isolate any age-related effects on the efficacy of the training programme (Figure 25). Despite being 21 years older than the youngest subject the oldest subject in this sample commenced the study with a BMI 4.2kg.m^{-2} lower than the youngest subject's 28.5kg.m^{-2} .

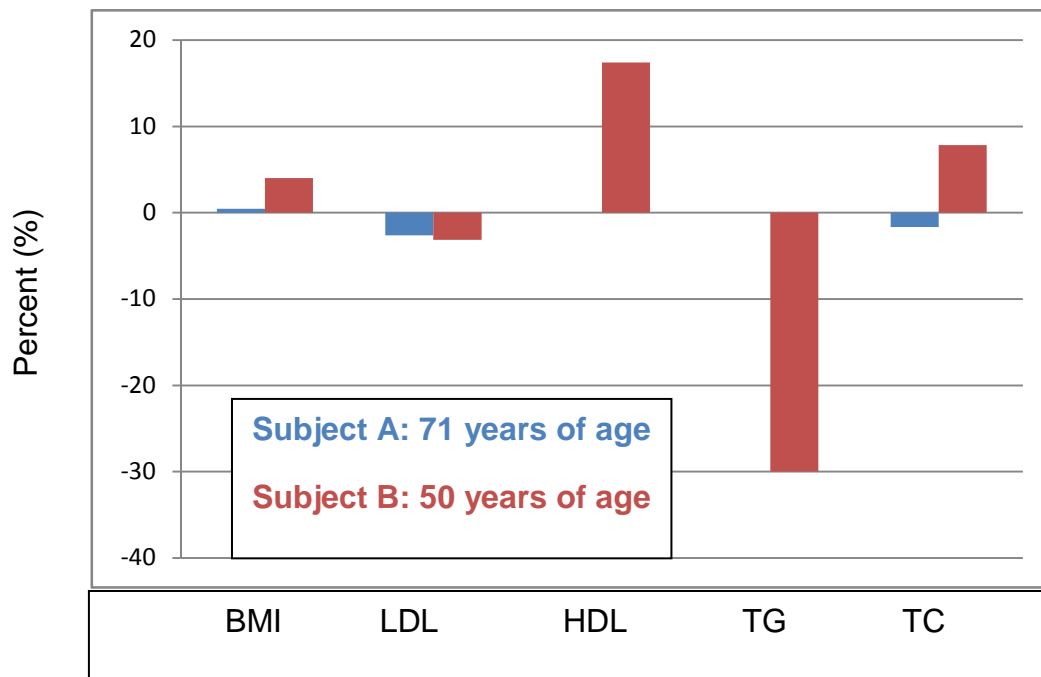


Figure 26: Changes over 24 weeks in the oldest (71 years of age) and youngest (50 years of age) subjects

Over the course of 24 weeks the oldest subject's BMI increased by $0.1\text{kg}\cdot\text{m}^{-2}$ and the youngest subject's by $1.1\text{kg}\cdot\text{m}^{-2}$. The blood lipid analyses for the 71-year-old revealed a very stable profile which decreased by $0.1\text{mmol}\cdot\text{L}^{-1}$ in the cases of LDL-cholesterol and triglyceride concentration but reflected no other changes over the course of the six month training programme. In contrast, the 50 year old had a $1.2\text{mmol}\cdot\text{L}^{-1}$ increase in LDL, a $0.4\text{mmol}\cdot\text{L}^{-1}$ decrease in HDL values, a $0.6\text{mmol}\cdot\text{L}^{-1}$ decrease in triglyceride concentration and an overall increase to total cholesterol of $0.5\text{mmol}\cdot\text{L}^{-1}$. The 50-year-old had not yet entered menopause and was classified as "peri-menopausal" which indicates that while menses have not stopped entirely the occurrence is less frequent and some hormonal changes are noted. The 71-year-old was a post-menopausal woman and it can be inferred that the concentration of

circulating oestrogen is therefore lower than in the younger woman. Despite very similar body mass changes throughout the study and compliant adherence to the same exercise protocol the reaction by the plasma lipoproteins in each case was very different.

BODY MASS

Multivariate analyses suggest that pre-test body mass did not affect the blood lipid responses. The subject who commenced the study with the highest body mass (119.12kg) was compared to the lightest subject (55.36kg) in order to establish whether pre-test body mass affected the kinetics of the blood lipoproteins (Figure 26). Aged 55 and 57 years of age respectively, the heavier subject had a BMI of 48.9 and the lighter subject's BMI was 21.9. These individuals represent age-matched women with very different morphologies. Both women reported that they were post-menopausal as defined by a minimum of 12 months since menstruation had taken place. The heaviest subject lost a total of 4.12kg over the course of the 24 weeks study (3.46% of pre-test total body mass) while the lightest subject lost 0.22kg, or 0.4% of original body mass prior to commencing the progressive resistance training programme. Blood lipid analyses revealed that LDL increased by 0.4mmol.L^{-1} in both subjects, and that HDL remained unchanged in both cases. Triglycerides remained stable in the lightest subject, but increased by 0.5mmol.L^{-1} in the obese subject. Total cholesterol increased by 0.7mmol.L^{-1} and 0.4mmol.L^{-1} respectively after 24 weeks. This analysis revealed that despite a body mass difference of 63.76kg the subjects' lipoproteins were similarly affected by the resistance training programme. In addition despite losing a greater percentage of

initial body mass during the 24 week study, the obese subject did not experience greater changes to the blood lipid profile.

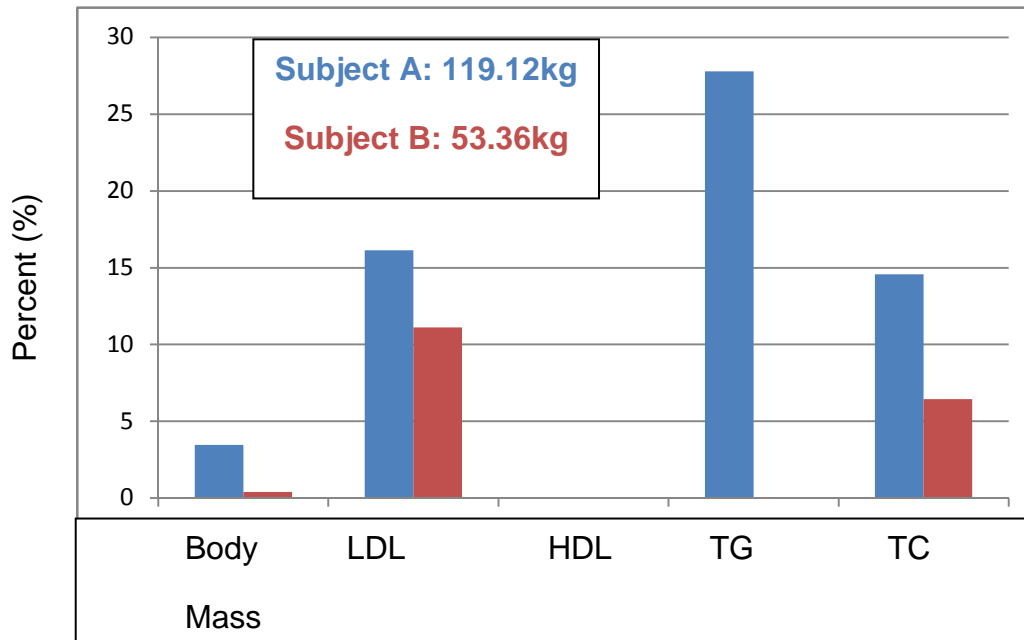


Figure 27: Heaviest and lightest subject comparison of changes over 24 weeks

One subject commenced the study at 94.24kg and after 24 weeks weighed 83.90kg which translates into a 10% loss of starting body mass. The effect of this decrease in body weight was analysed. This subject had never had a full blood lipid profile analysis prior to commencing this study, and after the pre-test analysis it was revealed that the triglyceride concentration was abnormally high (16.3mmol.L^{-1}). This value, coupled with a total cholesterol of 7.6mmol.L^{-1} indicated very high risk for cardiovascular complications. The 10% drop in body mass was accompanied by a 76.1% drop in triglyceride concentration most of which occurred within the first eight weeks (60.1%), and a 25% drop in LDL cholesterol concentration, with this change

taking place within the first eight weeks of training and thereafter remaining stable. HDL cholesterol remained stable throughout the training programme, and total cholesterol dropped from 7.6mmol.L^{-1} to 5.7mmol.L^{-1} . This peri-menopausal subject was 53 years of age, and attended 100% of the training sessions.

WAIST-TO-HIP RATIO

Table VIII: Comparison of the pre-test plasma lipoprotein levels in subjects with the highest and the lowest waist-to-hip ratios

	WHR: 1.01	WHR: 0.73
LDL (mmol.L⁻¹)	3.2	3.9
HDL (mmol.L⁻¹)	1.1	1.4
Triglycerides (mmol.L⁻¹)	3.4	1.2
Total Cholesterol (mmol.L⁻¹)	5.8	5.8

'Healthier' values shaded

Both of these women (Table VII) had an initial total cholesterol of 5.8mmol.L^{-1} while the individual with the WHR of 1.01 had the lower LDL (3.2mmol.L^{-1}) cholesterol, 21.88% healthier than the subject who tended to carry more weight around the hip area. The 'pear-shaped' subject's revealed a healthier level of HDL (1.4mmol.L^{-1} as

opposed to 1.1mmol.L^{-1}) and of triglycerides (1.2mmol.L^{-1} versus 3.4mmol.L^{-1}). Therefore the subject with the WHR of 1.01 possessed a riskier LDL:HDL ratio of 2.91 compared to the subject whose WHR was 0.73 who had a comparatively healthier ratio (4.12% lower) of 2.79.

PERI- AND POST-MENOPAUSE

It was necessary to compare the 100% compliant peri-menopausal subject to a post-menopausal subject who had also completed 100% of the sessions over the course of six months. A 67-year-old subject was compared to the 51-year-old subject. The post-menopausal subject lost 0.56% of initial body mass over the course of 24 weeks, in contrast to the peri-menopausal subject's gain of 5%. The response of the blood lipid profile in the post-menopausal subject was a 9% increase to LDL, 11.11% decrease in HDL, 22.22% increase in triglyceride concentration and a 4.76% increase to total cholesterol values. The changes to the blood lipid profile values in the post-menopausal subject who had attended 100% of sessions were less desirable than the changes seen in the peri-menopausal, younger subject who had attended a similar number of sessions and who had engaged in the same type and intensity of training.

COMPLIANCE

Regularity of attendance at weekly sessions was a requirement, and only those subjects who attended a minimum of 80% of the sessions over the course of 24 weeks were included in the analyses. In total 87% of the subjects achieved 80%

compliance rates, and of these subjects 8.8% achieved 100% attendance for 72 sessions. For the remainder of the candidates, 3% attended 70-75% of sessions and 10% were registered at 50-60% of scheduled training sessions. Of the initial 34 candidates only 26 subjects' data was utilized after correcting for this compliance data.

A comparison was undertaken between a subject who had attended 100% of sessions, and a subject who had only attended 80% of the required sessions (Figure 27). Both subjects were 51 years of age and both were peri-menopausal.

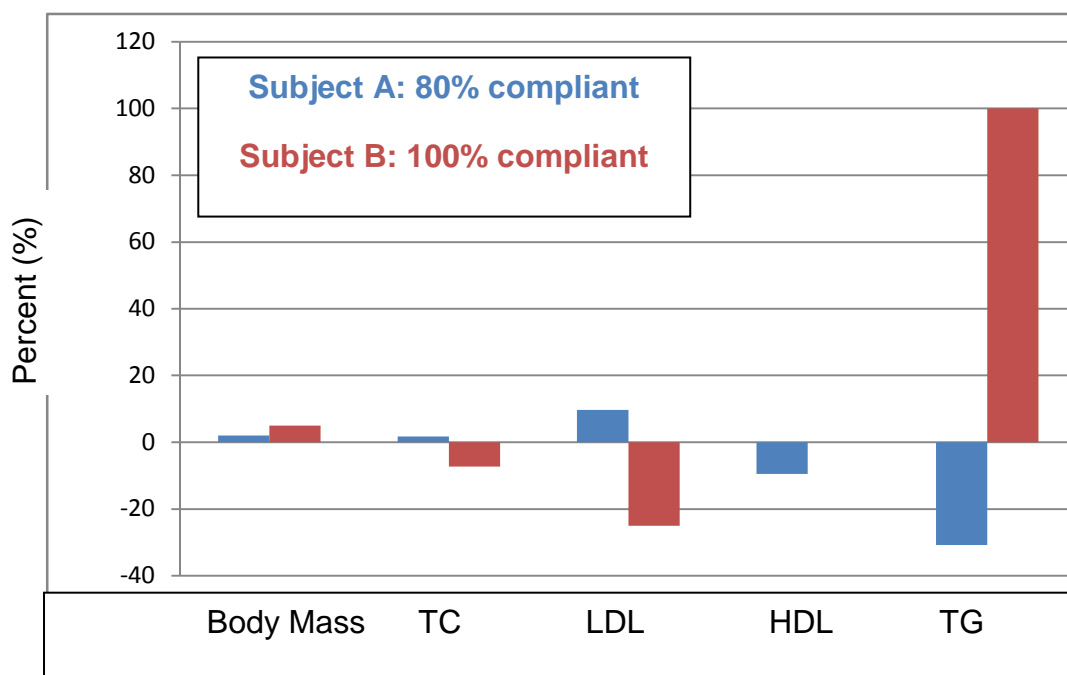


Figure 28: Effect of compliance on blood lipid profile changes

The most compliant subject weighed 64.12kg at the commencement of the programme and gained 5% body mass over the course of 24 weeks, and the least

compliant weighed 70.78kg and gained only 2% body mass by the time the study had drawn to a close. In comparison to the most compliant subject's decrease in total cholesterol (7.3%) and LDL cholesterol (25%) the least compliant subject's total cholesterol decreased by 1.72% and LDL cholesterol increased by 9.7% overall (Figure 17). HDL-cholesterol which is viewed as the healthy cholesterol remained constant in the case of the most compliant subject but decreased by 9.5% in the less compliant, age-matched counterpart. Overall the effect of 100% compliance was positive on the blood lipid profile when compared to an age-matched counterpart who did not manage to attend all sessions due to illness, work or other commitments.

QUALITATIVE REPORTS

While the primary objective of this research was a focus on the blood lipid profile, other positive effects were noted as a result of the six month progressive resistance training study. Improved quality of life is not always quantifiable, and subjective reports from the individuals who comprised the study cohort provide interesting information.

Musculoskeletal improvements were widely noted (60% of responses) (Table VIII). Social benefit and the motivation which accompanied working in small groups was also mentioned by 60% of the participants. Despite the value placed on skeletal improvements muscular strength increase was only referred to by 40% of respondents. Improved flexibility which is an important outcome of any general conditioning programme received mention by 10% of the participants. Table VIII

includes psycho-emotional values such as emotional wellbeing (reported by 50% of the group) and an increased feeling of empowerment brought on by the addition of exercise into a previously sedentary lifestyle (included in 30% of the reports received).

Table IX: Summary of the subjective feedback received from the participants

ELEMENT	REPORTS	ELEMENT	REPORTS
Skeletal/Joint improvement	60%	Better Awareness/Education about Cholesterol	40%
Social Benefit / Motivation	60%	Improved Body Shape	30%
Improved Psycho-Emotional Wellbeing	50%	Feeling of “Empowerment”	30%
Increased Energy	50%	Reduced occurrence of Menopausal Symptoms	10%
Improved endurance capacity	40%	Increased Flexibility	10%
Muscular Strength Improvement	40%	Increased Circulation	10%

Shaded areas depict highest rated outcomes

Specific examples of reports included the following: “I also find that I am definitely stronger and less likely to feel stiff after exertion. I notice this particularly when I engage in heavy gardening. I do think my joints are stronger and on the whole I can do more physically-demanding exercise without feeling ill-effects to my back” (Report 1, Appendix F). A further report indicated that “my back problem has eased - I don't hobble around so much and I reckon that I am without the pain I used to have” (Report 4, Appendix F).

The importance of social interaction to naturally gregarious people provided an important external motivating factor throughout this study, and also contributed to the subjects' feelings of 'belonging' and 'togetherness' (Table VIII). One individual wrote: “I have met some really nice ladies whom I can relate to - I actually didn't know many people of my own age group, so that has been brilliant and we have had some fun”, while another reported that “I have loved being part of a group, making friends with a whole different set of people”. As the management and prevention of lifestyle-related chronic conditions is dependent on long term adjustments to previously poor lifestyle habits it is important that the individuals feel a part of something so that the motivation to continue (in this case to continue exercising) remains. Creation of a social network, as has naturally evolved during the 24 week study, contributes immensely to this motivation. It is worth noting that of the 26 subjects who completed the study, 20 have continued attending sessions as regularly as during the study period and are continuing to pay attention to the need for regular activity in their daily lives.

Increased levels of energy as well as improved general physiological well-being were also noted (Table VIII, page 113), as indicated in this self-report: “I think that my energy levels are definitely better as a result of regular exercising”. Evidence of

better stamina and cardiovascular endurance was also reported with subjects noting better endurance on routine walks and reduced tiredness toward the end of the day. One subject noted an improvement in a condition of varicose veins and improved systemic blood circulation.

Education remains a key factor in drives to prevent and manage chronic diseases of lifestyle. The more aware individuals are about the dangers of sedentary living and poor dietary habits, the more likely people will be to consider altering bad habits. Most subjects who commenced this study were completely unaware that women should have blood lipid profiles checked regularly and most were unaware that women stand as great a risk as men for cardiovascular complications, particularly post-menopause. Some subjects referred to this in the reports indicating greater awareness of cholesterol as a health index. "I am thrilled to have had my cholesterol levels checked, and to be made aware of them and the dangers, having not really thought about it much before" reported one subject, while another raised an equally salient point: "I had never had my cholesterol measured before, so the fact that I am now aware of the various components that are tested (HDL, LDL and triglycerides) and their significance is obviously important".

Psycho-emotional well-being is often an area which is not explored in quantitative research, and is often overlooked as an important effect of regular exercise. Individuals might not even notice that their emotional wellness has improved, particularly as the changes can be gradual rather than sudden and noticeable. Subjects self-reported better emotional states, for example: "Certainly much happier in myself and look forward to the classes". Improved body composition contributed to improved self-esteem as noted by a subject who commented: "I have lost

centimeters and kilograms which has improved my confidence...no longer self-conscious when I walk into a room”.

As depicted in Table VIII (page 113) most subjects reported that improvement to joint function was most important to them, along with the social benefits of undertaking the exercise programme in groups. Those who reported joint improvement also reported on the importance of the social interaction and mentioned increased energy levels. Among those who ranked social importance first it appeared that improved muscular strength was seen as a catalyst to the feeling of wellbeing that they felt having been part of the exercise programme. Of interest is the fact that greater awareness about cholesterol levels and the associated risk for cardiovascular disease was not ranked highly. The only exception was one subject who had never had a blood lipid test prior to engaging in this study. The pre-test values revealed lipid levels at extremely dangerous levels and this information certainly prompted this individual to alter a previously sedentary lifestyle. Apart from this subject it appeared that knowledge of cholesterol levels whether ‘normal’ or ‘above normal’ would not have provided sufficient motivation to continue an active lifestyle, rather it was the associated benefits such as social interaction and reduced occurrence of joint pain that provided the greatest motivating factors. This information offers insight into the success or failure of lifestyle intervention programmes as it highlights the fact that individuals are more likely to adhere to exercise programmes for “tangible” reasons, and the less tangible reasons such as cholesterol levels which cannot be felt or experienced do not provide similar levels of long term motivation.

CHAPTER V

DISCUSSION

HYPERCHOLESTEROLAEMIA

Hypercholesterolaemia is directly related to cardiovascular complications (McArdle **et al.**, 1996) and it is thus an important risk factor to examine. High levels of plasma lipoproteins can be the result of poor lifestyle habits such as sedentary living and diets high in saturated fats (Haskell 2003; Tibazrwa **et al.**, 2008). Treatment of chronic diseases of lifestyle (such as hypercholesterolaemia) can be either pharmacological or by means of lifestyle intervention, as has been researched in this study. Lifestyle alterations carry reduced secondary risk and associated complications (Poli **et al.**, 2008) and while diet has proved effective in reducing high plasma lipid levels the effect of exercise in doing so is as yet unclear (Trejo-Gutierrez and Fletcher, 2007).

ANTHROPOMETRY

While body mass and body mass index did not display significant changes waist-to-hip ratio (WHR) after 12 weeks was significantly different to the pre-test group mean. Girth measures at all sites decreased significantly over the course of 24 weeks, indicative of changes to body composition (Table V, page 87).

BODY MASS AND THE BODY MASS INDEX

One of the distinguishing features of this sample was a large range (63.76kg) between the highest and lowest pre-test body mass (Figure 10, page 82). The average pre-test body mass was 79.08 ± 17.42 kg. Body mass did not change significantly over the course of the training programme, and displayed a total mean decrease of 0.77kg (0.97%). This result was expected as resistance training is not associated with large loss of body mass unless there is simultaneous caloric restriction (McArdle **et al.**, 1996). The fact that body mass did not change significantly means that any responses of the blood lipid profile during the training programme are the result of the exercise intervention and not a reaction to body mass changes. Reflecting a similar pattern to that of body mass the BMI of the group did not change significantly over 24 weeks (BMI decreased by 0.29kg.m^{-2} overall). As in the case of the body mass this is a 0.97% decrease.

Pre-test BMI did not affect body mass fluctuations during the training programme. It appeared that those subjects with a BMI greater than 35kg.m^{-2} (obese) did not lose more body mass than subjects who fell within the “normal” body mass index range ($20 - 24 \text{kg.m}^{-2}$).

WAIST-TO-HIP RATIO

The waist-to-hip ratio (WHR) decreased significantly over the course of 12 weeks (Table III, page 81). The initial decrease of 0.02 at 12 weeks narrowed to an eventual total decrease of 0.01 at 24 weeks indicating that initial loss of circumference at the waist and hips reached a plateau after 12 weeks. The group

mean pre-test value of $0.85(\pm 0.08)$ reflects individuals who fall between the WHR classifications of “apple” and “pear” and suggests that this cohort were predominantly “apple” shaped. This implies that these women were at risk for high levels of abdominal visceral fat (AVF) which has been linked to elevated levels of plasma lipoproteins and is also considered more “risk laden” than fat mass carried on the hips and thus further away from the functioning organs and the heart (Weltman **et al.**, 1993, Piche **et al.**, 2008). The findings of this study which suggest that the current sample of post-menopausal women possessed high levels of AVF are in agreement with Weltman **et al.** (2003) and with the findings of the SADHS (2003) wherein it is reported that post-menopausal women had higher levels of AVF as indicated by significantly higher waist circumference measures than women aged 15 to 44 years.

GIRTH MEASURES

Girth measures including waist circumference were taken prior to the exercise programme and then every four weeks thereafter. These were seen to decrease significantly from eight weeks, continuing to decrease over the course of the following 16 weeks.

CENTRAL CIRCUMFERENCE MEASURES

Resistance training has effectively lowered waist circumferences in previous studies (Maesta **et al.**, 2007). The measure of waist girth is important in that it is indicative of android adiposity which is in turn strongly correlated to higher levels of plasma

lipoproteins (Weltman **et al.**, 2003; Piche **et al.**, 2008). The group mean waist circumference prior to the training programme was 947.9(\pm 149.9)mm which is 66.9mm higher than the average waist circumference for South Africa post-menopausal women (SADHS, 2003). Waist circumference decreased significantly by 48.3mm within the first 12 weeks of the training programme which was the lowest value. Waist circumference gained 2.7mm during the final 12 weeks of the training programme.

Over-bust chest measurement also displayed significant decreases during the training programme. The group's pre-test mean (1062.2 \pm 136.9mm) dropped by 39.2mm over 16 weeks to the lowest value, and increased by 5.9mm during the final eight weeks. Despite the increases during the latter stages of the study both the waist and the chest circumferences remained significantly lower than the pre-test values at 24 weeks.

Hip measures continued to decrease steadily over the course of 24 weeks, dropping significantly by 41.1mm overall (Table IV, page 86). The total girth decrease at the site of the hips was 3.69% which was a relatively small decrease overall when compared with waist (4.81% decrease). The total decrease in the case of the chest measurement, however, was 3.14% (the lowest percent change of the girth measures).

EXTREMITY CIRCUMFERENCES: UPPER AND LOWER

Mid-humerus measures decreased significantly from four weeks, and dropped by 14.5mm in total over the course of the training programme. While this is a significant

decrease of 4.64% it remains a smaller drop than at the lower extremities (mid-quadricep and mid-gastrocnemius). Mid-quadricep measures decreased by 6.44% overall representing the highest total decrease (Table V, page 91). Similarly, mid-gastrocnemius dropped by 4.86% during the course of 24 weeks, indicating that the highest percentage of circumference loss occurred in the lower extremity. Given that the “pear” shape indicates that fat mass is carried below the waist (on the hips and upper leg) it is of note that these are the areas at which the greatest loss of circumference occurred. Loss of fat mass at the site of the waist was also significant and high, relative to the upper extremity and chest, but was still not as great as the loss at mid-quadricep. It is hypothesized that this finding could bear relevance to further investigations into the efficacy of exercise in reducing AVF concentrations.

BLOOD LIPID PROFILE

HIGH DENSITY LIPOPROTEIN

HDL-cholesterol decreased significantly (8.39%) over the course of 24 weeks (Table VI, page 94). This decrease occurred steadily over the course of the training programme, reaching the lowest point at the final measurement at 24 weeks. This perturbation reflects a less healthy mean level of HDL-cholesterol despite the addition of regular resistance training to the lifestyles of the post-menopausal women. This finding is in agreement with Jensen (1992) who found that HDL decreased by 7% in a cohort of post-menopausal women, but this finding was related solely to reduced circulating oestrogen. In addition Joseph **et al.** (1999) found that 12 weeks of resistance training reduced HDL cholesterol significantly in a

cohort of older women. In contrast, Trejo-Gutierrez and Fletcher (2007) reported that HDL remained unchanged after resistance training interventions.

LOW DENSITY LIPOPROTEIN

LDL-cholesterol increased significantly over the course of 24 weeks (12.74%). The increase accelerated during the final 12 weeks of the training programme, reaching the highest measurement at the end of the training programme and testing period. In contrast, Trejo-Gutierrez and Fletcher (2007) have found that LDL decreased in most studies where resistance training resulted in increased lean mass and decreased fat mass but unchanged total body mass. Similarly Goldberg and Elliot (1985) and Boyden **et al.** (1993) reported that LDL decreased in pre-menopausal female subjects after resistance training protocols. The findings of the current study are not in agreement with the reviewed literature. It is hypothesized that the effect of the loss of oestrogen due to cessation of ovarian function may have an effect on the responses of the plasma lipoproteins to exercise intervention. However, to the author's knowledge no study has investigated this and thus this aspect requires future research and focus.

Reducing the risk of an atherogenic lipid profile is strongly associated with reducing total LDL-cholesterol levels (Robinson, 2008). The findings of the current study are in contrast to those of Halverstadt **et al.** (2007) (aerobic endurance training) and of Boyden **et al.**, (1993) (resistance training). Total cholesterol increased by 0.43mmol.L^{-1} during the course of the 24 week study under discussion.

TRIGLYCERIDES

In the current study triglyceride content increased significantly until eight weeks and then decreased with the final measure remaining 0.12mmol.L^{-1} higher than the pre-test value. Similarly, Joseph **et al.** (1999) found that triglyceride levels remained unchanged after 12 weeks of resistance training in older women. In contrast, resistance training appears to positively impact triglycerides in males. Williams **et al.** (2007) correlated greater upper- and lower-body strength following resistance training in male subjects to reduced triglyceride levels. The female subjects in the current study progressed from 50% of 1-RM to 80% of 1RM which indicates an increase in upper- and lower-body strength, but this did not translate to reduced triglyceride levels and suggests that older women may respond differently.

High triglyceride concentrations may be indicative of poor dietary and lifestyle choices and in the case of this sample 3.4mmol.L^{-1} was the highest pre-test concentration in a subject weighing 71.32kg (BMI 27.2kg.m^{-2}) (7.76kg lower than the group average). With a BMI of 29.8kg.m^{-2} and differing from the group mean by an additional 0.02kg the highest pre-test measure of total cholesterol in a subject was 9mmol.L^{-1} . The selection criteria for participation in this study did not restrict body mass or BMI, but required that there be at least one abnormality in the lipid profile. This resulted in a broad body mass range and indicates that body mass per se may not predict cholesterol level in post-menopausal women.

TOTAL CHOLESTEROL

Total cholesterol also remained unchanged, a finding consistent with that reported on by Trejo-Gutierrez and Fletcher (2007) who noted that where resistance training did not result in body mass change, total cholesterol also remained unchanged. If diet is altered during training programmes the resulting imbalance between energy intake and expenditure can result in a loss of body mass (McArdle **et al.**, 1996) but diet was not altered during the current study.

COMPLIANCE

A subject not broached in the literature reviewed for this research was the fundamental issue of compliance. Human nature dictates that attendance at sessions may well fluctuate especially over a prospective study design of 24 weeks. Individual motivation differs with changing seasons, as do externally motivating factors. Attendance at 80% of the sessions (72 in total) was required for subjects to be included in the data analyses, and 87% of the initial sample (n=34) achieved this. Of the 87%, 8% achieved 100% attendance, as reflected by the attendance registers. Of those who did not meet the compliance criteria, reasons for not doing so included unforeseen family crises and responsibilities, as well as seasonal illness (in winter the 'flu is more common than in summer). Attendance of over 70% was achieved by a further 3% of the sample, and attendance of 50% to 60% was attained by 10%. Those who failed to reach 50% attendance had in fact dropped out of the study due to pre-existing conditions, such as fibromyalgia and chronic back pain.

MULTIVARIATE ANALYSES

BODY MASS, BODY MASS INDEX AND THE BLOOD LIPID PROFILE

The highest pre-test LDL-cholesterol value (4.6mmol.L^{-1}) was noted in a subject who was 4.76kg lighter than the group mean (74.32kg) while the lowest (or the 'healthiest') LDL-cholesterol value of 2.3mmol.L^{-1} was recorded for a subject who weighed 99.4kg, 20.32kg heavier than the group average (and in addition this value fell outside the standard deviation range of 17.42kg).

HDL-cholesterol is considered a desirable cholesterol as it plays an important role in absorbing and removing the harmful LDL-cholesterol from the vascular system. In keeping with the findings of Laws **et al.** (1993) the lowest HDL value prior to commencing the training programme was observed in the heaviest subject (119.12kg, BMI of 29.8kg.m^{-2}) who was 40.04kg heavier than the group mean. In contrast the highest HDL-cholesterol reading was applicable to a subject who was 4.32kg lighter than the group mean.

Those with the lowest BMI had mean triglyceride levels of $0.88\pm 0.21\text{mmol.L}^{-1}$ which was significantly lower than the mean of $1.77\pm 0.19\text{mmol.L}^{-1}$ for the subjects with the highest BMI (greater than 35kg.m^{-2}). A direct relationship between triglyceride concentration and BMI was found by Laws **et al.** (1993) who concluded that obesity predicts HDL-cholesterol and triglyceride concentration in post-menopausal women.

These findings for HDL cholesterol and TG concentrations are consistent with the findings of Xu **et al.** (2008) who examined the relationship between the blood lipid profile and BMI and waist circumference. It was found that as BMI increased so did

triglyceride concentration as well as LDL and total cholesterol. Conversely, as BMI increased it was noted that HDL cholesterol levels decreased (Xu **et al.**, 2008).

WAIST CIRCUMFERENCE AND THE BLOOD LIPID PROFILE

The largest individual pre-test waist circumference in this study was 1360mm and the smallest was 722mm, whereas the group mean at the same stage was 947.9mm. After 24 weeks the group result for LDL-cholesterol indicated an 11.3% increase overall.

The subject with the largest waist circumference experienced a 16.13% increase and the subject with the smallest waist circumference demonstrated a 25.71% increase to LDL-cholesterol over the six month training period. The 'healthy' cholesterol (HDL) decreased overall by 9.15%, remained constant in the subject with the largest waist circumference, but decreased 31.25% in the subject with the smallest waist circumference. Conversely, triglyceride concentration remained unchanged for the subject with the smallest waist circumference, but increased 21.33% more than the group mean in the case of the largest waist circumference. This evidence suggests that waist circumference, in this instance, was not related to hypercholesterolaemia and risk of cardiovascular disease as a result. The correlation between levels of AVF and plasma lipoproteins as noted by Piche **et al.** (2008) were not found to apply to this sample of post-menopausal women.

POST-MENOPAUSAL WOMEN

As limited attention has been paid to hypercholesterolaemia in post-menopausal women to date, these women, aged between 50 and 75 years were selected for this study. Once ovarian function has ceased, it is noted that levels of circulating oestrogen decrease rapidly. While oestrogen does not leave the system entirely, the remaining substance, called 'estrone', is a very weak form of oestrogen (Silva **et al.**, 2004). Oestrogen has been demonstrably linked to cardiovascular protection, most clearly indicated by the exponential increase in cardiovascular risk seen once menopause has been reached in the female population (de Aloysio **et al.**, 1999).

In the current cohort 76% were post-menopausal while 23% of the subjects were classified as "peri-menopausal" which inferred that while menstrual function had become erratic it had not yet ceased entirely. This means that hormonal changes had taken place and the volume of circulating oestrogen was declining but ovarian function had not reached the stage of complete cessation. Menopause is a period of time which can last anything from a few months to a few years, and it is also a period in a woman's life which occurs any time from the late 30s to the early 60s. Most women will have entered menopause by the sixth decade and it is only the exceptions who have passed through menopause earlier or who have not experienced any hormonal changes by this stage in their lives.

Symptoms and characteristics of the menopause have been documented and range from emotional instability and irritation, to hot flushes and fatigue (Teoman **et al.**, 2006). Certain subjects reported a decrease in menopause-related discomfort, such as reduced hot flushes, attributed directly to the inclusion of regular exercise into habitual lifestyle activity.

RESISTANCE TRAINING

The efficacy of resistance training on general well-being and muscular health in a cohort of women over the age of 50 years is an important element to consider. Beyond the need to prevent or contain the development of osteoporosis, the effect of greater muscle density on metabolic rate has important bearing on age-related body fat increases and concomitant health indices. Strength gains and by inference, muscle mass gains, did occur during the resistance training programme, most simply indicated by the fact that the cohort progressed from a training intensity of 50% of the 1RM to 80% of the 1RM within the course of 24 weeks. Beneka **et al.** (2005) and Reeves **et al.** (2006) have found that moderate to high-intensity resistance training produces strength gains in both sexes, as has been found in the current research. Similarly, the sample fell in line with Nakamura **et al.** (2007) who recommended that women should engage in three sessions of resistance training per week to derive the benefits associated with resistance training. The impact of the exercise programme was also associated with changes in shape as waist circumference dropped by 5.06% within 12 weeks of resistance training alone, which is indicative of loss of abdominal visceral fat.

DIET

One of the limiting factors of this study was that diet was not altered or prescribed in an attempt to isolate the resistance training intervention. It is known that positively changing dietary habits can reverse hypercholesterolaemia (Martini **et al.**, 2008; Volek **et al.**, 2008) and that discrete dietary elements such as water-soluble dietary fibre can have an effect on plasma lipoproteins (Haskell **et al.**, 1992). Had the

subjects reduced their habitual caloric intake during the course of the training programme this would have become apparent by decreases in body mass. That was why the upper limit for weight loss was set at 10% during this study. It is possible that the energy expense of the resistance training regime resulted in the subjects taking in more energy than usual to restore the energy balance. With no controls in place guiding dietary intake, the nature of the food chosen by the subjects could have affected both body mass and plasma lipoprotein content. However, Rhew **et al.** (2007) noted that one healthy behavior usually has an effect on other behaviours, for example being physically active usually leads to healthier dietary choices.

THE EFFECT OF HORMONES

A number of previous studies have researched the effect of exercise on plasma lipoproteins in post-menopausal women. Hormone replacement therapy (HRT) results in improved levels of HDL cholesterol when combined with exercise (Seip **et al.**, 1993; Lindheim **et al.**, 1994; and King **et al.**, 1995). The subjects in the current study were not taking any form of HRT, as this may have affected the reliability of the results.

Lipoprotein responses to progressive resistance training differed substantially between peri- and post-menopausal subjects in this study (Figure 28, page 128). In a comparison between a peri- and a post-menopausal subject it became apparent that the plasma lipoproteins did not respond to the training programme in the post-menopausal individual. In contrast, the peri-menopausal subject's blood lipid profile displayed changes throughout the 24-week programme. Until menopause

commences, oestrogen remains in the system. After menopause is reached, a weak oestrogen-marker called estrone is all that remains. While the exact levels of oestrogen per subject were not analysed, it is expected that they would be higher in the peri-menopausal subject compared to the post-menopausal subject. Body mass also appeared to react differently, as the peri-menopausal subject gained 5% of body mass, whereas the post-menopausal participant lost 0.56% of original body mass.

Given that these changes occurred in the context of progressive resistance training at sufficient intensity to elicit muscular strength improvement, the effect of oestrogen on the development of muscle density must be questioned. In general, the sample demonstrated loss of circumference measures and this indicates that fat mass was lost during the course of the study. The fact that the sample did not demonstrate loss of body mass overall indicates that, while fat mass was lost, the resistance training facilitated the development of muscle density. This, in turn, indicates a transition to a more healthy body composition. The post-menopausal subject lost 0.56% of pre-test body mass (in this instance pre-test BMI for the post-menopausal subject was in keeping with the group mean so it can be inferred that fat mass lost did not exceed muscle mass gained to produce this negative reading) which is not in keeping with the sample trend. In contrast, the peri-menopausal subject gained 5% body mass over the course of 24 weeks.

QUALITATIVE FEEDBACK

An important outcome of this study was the significance of the “practical” effect the addition of a structured training programme had on the participants’ lifestyles, feeling of wellbeing and overall health status.

As the study was primarily interested in the effect of progressive resistance training on the blood lipid profile, it was interesting that only 40% of respondents indicated that an improved awareness about the importance of cholesterol was a valued outcome for them. Three respondents particularly mentioned that knowledge of their own lipid profiles was important (they will be referred to as Subjects A, B and C for this discussion). It would be interesting to establish whether the importance the individuals placed on this newfound knowledge was related to the discovery that their own lipid profiles were unhealthy and placed them at risk.

Pre-test full fasting blood lipid profile results for Subject A and B fell very close to the group mean for the same time period but Subject C had an extremely risk-laden triglyceride level (16.3mmol.L^{-1}) and total cholesterol value (7.6mmol.L^{-1}). Subject C became aware of the extreme risk represented by this pre-test lipid profile, and more so as this medical condition had not previously been identified. Subjects A and B, while possessing “above average” lipid profile levels were not at particular risk compared to the group in general, and so the assumption that particular risk led to placing importance on greater awareness about cholesterol was not noted.

In order to assess the correlation between the subjects’ perceptions of “improved body shape” a comparison between subjective reports of being “trimmer” and actual girth measures was carried out (Figure 29). Three subjects were compared to the group mean in order to assess whether these subjects had in fact decreased substantially at each site at which girth measures were taken throughout the 24 week study. Subject A’s girth measures did indeed reflect a far greater decrease than the group mean, indicating that this subject’s subjective perception of “feeling trimmer” was in fact quantitatively based on substantially reduced circumference measures. In the case of Subject B the opposite is true. Subject B not only did not

lose the same percentage per girth site as the group did, but in fact increased circumference measures at four out of six measurement sites over the course of 24 weeks.

A subjective perception of an “improved body shape” need not, however, be related to weight reduction but may in fact relate to a feeling of increased muscle tone and “tightness”. Increased circumference measures may indicate increased muscle density at these sites and concomitantly, improved muscle tone and thus the feeling of being “trimmer”. Subject C’s girth changes were very similar to those of the sample but do reflect a downward trend in girth measures, and thus the subjective perception of feeling “trimmer” can indeed be attributed to weight loss.

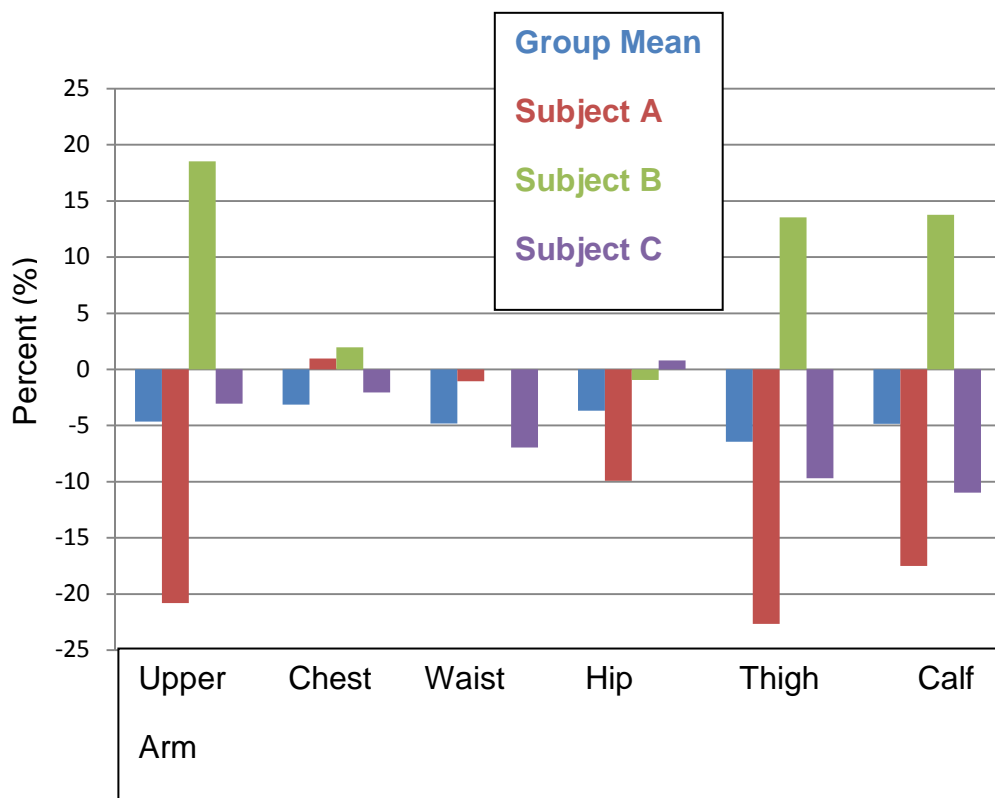


Figure 29: Relationship between perception of and actual anthropometric changes

Of the responses received, 60% referred to improved joint health and range of motion. Flexibility was not measured as part of this study, but after each exercise session stretching was encouraged and supervised. Muscle strength was also not measured over the course of the study but it can be inferred that strength gains occurred as the subjects progressed from a resistance intensity of 50% of 1-RM to 80% of 1-RM which could only have taken place with improved ability of the muscles to handle the increased loads placed upon them. Individual variation dictates that there were differences in upper- and lower-body strength development, but the trend was for muscular strength to improve and, along with this, joint function and skeletal health.

CHAPTER VI

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

INTRODUCTION

The blood lipid profile remains an important early warning tool for the prevention of cardiovascular disease (Jeppeson, 2003; St Pierre **et al.**, 2004, Windler 2005). The current study undertook to evaluate the effect of progressive resistance training on the blood lipid profile in a cohort of post-menopausal women. It is known that reduction to plasma cholesterol levels results in slowing of atherogenicity (and the formation of plaque on the arterial walls which can cause narrowing of the artery) and thus a reduction in cardiovascular events (Kotseva **et al.**, 2008).

Drugs used for treating high cholesterol levels include the statins, niacin, bile-acid resins and fibric acid derivatives. All have side-effects ranging from headaches to stomach upsets and impaired liver function (Schmitz and Langmann, 2006). It is thus important to focus on non-pharmacological interventions as a healthier alternative to drug-use, and also in the light of escalating medical costs and the increasing number of individuals requiring intervention for hypercholesterolaemia (Poli **et al.**, 2008). Non-pharmacological intervention for hypercholesterolaemia to date has focused primarily on nutrition status, and dietary intervention is known to be effective in reducing the plasma lipoprotein concentrations (Martini **et al.**, 2008; Volek **et al.**, 2008).

Less is known about the efficacy of exercise interventions, and specifically resistance training programmes for combating high cholesterol, and to date, investigations remain inconclusive (Maesta **et al.**, 2007; Trejo-Gutierrez and Fletcher, 2007). Goldberg and Elliott (1985) found that LDL, triglycerides and total cholesterol decreased in middle-aged male and female subjects following a regime of resistance training, but in contrast to this Joseph **et al.** (1999) found that plasma lipoproteins remained unaffected in female subjects (aged 54 to 71 years of age) following a resistance training programme.

A cohort of post-menopausal women has inherent characteristics which need addressing. In particular, menopause, which is the cessation of ovarian function which results in a significant decrease in levels of circulating oestrogen. In addition, advancing age, particularly in women, is associated with android fat patterning, regardless of body mass index (BMI) rating (Weltman **et al.**, 2003). This implies that one need not be clinically overweight or obese for abdominal visceral fat (AVF) to increase with increasing age. Weltman **et al.** (2003) have noted that increased levels of AVF are strongly associated with increased atherogenicity. In addition, oestrogen is linked to protection against hypercholesterolaemia and the absence of oestrogen does result in an increased risk for the development of high cholesterol levels. Senoz **et al.** (1996) have shown that it is reduced circulating oestrogen, and not advancing age alone, which has the greatest effect on increased atherogenicity in women.

During the current prospective study, diet was not controlled or altered. This is a limiting factor in the study design, but in an attempt to isolate exercise as a lifestyle intervention, as well as to ensure that each participant continued to live out their daily lives as usual, manipulating the diet was not possible. It is accepted that dietary

changes can positively affect hypercholesterolaemia. The cohort in the current study were requested not to make major changes to their dietary and lifestyle habits, other than adding regular resistance training to their previously sedentary lives.

Resistance training is known to increase muscle density and thus increase metabolic requirements of the metabolically active muscle tissue (Winett and Carpinelli, 2001). It is accepted that sarcopenia associated with advancing age can be reversed by resistance training, and thus advanced age is not a limiting factor for muscle development (relative to the amount of muscle at the onset of training) (Calder and Gabriel, 2007). Body mass does not decrease with resistance training alone as any fat mass loss which takes place due to increased metabolic function is offset by increased muscle mass. Improved body composition may be reflected in reduced circumferences, such as waist and hip measurements, or girth measurements at the extremities. This reflects better muscle tone and reduced fat mass in these areas.

An initial training routine soon becomes more manageable by the body, and if the intensity is not altered as the body becomes more able to cope with the stress placed upon it, a “plateau” is reached (McArdle *et al.*, 1996). In order to counteract this effect, the training programme is designed to be progressive, and in the case of this study, the intensity of the programme was increased every four weeks.

SUMMARY OF PROCEDURES

Post-menopausal women aged between 50 and 75 years were recruited for this study. Other than one or more abnormal blood lipid parameter levels the participants

were healthy and free of heart, lung, liver or kidney disease. In addition, the subjects were non-smokers and were not taking hormone replacement therapy.

Prior to commencement of the programme each subject underwent a full physical examination by a medical practitioner. In the same session a sub-maximal cycle ergometry test (following the Bruce Protocol (ACSM, 1986)) was undertaken in order to obtain active electro-cardiogram (ECG) data. Age and sedentarism are risk factors for exercise, and in combination with an abnormal blood lipid profile placed the current sample in a "high risk" category for commencement of an exercise programme. These tests ensured that all participants were safely able to commence activity without imminent danger of cardiovascular events.

Once the progressive exercise programme which focused on resistance training was underway, participants were required to attend three sessions weekly, each for a duration of 45 minutes. These sessions were supervised by the researcher and research assistants. The resistance training protocol began at 50% of the 1-repetition maximum (1-RM) which had been obtained from participants during an introductory session. The intensity of the programme was increased every four weeks (or twelve sessions) by 10% of the 1-RM.

Measurements initially obtained prior to commencement of the exercise protocol (anthropometric and full lipogram) were repeated every four weeks throughout the prospective study. The full, fasted lipogram was carried out at a local pathology laboratory, while the anthropometric data was obtained by the principal researcher. Subjective error is a reality in obtaining girth measures, and this inherent error is reduced if the same individual repeats the measures.

SUMMARY OF RESULTS

Following the 24 week training programme good compliance was noted in the current cohort. From this it can be concluded that compliance did not necessarily impact negatively on the results. Subjects who did not complete the required number of sessions (80%) due to unforeseen illness or failure to attend sessions were not included in the analyses of results.

Results indicated that the training programme was of sufficient intensity to elicit expected results for resistance training. Circumference measures for upper arm, chest, waist, hip, mid-quadricep and mid-gastrocnemius all showed significant decreases from the start to eight, twelve, sixteen, twenty and twenty-four weeks. Body mass did not change significantly (mean of 79.08 ± 17.42 kg and 78.31 ± 16.80 kg pre and post the exercise intervention), which is also consistent with expectations of a resistance training programme especially if diet is not positively altered. In combination, the circumference measures and the body mass measure may be used to conclude that body composition did improve in the current cohort (increased muscle mass and decreased fat mass).

The blood lipid profile results were unexpected. While changes to the plasma lipoproteins were noted throughout the study, the nature of these changes was unexpected. A more healthy blood lipid profile would infer reduced LDL-cholesterol, triglyceride concentration and total cholesterol, in conjunction with increased HDL-cholesterol. If this trend was established and then remained, it might be concluded that the dose of exercise had indeed resulted in reduced atherogenicity and thus a reduced risk for cardiovascular events. However, the current study found that LDL increased significantly within the first eight weeks and despite decreasing over the

following 12 weeks was still 0.12mmol.L^{-1} higher than the pre-test values at 24 weeks. HDL which is commonly referred to as the “good” cholesterol has previously been recorded as having increased following resistance training (Drygas **et al.**, 2000) but this was not the finding of the current study. Pre-test HDL values were 0.13mmol.L^{-1} higher than the values at 24 weeks indicating a significant decrease in HDL concentration.

Joseph **et al.** (1999) report that triglyceride concentration remained unchanged in female subjects after resistance exercise. A significant increase of 0.32mmol.L^{-1} occurred within the first eight weeks of the current training programme, but the concentration did decrease over the following 16 weeks to 0.12mmol.L^{-1} higher than the pre-test values at 24 weeks which is not significantly different to the pre-test concentrations. This supports the findings of Joseph **et al.** (1999).

Total cholesterol is a combination of the concentrations of LDL, HDL and triglycerides. Trejo-Gutierrez and Fletcher (2007) report that total cholesterol was not affected by resistance training in a review of methodologies which had utilized resistance training as an intervention against hypercholesterolaemia. In contrast, the findings of this study showed a significant increase of 0.43mmol.L^{-1} between pre-test values and values obtained at 24 weeks.

HYPOTHESES

A tabulation of the significant deviations from the pre-test blood lipid profile values is presented in order to provide further insight into the acceptance and rejection of the hypotheses (Table IX).

- (i) In the case of LDL cholesterol the null hypothesis is retained for months one, two and three. However, the null hypothesis is rejected in favour of the alternate hypothesis for months four, five and six which were found to differ significantly from the pre-test values at a 5% level of significance. The alternate hypothesis is accepted for 33.3% of the cases pertaining to LDL, and thus the null hypothesis is retained for LDL cholesterol.
- (ii) For the HDL cholesterol the null hypothesis is retained for months one, two, three, four, five and six. The alternate hypothesis is accepted for month six which differed significantly to the pre-test mean HDL value at $p=0.05$. The alternate hypothesis holds true in 5.5% of the instances, and thus the null hypothesis is retained for HDL cholesterol.
- (iii) The null hypothesis is retained for months one, three, four, five and six for mean triglyceride levels. The alternate hypothesis is accepted only in the case of month two, where significance was found at a level of 5%. The alternate hypothesis pertains to 5.5% of mean triglyceride values, and thus the null hypothesis is retained for triglyceride content.
- (iv) The final hypothesis relates to total cholesterol levels. For this mean value the null hypothesis is accepted for months one, two and three, but is rejected for months four, five and six for which significant differences were found ($p=0.05$) compared to the pre-test mean total cholesterol value. While the alternate hypothesis held true for 16.6% of the analysis, the null hypothesis is retained for total cholesterol.

Table X: Grid tabulating blood lipid profile significance

	PRE	1	2	3	4	5	6
PRE			TG		LDL; TC	LDL; TC	LDL; HDL; TC
1							
2	TG				LDL	LDL	LDL
3							
4	LDL; TC		LDL				
5	LDL; TC		LDL				
6	LDL; HDL; TC		LDL				

Where: shaded areas indicate significances, indicated by

- LDL= low density lipoprotein
- HDL = high density lipoprotein
- TG = triglycerides
- TC = total cholesterol

CONCLUSIONS

RESISTANCE TRAINING PROGRAMME

Strength increases were not directly measured in the current sample, but the progressive nature of the programme required that all subjects increased the

intensity of training from 50% of 1-RM to 80% of 1-RM in 10% increases every four weeks. Reeves **et al.** (2006) have reported that resistance training does elicit a strength increase in individuals (men and women) over the age of 65 years, and the findings of this study are in line with those conclusions. Energy expenditure was not measured in this study as the focus was the plasma lipoproteins but it is worth noting that Campbell **et al.** (2002) and Santa-Clara **et al.** (2006) report that resistance training did not increase energy requirements in post-menopausal women. Orsatti **et al.** (2008) however have offered the argument that resistance training has the effect of increasing fat-free mass which increases the metabolic rate by increases the amount of metabolically active tissue in the body composition and therefore caloric requirement must increase as a result of resistance training, at any age. Diet was not analysed during this study but as body mass did not decrease it can be concluded that the subjects were not experiencing caloric restriction during the training programme.

BODY MASS

The exercise regime employed in the current study did not affect body mass regardless of pre-test BMI. There was a large range (63.76kg) in this sample, as can be observed in Figure 10 (page 83). No significant changes occurred over the course of 24 weeks, with body mass at 24 weeks measuring 78.31 ± 16.80 kg compared to the pre-test measure of 79.08 ± 17.42 kg. This result was expected as resistance training does not have the effect of reducing body mass unless diet is restricted as well. As Volek **et al.** (2008) have observed, changes to the body mass alone can have an impact on the blood lipid profile, so a conclusion drawn for the purposes of

this study is that body mass alterations did not occur and therefore did not impact on any blood lipid profile changes that occurred during the course of the training programme.

BODY MASS INDEX AND WAIST-TO-HIP RATIO

In keeping with the trend noted for body mass, the body mass index (BMI) reflected a similar non-significance over the course of the training programme (Table I on page 66 refers). As revealed by the multivariate analyses, pre-test BMI was not related to subsequent changes to the blood lipid profile so a relationship between BMI and the plasma lipoproteins has not been found in this study. BMI can therefore not be used as a predictive tool for hypercholesterolaemia in post-menopausal women.

Waist-to-hip ratio (WHR) decreased significantly over the course of the first 12 weeks from 0.85 ± 0.08 to 0.83 ± 0.07 . During the course of the remaining 12 weeks the WHR stabilized and then increased slightly and at 24 weeks had dropped by an insignificant 1.18%. An analysis of the waist girth measure and of the hip measure reveal that the central region reacted more quickly to training (lowest measure at month three) and the hip region reacted more slowly to training (lowest measure at month six after a steady decrease over the course of 24 weeks). Overall the changes seen at waist and at hip were very similar.

GIRTH MEASURES

Circumferences, which were measured every four weeks, were positively affected by the exercise programme, with significant decreases from pre-test to final measure at

24 weeks recorded for mid-humerus, (over bust) chest, waist, hip, mid-quadricep and mid-gastrocnemius.

BLOOD LIPID PROFILE

Plasma concentrations of low density lipoprotein (LDL) were not positively affected by resistance training in the current sample. Similarly, high density lipoprotein (HDL) which is a protective element of the lipid profile did not increase and thus the atherogenicity of the lipid profiles of the current sample was not decreased. These results are similar to those reported on by Trejo-Gutierrez and Fletcher (2007). Boyden **et al.** (1993) found that the plasma lipoproteins did elicit positive and significant changes after resistance training but the sample for that study comprised pre-menopausal women. Joseph **et al.** (1999) studied post-menopausal (described as “older” women) and found no changes to the plasma lipoprotein concentrations and, as was found in this study, report that HDL-cholesterol decreased after a resistance training programme. Triglyceride concentration did not decrease and total cholesterol levels did not reduce. In combination these results for the plasma lipoproteins do not indicate reduced cardiovascular risk as a result of the addition of resistance training to the lifestyles of a sample of post-menopausal women.

It has become clear that in relation to the blood lipid profile which remains one of the four main risk factors for the development of cardiovascular heart disease and is also one of four diagnostic risks for the “metabolic syndrome” a distinction must be made between pre-, peri- and post-menopausal women.

QUALITATIVE ANALYSES

Qualitative analyses revealed high “practical” significance as a result of the training programme. Musculo-skeletal, social and psycho-emotional improvements were noted in self-reports submitted by the subjects (Appendix F). It can be concluded that the resistance training programme had a positive effect on the general health and wellness of the sample and resulted in better lifestyle choices by the subjects.

RECOMMENDATIONS

PERI- AND POST-MENOPAUSE

The sample comprised largely of post-menopausal women although 23% were classified as peri-menopausal as they did not meet the criteria for complete cessation of ovarian function in that while menstruation was erratic, it had not completely disappeared. While this might seem to be a limitation to the study the insight offered into the possible role of oestrogen proved invaluable (Figure 28). The responses of the plasma lipoproteins to progressive resistance training in peri- versus post-menopausal women were very different. While the peri-menopausal subjects’ plasma lipoproteins appeared responsive to the training regime, the opposite appeared true of the post-menopausal women. This was noted in an age comparison in which the youngest participant (50 years of age) and the oldest (71 years of age) were compared and this trend applied to an age-matched comparison of a peri- and a post-menopausal subject indicating that age alone was not responsible for the different responses of the blood lipid profile. This needs to be investigated further.

OESTROGEN

With this in mind, the effect of circulating levels of oestrogen which reduce substantially at the onset of menopause, needs further evaluation. In the current study none of the participants was taking synthetic hormone replacement therapy (HRT). This was one of the factors used to screen subjects for suitability for this study. Two of the participants were taking herbal hormone supplements for the purpose of masking the symptoms of menopause and, as this did not classify as synthetic oestrogen replacement, these subjects were included in the study. It is of interest that the herbal supplements did not appear to affect the responses of the blood lipid profile to progressive resistance training. Lindheim **et al.** (1994) have demonstrated that HRT in combination with an exercise programme does have a positive effect on the plasma lipoprotein levels when compared to counterparts who did not take any form of HRT completing the same exercise programme. Given the comparison between the peri- and the post-menopausal subjects in the current study (in the instance of an age-matched comparison and a comparison of two subjects with a 21 year age difference between them) it is clearly evident that the plasma lipoproteins reacted to the training programme in the peri-menopausal subjects but did not do so in individuals who had been classified as menopausal for a number of years. Taking individual variation into account, it might assist future investigations to record how long the subjects had been menopausal. This would establish whether the length of time of oestrogen deprivation affects the responsiveness of the plasma lipoproteins to lifestyle modifications and risk management.

BODY COMPOSITION

Body composition was not analysed during this study as it was felt that girth measures would reveal body shape changes effectively. In an investigation into the relationship between pre-test body mass and LDL-cholesterol levels prior to commencing the training programme it was noted that the highest pre-test LDL level (4.6mmol.L^{-1}) was noted in the lightest subject. Conversely the lowest LDL level (2.3mmol.L^{-1}), at the same time, was found in a subject who was 20.32kg heavier than the group mean. It is accepted that being “thin” is not necessarily being “healthy”, as thin individuals often have a high percent of body fat while some heavier individuals may possess a higher percentage of muscle mass.

BODY MASS INDEX

Laws **et al.** (1993) clearly demonstrated a link between the BMI and HDL-cholesterol levels. The relationship highlighted by these researchers was inverse in nature and the findings of the current study fall in line with this. It was found that the lowest HDL-cholesterol levels were possessed by the heaviest subject on the programme, whereas the highest HDL levels were seen in a subject whose body mass fell 4.32kg below the group mean. Whether this relationship can be inferred across both peri- and post-menopausal women needs further investigation. While body mass alone seemed to be related to HDL levels in this study, the relationship between lean and fat mass and the plasma lipoproteins requires further investigation.

The findings relating to the dangerous cholesterol, LDL, are less clear. Having extrapolated that body mass and BMI are related to the levels of HDL (the good

cholesterol) it may be inferred that LDL would relate in a similarly clear manner. This was not the finding of the current study wherein a subject 40.04kg heavier than the group mean expressed with the lowest pre-test LDL-cholesterol. Further analyses into the relationship between LDL and body composition would also provide necessary insight into preventing and managing the cardiovascular risk related to high levels of plasma LDL-cholesterol.

DIET

Diet was not controlled for the duration of this study. This was a limitation to the efficacy of the research but was also a practicality as apart from the training sessions the participants continued their routine lifestyles. In addition, this study did not purport to include an analysis of dietary effects on plasma lipoproteins, as there is sufficient evidence to indicate that there are very clear links between dietary choices and the concentrations of the plasma lipoproteins. While Rhew **et al.** (2007) have noted that one healthy behaviour infers another, it cannot be ignored that additional metabolic expenditure through resistance training does lead to increased fuel consumption and the researcher did not control what type of food the participants self-selected during the course of the training programme. The participants in the current study were requested not to deviate from their habitual diet for the course of the study and were requested not to commence any form of weight-loss diet. It is the understanding of the researcher that for the 24-week period the subjects did adhere to this undertaking, and they were continually encouraged in this by the researcher and research assistants. The viability of controlling dietary intake for a prospective 24-week study would need serious consideration, but options such as

diet diaries or diet education during the programme might be recommended for future studies. It was clear that the participants were conscious about what foods they chose as food and recipes were a frequent topic of discussion during training sessions.

ABDOMINAL VISCERAL FAT

Abdominal visceral fat (AVF) is known to increase with increasing age, irrespective of the body mass index (BMI). As peri- and post-menopausal women are middle-aged, and AVF increases with increasing age, further insight into any possible relationship between these factors needs exploration before any possible link to the lipoproteins can be established. If the waist circumference measure could be used to predict cardiovascular risk, this would prove an invaluable tool in primary chronic disease prevention and management.

MODALITY OF EXERCISE

Alternative exercise modalities exist. This study focused on progressive resistance training as opposed to aerobic endurance training. A number of studies have demonstrated that aerobic endurance training sessions are effective in lowering the concentrations of plasma lipoproteins and thereby decreasing the risk for cardiovascular disease in post-menopausal women (King **et al.**, 1995) but in the case of the efficacy of resistance training there remains doubt (Trejo-Gutierrez and Fletcher, 2007). Resistance training provides muscular and skeletal benefits as indicated by the qualitative reports voluntarily submitted by the participants.

Self-reports of improved joint range of motion and muscular flexibility were considered the most important effect of the study for 60% of the participants. Joint flexibility was not measured during this study but a qualitative measure of this perceived benefit could offer insight into the musculo-skeletal health benefits offered by resistance training to post-menopausal women. Reports of greater strength were noted by 40% of participants and, while this was not directly measured during the course of this investigation, the fact that subjects progressed from 50% of 1-RM to 80% of 1-RM is an indication of a 30% increase in strength of upper extremity, lower extremity and trunk muscles. The inclusion of strength analyses in future research would offer valuable insight with which to motivate for the efficacy of resistance training for post-menopausal women.

MOTIVATION

Motivation is central to a training programme which extends over a period of 24 weeks. The programme commenced in summer, encompassed autumn, progressed through winter, and came to an end as spring was expected in late August. The effect of seasons was marked with most drop-out from the study occurring in the months of June and July. The highest occurrence of colds and 'flu were also associated with the winter months, and it was noted that the motivation to re-establish the routine of attending training sessions was low after individuals had missed more than three consecutive sessions. The social benefit and motivation of training in small groups was important to 60% of respondents in the qualitative analyses. In contrast to the importance placed on the social aspect, an increased awareness of the risks associated with unhealthy plasma lipoprotein levels was only

important to 40% of respondents. This has direct bearing on compliance and further prospective studies. Adherence to regular training sessions in previously sedentary individuals is a challenge and one which the participants in the current study admit would not have been overcome simply by the knowledge that unhealthy cholesterol levels are life-threatening. Tangible motivators such as belonging to a group, meeting like-minded individuals, and the inevitable competition between individuals, are required for compliance. What is more concerning is that the researcher held frequent meetings with the group and at each meeting questions pertaining to cholesterol levels were encouraged and were fully discussed, and the risk for cardiovascular disease was clearly explained at the outset of the study. Certainly for the current cohort it appeared that awareness of a chronic condition which bore inherent risks did not provide the motivation required to alter habitual health behaviours.

It is the belief of the researcher that these individuals were not affected by the knowledge of the risk for mortality and morbidity because the plasma lipoproteins could not be “seen” and despite creative analogies likening HDL to a “soft sponge” and LDL to “hard grit” in the blood vessels only 40% of the participants were able to comprehend the level of risk represented by the group mean plasma lipoprotein levels of $3.61 \pm 0.78 \text{ mmol.L}^{-1}$ (LDL-cholesterol), $1.55 \pm 0.38 \text{ mmol.L}^{-1}$ (HDL-cholesterol), $1.54 \pm 1.27 \text{ mmol.L}^{-1}$ (triglyceride concentration) and $5.81 \pm 0.92 \text{ mmol.L}^{-1}$ (total cholesterol).

CONCLUDING STATEMENTS

The original aims of this study were to evaluate the effect of a longitudinal progressive resistance training protocol on the blood lipid profiles of a cohort of post-menopausal women. As such it was noted that compliance to the protocol was excellent. Based on the current cohort it may be concluded that progressive resistance training does not positively affect blood lipid responses.

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APPENDIX A
PARTICIPANT INFORMATION AND RISK STRATIFICATION



PO Box 94, Grahamstown 6140; Tel: (046) 603 8367; Fax (046) 622 9704;
Email: J.Kelly@ru.ac.za; www.ru.ac.za/sport

**A STUDY OF THE EFFECTS OF PROGRESSIVE RESISTANCE TRAINING ON
THE BLOOD LIPID PROFILE**

TEST SUBJECTS: INFORMATION SHEET

Thank you for agreeing to participate in this testing programme. As titled, this research will explore the effect of a progressive resistance training programme on the blood lipid profile [cholesterol levels] over a period of 24 weeks, or 6 months.

If you are successfully selected to participate in this study I trust that it will be a mutually beneficial time. You will commence an exercise regime, with a complementary personal trainer, and I will gather data as you progress through the programme. During your initial sessions it is important that we establish that you are healthy enough to commence with an exercise programme. To that end, Dr Celia Jameson will be present at an ECG stress-test, during which you will be required to walk on a treadmill, while your heart beat is monitored. We also need to ensure that you are not likely to develop any diabetic-related complications and will require you to undergo a 2-hour glucose tolerance test, again, this is non-invasive and requires only a small withdrawal of blood. A pre-test blood lipid profile test will reveal your current cholesterol values, via withdrawal of a blood sample. Please note that ALL blood sampling will be done at Du Buisson's Laboratory in Peppergrove Mall by qualified Nursing Sisters. In addition, please note that all blood tests as well as the stress-test in Dr Jameson's care are paid for by the researcher's funds.

Once we have the results of the preliminary tests, we will commence with the next round of introductory sessions. You will be required to complete Consent forms, and provide information pertaining to your previous lifestyle history. Please rest assured that all information that is gathered is treated with great confidentiality, and is coded for use. You will never be identified by name nor recognised in the presentation of the results. The information may be kept for use for a period of 24 months after your participation is complete, and this is merely for the researcher's use. The results of this study may be published in recognised academic journals if accepted.

A third introductory session will deal with the complex issue of diet. We are attempting to isolate the effects of exercise alone on the blood lipid profile, and thus we will educate you accordingly regarding weight gain and loss. We will not require you to embark on any special diet, and we will not request you to lose weight during this study.

Your exercise sessions will be supervised at all times. You will be placed in a small group of co-participants, at a time suitable to your schedule. The sessions will take place in the Department of Human Kinetics and Ergonomics, making use of standard gym equipment as well as “free” core training equipment such as exercise balls, medicine balls, ‘bosu’ balls and foam rollers. The exercise programme you will commence is generic, safe, and progressive, in other words as you get stronger and fitter, the difficulty level will increase. You will be required to attend 3 sessions weekly, of a duration of 30-45minutes, depending on the progression state. You may encounter different supervisors, all of whom will be postgraduate students of the Department. All will have been properly briefed by the principal researcher. You are encouraged to ask questions at any time, and to contact the principal researcher at any time should you have any comment or query.

You will be required to have all the elements that were tested at the start of the study re-tested every 4weeks, a total of 6 times during the study. These elements include girth measures [waist and hip]; body composition measures [% fat via skinfold and Bio-Electrical Impedance]; body mass; blood pressure; as well as a full blood lipid profile [at Du Buisson’s laboratory]. You are welcome to keep copies of these measures for your own interest, and the researcher will keep copies of the results for the purpose of data collation and reduction.

Please note that resistance training is recommended for pre- and post-menopausal women. Conditions of osteoporosis are greatly assisted by weight training, and the use of more muscle fibres increases metabolic rate. Resistance training does not encourage unsightly development of muscle, but strengthens the muscles, protecting the skeletal frame.

Please do not hesitate to contact me at any stage, and please ask as many questions as you would like to!

Janet Kelly

Principal Researcher

072 180 7757

J.Kelly@ru.ac.za

CONSENT FORM

I, _____, do hereby consent to participate in the study entitled: **“An investigation of the effect of a progressive resistance training protocol on the blood lipid profile”**. I agree that I have been fully informed, both verbally and in writing, of the procedures involved in this study. I have also been made aware of any potential risks associated with the protocol.

I realise that whilst my anonymity will be protected at all times, my results may be published or used for scientific and statistical purposes. I understand the conditions with which I am expected to comply for the duration of the tests, and any queries I have with regards to this have been answered to my satisfaction.

By voluntarily consenting to participate in this research I waive any legal recourse against the researcher, or against Rhodes University, in the event of any personal injuries sustained. This waiver shall be binding upon my heirs and legal representatives. I will inform the researcher immediately if at any point I experience distress or abnormality, and am fully aware that I may withdraw from participation in this study at any time.

I have read and understood the above information, as well as the information provided in the letter accompanying this form.

Signed at the Department of Human Kinetics and Ergonomics, Rhodes University, on [yyyy/mm/dd] _____.

SUBJECT: _____ **(SIGN)** _____

WITNESS: _____ **(SIGN)** _____

RESEARCHER: _____ **(SIGN)** _____

PARTICIPANT SCREENING

MASTER'S RESEARCH PROJECT

PRINCIPAL RESEARCHER: JANET KELLY

In order to select individuals who fit the required profile to participate in this study, please complete the following:

Please indicate your AGE in years and months:		This study requires females who are 50-75 years of age.
Have you ever been told that you have DIABETES?		This study precludes individuals who are diagnosed Diabetics, either Type I or II.
Do you SMOKE?		Smokers are excluded.
Do you do any "formal" EXERCISE?		Those who do more than 2 days of formal activity per week are not classified "sedentary"
Do you have any HEART problems?		For medical safety, and for the purposes of deriving the most reliable results from this study, we cannot select individuals with known complications of these organs.
Do you have any LUNG [or related breathing] problems of difficulties?		
Do you have any LIVER problems?		
Do you have any KIDNEY problems?		
Can you COMMIT to 3 weekly sessions of 30-45minutes duration, for the next 6months?		

I [full name] _____ declare that the information that I have provided above is truthful and correct.

Signed by participant

Department of Human Kinetics and Ergonomics

Date

Rhodes University

PAR-Q RISK STRATIFICATION FOR EXERCISE

PLEASE NOTE THAT THE INFORMATION YOU WILL PROVIDE ON THIS FORM REMAINS STRICTLY CONFIDENTIAL. THIS INFORMATION IS REQUIRED FOR YOUR SAFETY DURING EXERCISE.

Subject Code: _____

Participation in Master's Degree Research Project

Principal Researcher: Janet Kelly [072 180 7757]

PERSONAL DETAILS

Name and Surname	
Date of Birth	
Emergency Contact Person [and relationship to you?] Emergency Contact Person's Mobile No.	
Physician [local] Physician Contact No.	

PREVIOUS EXERCISE EXPERIENCE

1. Please outline your previous involvement, if any:

Gym / Aerobics / Spinning	Organised Sport [ie Tennis] FREQUENT	Recreational Sport [ie Soccer] INFREQUENT	Other	None
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2. How often have you exercised [per week] in the last 6 months?

Never	1 x per week	2-4 x per week	Daily
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MEDICAL HISTORY

1. Have you sustained any Motor Vehicle Accident related injuries? Comment:	[Y]	[N]
2. Have you sustained any Sports Injuries? Comment:		
3. Have you been diagnosed with any Heart related complications?		
4. Has your Doctor ever informed you that you should NOT enter into an exercise programme without medical consent?		
5. When was your last complete physical check up? Date:		
6. Do you experience Chest Pains while exercising?		
7. Do you have High Blood Pressure? Current Value:		
8. Do you have Diabetes?		
9. Do you suffer from Asthma?		
10. Do you have any Allergies?		

Comment:		
11. Are you currently taking any Chronic Medication? Comment:		
12. Do you have any family history of the following: Heart, lung, metabolic disease, stroke, sudden death Comment:		
13. What level of activity is required during your average daily work? Please specify if there is a lot of upper body activity required. Comment:		

ADDITIONAL INFORMATION

1. Have you undergone SURGERY within the last 12 months? Comment:	[Y]	[N]
2. Are you currently receiving treatment [ie Chemotherapy, Psychotherapy]? Comment:		
3. Are you currently PREGNANT?		

BASED ON THE INFORMATION PROVIDED, WE RESERVE THE RIGHT TO EXCLUDE YOU FROM THE CURRENT RESEARCH PROJECT, BASED ON THE REQUIREMENTS WHICH POTENTIAL SUBJECTS MUST FULFIL, AND FOR MEDICAL SAFETY.

I, _____ [full name] do confirm that the information here provided is complete and is correct.

Signed [Subject for Research Study]

Date

Signed [Researcher]

Date

*Department of Human Kinetics and Ergonomics
University*

Rhodes

ANTHROPOMETRIC AND BLOOD LIPID DATA SHEET **CODE:** _____

Date commenced Programme: _____	TEST DATE 1:	TEST DATE 2:	TEST DATE 3:	TEST DATE 4:	TEST DATE 5:	TEST DATE 6:
Body Mass [kg]						
Stature [m]						
BMI Ratio						
Waist Circumference [mm]						
Hip Circumference [mm]						
Waist to Hip Ratio						
Blood Lipid Profile: HDL-C LDL-C VLDL –C TG [according to LAB report]						
Blood Pressure [mmHg]: Systolic Diastolic						
Girth Measures: Upper arm Chest Thigh Calf						

APPENDIX B

PILOT TEST INFORMATION



PO Box 94, Grahamstown 6140; Tel: (046) 603 8367; Fax (046) 622 9704;
Email: J.Kelly@ru.ac.za; www.ru.ac.za/sport

A COMPARISON OF THE EFFECTS OF PROGRESSIVE RESISTANCE TRAINING AND AEROBIC ENDURANCE TRAINING ON THE BLOOD LIPID PROFILE

PILOT TEST SUBJECTS: INFORMATION SHEET

Thank you for agreeing to participate in this testing programme. At this stage the testing is literally exploratory – and will provide data which will inform the eventual choice of subject gender and age.

Prior to commencing your exercise programme, I will require a printout of your blood cholesterol levels. We will require that these levels are analysed again at 4 weeks into the programme (or after 12 sessions). You will be allocated an exercise supervisor who will be a postgraduate student in the Department of Human Kinetics and Ergonomics. Initially we will obtain basic anthropometric data, simply for record purposes. We will also need to know information about any chronic medication you are currently taking, firstly to ensure that we can safely monitor you during exercise sessions, and secondly so that I can take this into account when analysing the data.

Each exercise session will last between 45 and 60 minutes, and you will be required to complete 3 per week (7 day period). These can be scheduled at your convenience, and will take place in the Weight Training Facility at the Rhodes University Health Suite. There are two exercise protocols, a progressive resistance training protocol and an aerobic endurance exercise protocol, and you will be randomly allocated to one of these.

Initially the programme will run for 4 weeks. At this stage I am still assessing whether this is sufficient time for the required results. There may be a need for your programme to run for a few weeks longer than 4 weeks.

Please do not hesitate to contact me at any stage, and please ask as many questions as you would like to!

Janet Kelly

Principal Researcher

072 180 7757

PILOT TEST SUBJECT: MASTER'S DEGREE RESEARCH [J.KELLY]

- **SUBJECT CODE:** _____
- **DATE SESSIONS COMMENCED:** _____
- **2ND TESTING DATE:** _____

Please note that this information is Confidential, and is for the use of the researcher only, in the interests of the research project. Thank you for participating as a Pilot Subject, and please do not hesitate to ask questions either of your supervisor during exercise sessions, or of the Principal Researcher at any time.

CONTACT DETAILS: PRINCIPAL RESEARCHER:

Janet Kelly 072 180 7757 [cell] / 046 603 8367 [office] / J.Kelly@ru.ac.za [email]

PLEASE PROVIDE THE FOLLOWING INFORMATION

Name and Surname	
Date of Birth and Age	
Indicate Male or Female	
Contact Detail [Tel/Cell]	
Contact Detail [Email Address]	
Any medical conditions [current]	
Any chronic medication currently taken	
Any previous injuries sustained	
Please sign to indicate that you are comfortable taking part in this study and that you are satisfied that all your questions have been answered satisfactorily	
Name of Exercise Supervisor	

APPENDIX C

APPENDIX D

APPENDIX E

APPENDIX E

APPENDIX F

QUALITATIVE FEEDBACK

Subject 1:

My observations on the practical significance would include the fact that I had never had my cholesterol measured before, so the fact that I am now aware of the various components that are tested (HDL, LDL and triglycerides) and their significance is obviously important.

I think that my energy levels are definitely better as a result of regular exercising.

I also find that I am definitely stronger and less likely to feel stiff after exertion. I notice this particularly when I engage in heavy gardening. I do think my joints are stronger and on the whole I can do more physically-demanding exercise without feeling ill-effects to my back.

Doing the exercises as part of a group has been fun and has ensured continued motivation.

It is very nice to feel that I am slightly trimmer and that my clothes fit more comfortably, even if I have not lost weight!

JP Kelly

Subject 2:

I am now able to walk up the hill at mountain drive without stopping.

Getting up for the early session is a great start to the day it gives you a real energy boost.

body shape has changed for the better and I am feeling much stronger and I am hoping that I will start to lose weight now.

It was very informative being part of the study and learning our lipid profile and sharing information with other women the same age about lifestyles

I have learned a lot about Grahamstown from the group and feel I know a lot more people around town - being a relative newcomer (8 yrs). I now have more friends, know where to get the best hair colour, style, coffee and all the latest gossip.

Pauline Mitchell

Subject 3:

I have thoroughly enjoyed my time at the Health suite with Janet and the girls. For me it was something I needed to kickstart me into better habits. I have loved being part of a group, making friends with a whole different set of people. I definitely feel a hundred times better for it. I did not change shape as much as I had hoped, but now that we have completed the 24 weeks I have started the South Beach diet – nothing drastic, and NOW I am beginning to feel the difference. I have loved getting up early and starting the day off with a bit of exercise – not always easy in the winter, but just imagine the summer mornings, it's going to be fantastic, and the coolest part of the day anyway!

I am thrilled to have had my cholesterol levels checked, and to be made aware of them and the dangers, having not really thought about it much before. The South Beach diet deals directly with cholesterol and onset-diabetes, which both scare me so I feel the programme has made me much more aware, and now I feel empowered to do something about it. Before, I just couldn't be bothered!!

For me, it has been one of the best things that happened to me this year, because of the effect it has had on my health and well being, and the awareness which I have mentioned.

Let me once again say thank you to Janet and all the girls who have got up early in the morning. You have changed my life.

Colleen Rippon

Subject 4:

Certainly much happier in myself and look forward to the classes.

I would say that my back problem has eased - I don't hobble around so much and I reckon that I am without the pain I used to have - never severe or debilitating, but just an uncomfortable pain - so that is a huge plus. Just wish I could get rid of the stiffness in the mornings!

Certainly I have more energy and boring stuff isn't such an effort - I don't "fade" in the afternoons and come supper time I still have the energy to produce a decent meal.

Just feeling so much better has been the motivation to continue, as well as a belief that with regular exercise the middle aged spread will vanish! Some hope of that, but I must believe.

Also I have met some really nice ladies whom I can relate to - I actually didn't know many people of my own age group, so that has been brilliant and we have had some fun.

I've worked out that my cholesterol is food-related, so it is now up to me to get it down - no more little treats as they do add up.

T Pitman

Subject 5:

The most beneficial thing for me has been the strengthening of my muscles!! I notice this when I am in the shop lifting heavy bags of clothes and I don't get worn out by the end of the day as I used to. I also notice it when walking up Mountain View Drive where I used to get out of breath and now just keep marching on. I think this is strength rather than the cardio-vascular angle.

I'm sure that my hot flushes have diminished during the programme and I feel generally fitter and have more energy. I also had a "frozen shoulder" at the outset and the movement is much improved I think because the muscles around the shoulder blade are stronger and support the shoulder better (thanks to my least favourite piece of equipment)!

I have also met such nice people that would never have crossed my path otherwise - and learned an awful lot about cholesterol!!

D Westcott

Subject 6:

You have saved our lives.

J Allcock

Subject 7:

Firstly you may recall that I attributed the quitting of nicotine to a combination of Tai Chie and gym - but walking back from gym yesterday it occurred to me that I have a once weekly Tai Chi class, but 3 times weekly gym routine - - so I think that (possibly the Oprah visuals being the cherry!!) - it is in all probability the result of the gym routine - walking more to and from gym - focusing on breathing in Tai Chi and gym - anyhow. You get the picture.

Then - I forget what your earlier e-mail referred to, but something about feeling stronger - leg muscles etc. so in my daily meanderings I have certainly noticed that (especially walking uphill) - that its just effortless -stairs also (although admittedly I have not really found them problematic - jumping up a couple at a time in my early childhood and teens!) way back. I have found that I am more flexible/agile. Must just get into cycling again.

I think that the general sense of well-being is partly physical and probably also that one's mental approach -attitude - whatever - is vastly improved - maybe just because we have accepted the challenge and no longer find it daunting - and have overcome negative attitudes by coping with a new-found optimism - this is being churned out hurriedly - not too articulately either - but without this project and your motivation we would (I am sure that I speak for most of us) not have headed to the gym - I for one planned to do just yet a couple of years ago during the end of year vac - so now we have that option also.

Also, with the ongoing monitoring - I believe that everyone will now more carefully consider their eating habits etc.

Thank you for everything and the very best wishes for your Masters thesis.
M Dickson

Subject 8:

Definitely keener to get out and about at a faster pace without tiring, which also applies mentally and emotionally you can think and sort your mind out quicker and more clearly. Speed of walking and length of gait improved (can now keep up with my husband on a beach walk!) Emotionally feel much better in my cloth's as I know that I can get back into my older jeans!

Any specific improvements to physical conditions ie. Chronic back problems, knee or hip issues... whatever

Approx. a 10 degree improvement in left knee flexion (a total knee replacement Feb.2005)
Improved spinal flexibility and back and neck much stronger due to strengthening of trunk muscles.
Shoulder girdle, shoulders, arms and leg muscles much stronger.(Can now spring out of the bath!)
All these exercises have been done within the limits of arthritic joints and I have not pushed the exercises beyond the limit thus not straining or injuring ligaments or capsules.

Range of movement has also improved.
It has improved leg circulation problems - varicose veins etc. One also sleeps much better when physically tired and perhaps has fewer stress headaches. It is a known fact that relaxation of a muscle occurs totally after physically exerting that muscle.

Any change to energy levels

Definitely, I am prepared to do more exercise so it unfortunately improves one's appetite -
I seem to crave sweetness more
to maintain my energy level my goal now is to try and bring in a low cholesterol diet as well
as daily exercise to bring down the cholesterol, centimetres and weight!

Any difference in lifestyle routines

It is quite daunting to know that you have a medical condition due to your life style so it is imperative that I must have a daily exercise routine, preferably a mix of aerobic and resisted exercises.
I think that ideally I must have at least 55 minutes resisted exercise five times a week and
aerobics such as walking combined with this for at least 30 minutes and on the other two
days walking for an hour.
If I don't continue with this I know that all that I have gained out of the six months will be lost.
I still believe that if I can stick to this and diet that eventually the cholesterol level will improve.

Anything.....

Other benefits: such as social, belonging to a group...

It is easier to exercise in a group as you have to push yourself against others.

What motivated you to continue, and motivates you to still continue now?

Because I certainly do not want to even begin to feel or look my AGE, and I am against chronic medication for lowering the cholesterol level if it can be done by not being a SLUG!

And ANYTHING else that comes to mind!

Thank you Janet for giving me the opportunity and getting me and all of us onto this wonderful course and I hope that we have been of some benefit to you and your thesis.

L White

Subject 9:

Amongst my aches and pains and stiffness when I started was a very sore knee – now gone including stiffness etc!!

Wasn't able to bend - now I can!

Unable to put slacks/socks on standing up - now I can!

Subject 10:

My smokers cough has disappeared and I am at least 70% less breathless on exertion.

L Parkins

Subject 11:

Having been through this exercise program, it has had a significant impact on my life! Not only do I feel much better within myself. I am more alert and my energy level is far greater. I am fitter and I am able to do much more physical activities without tiring quickly. The scary part is that I never realised that I wasn't feeling good!

From a medical point of view, this too has improved. Yes, I have had bronchitis and 'flu this year. Yes, I have had to take antibiotics, but I seem to have recovered much quicker than in the past. My asthma is much better and I am not so reliant on my pumps. My chest, when it has become tight, on many occasions has been able to open up on its own. My blood pressure, which has always been on the high side, is down. So much so that my medication has been halved and I am still having to monitor it as it is still a little bit low.

Best of all, I have lost centimeters and kilograms!!!! This has given me much more confidence in myself and I am feeling good about myself. I am not nearly as self

conscientious anymore and I don't mind walking into a room full of strangers. I don't feel my age and that might not be so good!

Thank you, Janet for giving me the opportunity to feel like I do. In others words for giving me a new outlook on life. For being able to meet new people and establish new friends. It has been a great year and I am very grateful to you for doing this study and allowing me to be part of it.

G van Rensburg

Subject 12:

I have so enjoyed being part of your exercise programme and have been surprised at what I have managed to do. Despite being a golfer (a rather ragged one if the truth be told!) I don't really exercise as much as I should , so this has really geared me up to do a little more. Our group has been such fun and we have so enjoyed your post-grad students' input and patience with us. There is lots of teasing in our group and many giggles so its really been a pleasure with little pain.

The potentially cronky right knee is no longer cronky, so that's a bonus. And I also used to have a lot of back ache, probably form sitting too much – that certainly has improved. The only cloud on my little horizon is the disappointment in the cholesterol figures – they were coming down gradually each month and then suddenly went on the upward grade – why????? I'll happily do more exercises next year if you want to expand your researches.

A Eales

Subject 13:

The values of exercise program:

Good companionship with other members of the group

Feeling of well being

Discovering new muscles

Euphoria and good feeling after exercise

Much less joint and muscle pain generally

Downside: Cramp in new muscles

Increased appetite

Guilt if I don't go

Addiction to exercise

Dr CP Jameson

APPENDIX G (1)

STATISTICS

ANALYSES OF VARIANCE

General Linear Model

Within-Subjects Factors

Measure: Scores

Times	Dependent Variable
1	Pre_LDL
2	T1_LDL
3	T2_LDL
4	T3_LDL
5	T4_LDL
6	T5_LDL
7	T6_LDL

Descriptive Statistics

	Mean	Std. Deviation	N
Pre_LDL	3.512	.6207	25
T1_LDL	3.5880	.59814	25
T2_LDL	3.560	.8907	25
T3_LDL	3.720	.7182	25
T4_LDL	3.880	.7405	25
T5_LDL	3.992	.7382	25
T6_LDL	4.020	.7832	25

Multivariate Tests^b

Effect		Value	F	Hypothesis df	Error df	Sig.
Times	Pillai's Trace	.626	5.302 ^a	6.000	19.000	.002
	Wilks' Lambda	.374	5.302 ^a	6.000	19.000	.002
	Hotelling's Trace	1.674	5.302 ^a	6.000	19.000	.002
	Roy's Largest Root	1.674	5.302 ^a	6.000	19.000	.002

Mauchly's Test of Sphericity^b

Measure: Scores

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon ^a		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
Times	.285	27.317	20	.130	.728	.910	.167

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

Tests of Within-Subjects Effects

Measure: Scores

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Times	Sphericity Assumed	6.705	6	1.117	9.016	.000
	Greenhouse-Geisser	6.705	4.367	1.535	9.016	.000
	Huynh-Feldt	6.705	5.459	1.228	9.016	.000
	Lower-bound	6.705	1.000	6.705	9.016	.006
Error(Times)	Sphericity Assumed	17.847	144	.124		
	Greenhouse-Geisser	17.847	104.808	.170		
	Huynh-Feldt	17.847	131.014	.136		
	Lower-bound	17.847	24.000	.744		

Tests of Within-Subjects Contrasts

Measure:Scores

Source	Times	Type III Sum of Squares	df	Mean Square	F	Sig.
Times	Linear	6.280	1	6.280	32.829	.000
	Quadratic	.063	1	.063	.339	.566
	Cubic	.194	1	.194	1.802	.192
	Order 4	.080	1	.080	1.054	.315
	Order 5	.072	1	.072	.846	.367
	Order 6	.015	1	.015	.156	.697
Error(Times)	Linear	4.591	24	.191		
	Quadratic	4.459	24	.186		
	Cubic	2.589	24	.108		
	Order 4	1.832	24	.076		
	Order 5	2.044	24	.085		
	Order 6	2.332	24	.097		

Tests of Between-Subjects Effects

Measure:Scores

Transformed Variable:Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	2465.064	1	2465.064	817.551	.000
Error	72.364	24	3.015		

APPENDIX G (2)

STATISTICAL ANALYSES

MULTIPLE ANALYSES OF VARIANCE

AGE AND BMI EFFECT

General Linear Model

Age effect

Within-Subjects Factors

Measure: Scores

Times	Dependent Variable
1	Pre_LDL
2	T1_LDL
3	T2_LDL
4	T3_LDL
5	T4_LDL
6	T5_LDL
7	T6_LDL

Between-Subjects Factors

		Value Label	N
Age_code	1	50-54 yrs	11
	2	55-64 yrs	11

Between-Subjects Factors

		Value Label	N
Age_code	1	50-54 yrs	11
	2	55-64 yrs	11
	3	65-75 yrs	3

Descriptive Statistics

	Age_code	Mean	Std. Deviation	N
Pre_LDL	50-54 yrs	3.736	.6516	11
	55-64 yrs	3.182	.5231	11
	65-75 yrs	3.900	.1732	3
	Total	3.512	.6207	25
T1_LDL	50-54 yrs	3.7545	.65017	11
	55-64 yrs	3.3455	.46768	11
	65-75 yrs	3.8667	.70238	3
	Total	3.5880	.59814	25
T2_LDL	50-54 yrs	3.745	1.1201	11
	55-64 yrs	3.327	.6498	11
	65-75 yrs	3.733	.7767	3
	Total	3.560	.8907	25
T3_LDL	50-54 yrs	3.873	.9371	11
	55-64 yrs	3.600	.5020	11
	65-75 yrs	3.600	.5568	3
	Total	3.720	.7182	25
T4_LDL	50-54 yrs	3.909	.9576	11
	55-64 yrs	3.773	.5479	11
	65-75 yrs	4.167	.5508	3
	Total	3.880	.7405	25
T5_LDL	50-54 yrs	4.309	.9471	11
	55-64 yrs	3.682	.3894	11
	65-75 yrs	3.967	.4619	3
	Total	3.992	.7382	25
T6_LDL	50-54 yrs	4.345	.9802	11
	55-64 yrs	3.645	.4390	11
	65-75 yrs	4.200	.4359	3

Descriptive Statistics

	Age_code	Mean	Std. Deviation	N
Pre_LDL	50-54 yrs	3.736	.6516	11
	55-64 yrs	3.182	.5231	11
	65-75 yrs	3.900	.1732	3
	Total	3.512	.6207	25
T1_LDL	50-54 yrs	3.7545	.65017	11
	55-64 yrs	3.3455	.46768	11
	65-75 yrs	3.8667	.70238	3
	Total	3.5880	.59814	25
T2_LDL	50-54 yrs	3.745	1.1201	11
	55-64 yrs	3.327	.6498	11
	65-75 yrs	3.733	.7767	3
	Total	3.560	.8907	25
T3_LDL	50-54 yrs	3.873	.9371	11
	55-64 yrs	3.600	.5020	11
	65-75 yrs	3.600	.5568	3
	Total	3.720	.7182	25
T4_LDL	50-54 yrs	3.909	.9576	11
	55-64 yrs	3.773	.5479	11
	65-75 yrs	4.167	.5508	3
	Total	3.880	.7405	25
T5_LDL	50-54 yrs	4.309	.9471	11
	55-64 yrs	3.682	.3894	11
	65-75 yrs	3.967	.4619	3
	Total	3.992	.7382	25
T6_LDL	50-54 yrs	4.345	.9802	11
	55-64 yrs	3.645	.4390	11
	65-75 yrs	4.200	.4359	3
	Total	4.020	.7832	25

Box's Test of Equality of Covariance Matrices^a

Box's M	33.087
F	.722
df1	28.000
df2	1393.829
Sig.	.855

Multivariate Tests^c

Effect		Value	F	Hypothesis df	Error df	Sig.
Times	Pillai's Trace	.545	3.395 ^a	6.000	17.000	.022
	Wilks' Lambda	.455	3.395 ^a	6.000	17.000	.022
	Hotelling's Trace	1.198	3.395 ^a	6.000	17.000	.022
	Roy's Largest Root	1.198	3.395 ^a	6.000	17.000	.022
Times * Age_code	Pillai's Trace	.640	1.411	12.000	36.000	.206
	Wilks' Lambda	.450	1.389 ^a	12.000	34.000	.219
	Hotelling's Trace	1.021	1.361	12.000	32.000	.235
	Roy's Largest Root	.756	2.269 ^b	6.000	18.000	.083

Mauchly's Test of Sphericity^b

Measure: Scores

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon ^a		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
Times	.259	26.710	20	.148	.702	.967	.167

Tests of Within-Subjects Effects

Measure: Scores

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Times	Sphericity Assumed	4.117	6	.686	5.705	.000
	Greenhouse-Geisser	4.117	4.211	.978	5.705	.000
	Huynh-Feldt	4.117	5.805	.709	5.705	.000
	Lower-bound	4.117	1.000	4.117	5.705	.026
Times * Age_code	Sphericity Assumed	1.970	12	.164	1.365	.191
	Greenhouse-Geisser	1.970	8.421	.234	1.365	.219
	Huynh-Feldt	1.970	11.610	.170	1.365	.194
	Lower-bound	1.970	2.000	.985	1.365	.276
Error(Times)	Sphericity Assumed	15.877	132	.120		
	Greenhouse-Geisser	15.877	92.633	.171		
	Huynh-Feldt	15.877	127.706	.124		
	Lower-bound	15.877	22.000	.722		

General Linear Model

BMI effect

Within-Subjects Factors

Measure: Scores

Times	Dependent Variable
1	Pre_LDL
2	T1_LDL
3	T2_LDL
4	T3_LDL
5	T4_LDL
6	T5_LDL
7	T6_LDL

Between-Subjects Factors

		Value Label	N
BMI_code	1	20-24.9	7
	2	25-29.9	9
	3	30-34.9	3
	4	35+	6

Descriptive Statistics

	BMI_code	Mean	Std. Deviation	N
Pre_LDL	20-24.9	3.686	.3805	7
	25-29.9	3.500	.5979	9
	30-34.9	4.000	.3000	3
	35+	3.083	.8134	6
	Total	3.512	.6207	25
T1_LDL	20-24.9	3.9000	.48990	7
	25-29.9	3.5222	.52148	9
	30-34.9	3.8333	.57735	3
	35+	3.2000	.70711	6
	Total	3.5880	.59814	25
T2_LDL	20-24.9	4.057	.7044	7
	25-29.9	3.522	.7396	9
	30-34.9	4.000	1.3000	3
	35+	2.817	.7305	6
	Total	3.560	.8907	25
T3_LDL	20-24.9	3.914	.8050	7
	25-29.9	3.800	.6614	9
	30-34.9	3.933	.7506	3
	35+	3.267	.6593	6
	Total	3.720	.7182	25
T4_LDL	20-24.9	4.229	.5964	7
	25-29.9	3.778	.8843	9
	30-34.9	4.300	.1000	3
	35+	3.417	.6306	6
	Total	3.880	.7405	25
T5_LDL	20-24.9	4.200	.5715	7
	25-29.9	3.922	.9628	9

	30-34.9	4.367	.5033	3
	35+	3.667	.5989	6
	Total	3.992	.7382	25
T6_LDL	20-24.9	4.286	.6694	7
	25-29.9	4.033	.9474	9
	30-34.9	4.400	.4583	3
	35+	3.500	.6132	6
	Total	4.020	.7832	25

Multivariate Tests^c

Effect		Value	F	Hypothesis df	Error df	Sig.
Times	Pillai's Trace	.597	3.952 ^a	6.000	16.000	.013
	Wilks' Lambda	.403	3.952 ^a	6.000	16.000	.013
	Hotelling's Trace	1.482	3.952 ^a	6.000	16.000	.013
	Roy's Largest Root	1.482	3.952 ^a	6.000	16.000	.013
Times * BMI_code	Pillai's Trace	.612	.769	18.000	54.000	.725
	Wilks' Lambda	.487	.735	18.000	45.740	.758
	Hotelling's Trace	.857	.699	18.000	44.000	.794
	Roy's Largest Root	.559	1.677 ^b	6.000	18.000	.184

Mauchly's Test of Sphericity^d

Measure: Scores

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon ^a		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
Times	.241	26.718	20	.148	.700	1.000	.167

Tests of Within-Subjects Effects

Measure: Scores

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Times	Sphericity Assumed	5.788	6	.965	7.464	.000
	Greenhouse-Geisser	5.788	4.197	1.379	7.464	.000
	Huynh-Feldt	5.788	6.000	.965	7.464	.000
	Lower-bound	5.788	1.000	5.788	7.464	.012
Times * BMI_code	Sphericity Assumed	1.563	18	.087	.672	.833
	Greenhouse-Geisser	1.563	12.591	.124	.672	.781
	Huynh-Feldt	1.563	18.000	.087	.672	.833
	Lower-bound	1.563	3.000	.521	.672	.579
Error(Times)	Sphericity Assumed	16.284	126	.129		
	Greenhouse-Geisser	16.284	88.140	.185		
	Huynh-Feldt	16.284	126.000	.129		
	Lower-bound	16.284	21.000	.775		

APPENDIX H

GROUP ADMINISTRATION

SESSION DATES: MASTERS DEGREE RESEARCH 2008

DATE	SESSION CONTENT	WHO TO ATTEND
15 January Venue: HKE Lecture Theatre	Introduction Participant Screening PAR-Q Lifestyle Q Consent Form Diet Discussion 1[request dietary diary for discussion 2] Preferred Times Form Next Dates [Timetable]	ALL potential subjects as recruited via Local GPs, Flyers and Grocott's Mail Advert
16 January [14h00-17h00] Venue: HKE Lab	Dr Jameson: Physical Examination Stress Test ECG Anthropometric Baseline Measures: Stature, mass Girth BMI, WHR Blood Pressure	ALL potential subjects
17 and 18 January Venue: Du Buisson's Lab	Du Buisson's Lab: 2hr OGTT Baseline BLP [fasted]	ALL potential subjects
21 January Venue: HKE Lecture Theatre	Dietary Discussion 2 Confirmation of Group Times	ALL Potential Subjects

21 January	Group 1 Commences on PRT Programme	First 10 Subjects
End January	Group 2 Commences	Next 10 Subjects
February	Until ALL 30 subjects have commenced PRT programme	

MSc TO DO LIST DECEMBER 2007	DATE	STATUS
Ethics form	26-Nov	Copy from June
PRT protocol refine	Jan	Confirmed
Check all equipment available in HKE	Jan	Confirmed
Advert for Grocott's	26-Nov	Matthias
Flyer	26-Nov	To Candice for app
Flyer distribution		
Dr Jameson	y	
Dr Oosthuizen	y	
Dr Pellisier	y	
Dr's Marx et al	y	
Dr Murali	y	
Dr Santhia	y	
Dr Lloyd et al	y	
Preliminary Dates for January	26-Nov	Email to CJ
Dates for Dr Jameson	26-Nov	Email to CJ
Path Labs re testing and discounts	21st Jan	Denise, East London
Subject form collation ALL needed	26-Nov	Collation of 1st copy
Subject Files and Codes		
Registration documentation	15-Jan	Done
Health History Q		PAR Q and
		Physical

GROUP SELECTION

[PLEASE NOTE THERE IS A MAXIMUM NUMBER THAT CAN BE ACCOMMODATED PER TIMESLOT]

	MONDAY, TUESDAY, WEDNESDAY, THURSDAY, FRIDAY		
06H00 – 07H00 [Meet at 06h00, session commences, finish time flexible]	1. Liz P 2. Denise 3. Gail 4. Christine 5. Emily 6. Pauline	1. Liz P 2. Denise 3. Gail 4. Christine 6. Emily 7. Pauline	1. Liz P 2. Denise 3. Gail 4. Ria 6. Emily 7. Pauline

APPENDIX I
COMMUNICATION WITH MEDICAL PRACTITIONERS



PO Box 94, Grahamstown 6140; Tel: (046) 603 8367; Fax (046) 622 9704;
Email: J.Kelly@ru.ac.za; www.ru.ac.za/sport

7th January 2008

Dear *[Medical Practitioner]*

Re: Master's Degree Research

I am embarking on research investigating the effect of Progressive Resistance Training on the Blood Lipid Profile, to date a particularly under-researched aspect of exercise physiology. What with morbid cholesterol levels being so prevalent, and the genuine risk this presents for cardiovascular complications, I hope through the research to offer some substantive proof for the efficacy of lifestyle modification for positively enhancing the blood lipid profile.

I have selected females, aged between 50-75 years as the population group from which to draw the sample. The subjects do need to express with one lipid abnormality [LDL, HDL, TG or total cholesterol above recommended medical levels] but should otherwise be healthy, and able to participate in regular, moderate exercise.

I would appreciate your assistance in recommending involvement in this programme to any individual who you believe would benefit from involvement, and who fits the "profile" required. I have attached a more detailed information flyer, plus some additional copies for distribution. I will happily provide more detailed information and answer any queries directly – my details are provided on the leaflet.

Yours sincerely

Janet Kelly

Health Suite Manager, Rhodes University

Master's Student, Human Kinetics and Ergonomics Department, Rhodes University



PO Box 94, Grahamstown 6140; Tel: (046) 603 8367; Fax (046) 622 9704;
Email: J.Kelly@ru.ac.za; www.ru.ac.za/sport

7th February 2008

Dear _____

Re: Cholesterol Test Results for [X]

I am currently researching the effect of progressive resistance training on the blood lipid profile, as a part-time student in the Human Kinetics and Ergonomics Department, Rhodes University. The study sample comprises women aged 50 to 75, who are sedentary but otherwise healthy [no presence of heart, lung, liver or kidney disease].

During the initial measurements, a pre-testing phase Lipogram showed that [X] who is a voluntary subject for this study, expressed with very high lipid values [please see laboratory report attached]. In the interests of subject safety I have requested that [X] consult her GP for guidance. As she has committed to the programme of exercise training, 3 x per week for the next 6 months, geared at evaluating the effect of exercise on this very risk factor – high cholesterol – my supervisor [Dr Candice Christie] and I would like to see [X] continue to exercise as treatment for this high lipid profile value, rather than be medicated – within reason, and having considered all safety elements. If at all possible, we would be grateful if you would consider monitoring your patient over the course of the next few months, and withholding prescription of medication – for the express purpose of assessing the efficacy of a lifestyle change instead.

We are very happy to remain in close communication at all times – and certainly do not wish to compromise any individual's health safety.

Yours sincerely

Janet Kelly [Researcher]